

Development of Digital Learning Tool in Teaching Vedic Mathematics

Francisco J. Aguanta II

Carlos Hilado Memorial State University, Talisay City, Negros Occidental

DOI: <https://doi.org/10.47772/IJRISS.2026.100800973>

Received: 07 September 2026; Accepted: 14 September 2026; Published: 22 September 2026

ABSTRACT

This study aimed to develop, validate, and evaluate the pedagogical alignment and user acceptability of a mobile digital learning tool incorporating Vedic Mathematics principles for 2-digit multiplication. It was conducted to the Grade 8 learners in a public high school in northern Negros Occidental during the School Year 2026–2027. Utilizing a design and development research design structured around the ADDIE framework, the project digitized four core Vedic Sutras: *Urdhva-Tiryagbhyam*, *Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam*. The evaluation process involved three participant groups: ten (10) expert validators, five (5) Grade 8 Mathematics teachers, and forty (40) Grade 8 student-users. Data collection instruments included the Department of Education (DepEd) Learning Resource Management and Development System (LRMDS) evaluation framework, the standardized Computer System Usability Questionnaire (CSUQ), and computational speed and accuracy assessments. Pre-assessment result of moderate to proficient level of computational accuracy, coupled with moderate operational speed, these findings highlighted a clear need for targeted instructional intervention to bridge procedural accuracy and execution gaps. Quantitative evaluation demonstrated that the developed digital tool attained high content validity and technical compliance, achieving an overall rating of Very Satisfactory on the DepEd LRMDS validation scale based on Content Quality, Instructional Quality, Technical Quality, and Technical Errors. CSUQ evaluations from teachers and learners confirmed high usability across System Usefulness, Information Quality, and Interface Quality, demonstrating the application's pedagogical soundness and technical reliability. The study recommends incorporating the software into mathematics enrichment programs to support foundational mental arithmetic skills and computational fluency.

INTRODUCTION

The educational landscape in the Philippines is defined by a profound crisis in mathematical literacy. As indicated by the Programmed for International Student Assessment (PISA), Filipino learners ranked 78th out of 78 countries in 2018 and 77th out of 81 in 2022, with scores of 353 and 355 remaining significantly below the OECD average (Congressional Policy and Budget Research Department, 2024).

Traditional pedagogy has failed to foster foundational computational fluency, creating arithmetic bottlenecks in multi-digit multiplication that cause classroom progression to lag and hinder higher-order problem-solving (Chakravarthi, 2014; Nawale et al., 2026; Sharma et al., 2025).

Global literature indicates that Vedic Mathematics a system of sixteen sutras reconstructed by Swami Bharati Krishna Tirthaji offers a framework to rebuild these computational heuristics (Pallathadka, 2025) Techniques such as *Urdhva-Tiryagbhyam* and *Nikhilam* generate simultaneous partial products, dramatically reducing working memory load (Mehera, 2012; Nawale et al., 2026).

Empirical data shows these methods can reduce multi-step operation time by 60% to 85% while increasing accuracy by over 30% (Srivastava et al., 2023; Williams & Gaskell, 2022).

However, a critical gap persists in integrating Vedic Mathematics into localized digital ecosystems. Online transitions have foregrounded student isolation and "objectification," while existing digital resources remain insufficient functioning as static "libraries of tricks" lacking the pedagogical structure to optimize cognitive

processing (Baksh et al., 2025; Cassibba et al., 2021; Gogoi, 2025).

Developing a specialized mobile application addresses this need. By leveraging native mobile architectures including dynamic problem generation, live timers, and immediate feedback this application delivers a structured tool to build mental agility in 2-digit multiplication (Singh et al., 2023; Srivastava et al., 2023). Grounded in the Cognitive Theory of Multimedia Learning (CTML), the app's visual architecture transforms abstract sutras into a structured computational framework (Goldie, 2021).

Addressing these challenges aligns with national educational reforms advocating for adaptive digital resources that overcome calculation bottlenecks (Ministry of Education, 2020; Sharma et al., 2025). Grounding the software in cognitive learning theories, this study evaluates whether technology-mediated Vedic instruction can enhance the mental calculation speed, accuracy, and problem-solving proficiency of Filipino learners facing significant academic challenges.

Objectives of the Study

This study aimed to develop, validate, and evaluate the user's acceptability and pedagogical alignment of a Vedic Mathematics digital learning tool designed for 2-digit multiplication among Grade 8 learners in a public high school in the northern part of Negros Occidental during the School Year 2026–2027.

Specifically, it sought to address the following:

1. Determine the frequency and percentage of the level of computational accuracy and speed in 2-digit multiplication of the grade 8 learners.
2. Design the blueprint for the Vedic Mathematics digital learning tool aligned with the LRMDs standards of Content Quality, Instructional Quality, Technical Quality, and technical error mitigation.
3. Determine the level of validity of the developed Digital Learning Tool in Teaching Vedic Mathematics in terms of:
 - a. Content Quality;
 - b. Instructional Quality;
 - c. Technical Quality; and
 - d. Technical Errors.
4. Evaluate the level of usability of the developed digital learning tool as perceived by Grade 8 student-users and Mathematics teachers using the Computer System Usability Questionnaire (CSUQ) in terms of:
 - a. System Usefulness (SysUse);
 - b. Information Quality (InfoQual);
 - c. Interface Quality (IntQual); and
 - d. Overall Usability Satisfaction.
5. Based on the results of the study, what enhancement of the digital learning tool may be employed.

Theoretical Framework

The theoretical framework of this study integrates Constructivist Learning Theory, the Cognitive Theory of Multimedia Learning (CTML), and the TPACK framework to provide a foundation for developing a mobile

application for Vedic Mathematics (Mayer, 2001; Mishra & Koehler, 2006; Piaget, 1952).

Constructivist Learning Theory posits that knowledge is actively constructed through experiential interaction rather than passively received (Piaget, 1952; Vygotsky, 1978). In math pedagogy, these shifts focus from rigid algorithms to letting learners discover numerical relationships (Lee & Ginsburg, 2009). Active engagement in constructivist environments fosters higher-order thinking and deep conceptual understanding (Keleszade et al., 2018; Vrasidas, 2000). Ultimately, replacing rote memorization with active discovery helps alleviate math anxiety and address critical "number sense" gaps identified in assessments (CPBRD, 2024; Sharma et al., 2025).

To facilitate this process, the Cognitive Theory of Multimedia Learning (CTML) guides the application's design (Mayer, 2001). CTML posits that learning is maximized when information is processed through separate visual and auditory channels, respecting working memory limits (Mayer, 2009; Sweller et al., 1998).

Applying the multimedia principle, the app transforms abstract Vedic sutras into spatial animations, combining words and graphics for better comprehension (Mayer, 2009; Waxman & Goldie, 2021), as demonstrated by platforms like VedicViz (Mathews et al., 2022). This approach reduces extraneous cognitive load and manages essential processing, allowing learners to perform complex 2-digit operations with minimal mental fatigue (Mayer, 2009; Srivastava et al., 2023).

Finally, the TPACK framework synthesizes these domains by modeling the interaction between Content Knowledge (Vedic sutras), Pedagogical Knowledge (constructivist strategies), and Technological Knowledge (mobile app architecture) (Koehler et al., 2013; Mishra & Koehler, 2006). Effective technology integration requires treating these domains as interdependent (Koehler et al., 2012; Singh & Malik, 2022). Leveraging TPACK ensures that the developed mobile tool functions as a cohesive pedagogical system, bridging ancient computational heuristics with modern digital learning to enhance mental calculation speed and accuracy (Nawale et al., 2026; Pallathadka & Roy, 2025).

This study uses three theories to guide the design of the Vedic Math mobile app: Constructivism, CTML, and TPACK. Constructivism helps learners to actively discover number patterns on their own rather than memorizing rigid formulas, which helps lower math anxiety. The Cognitive Theory of Multimedia Learning (CTML) guides the app's visual layout, using clear text and simple animations so learners do not get overwhelmed during mental math. Finally, the TPACK framework combines math content, effective teaching strategies, and mobile technology into one solid system.

Together, these theories ensure the app is easy to use and effective at improving calculation speed and accuracy.

Conceptual Framework

The conceptual framework anchors on the Input-Process-Output-Outcome (IPOO) model integrated with the ADDIE instructional design framework to guide the development and evaluation of the digital learning tool.

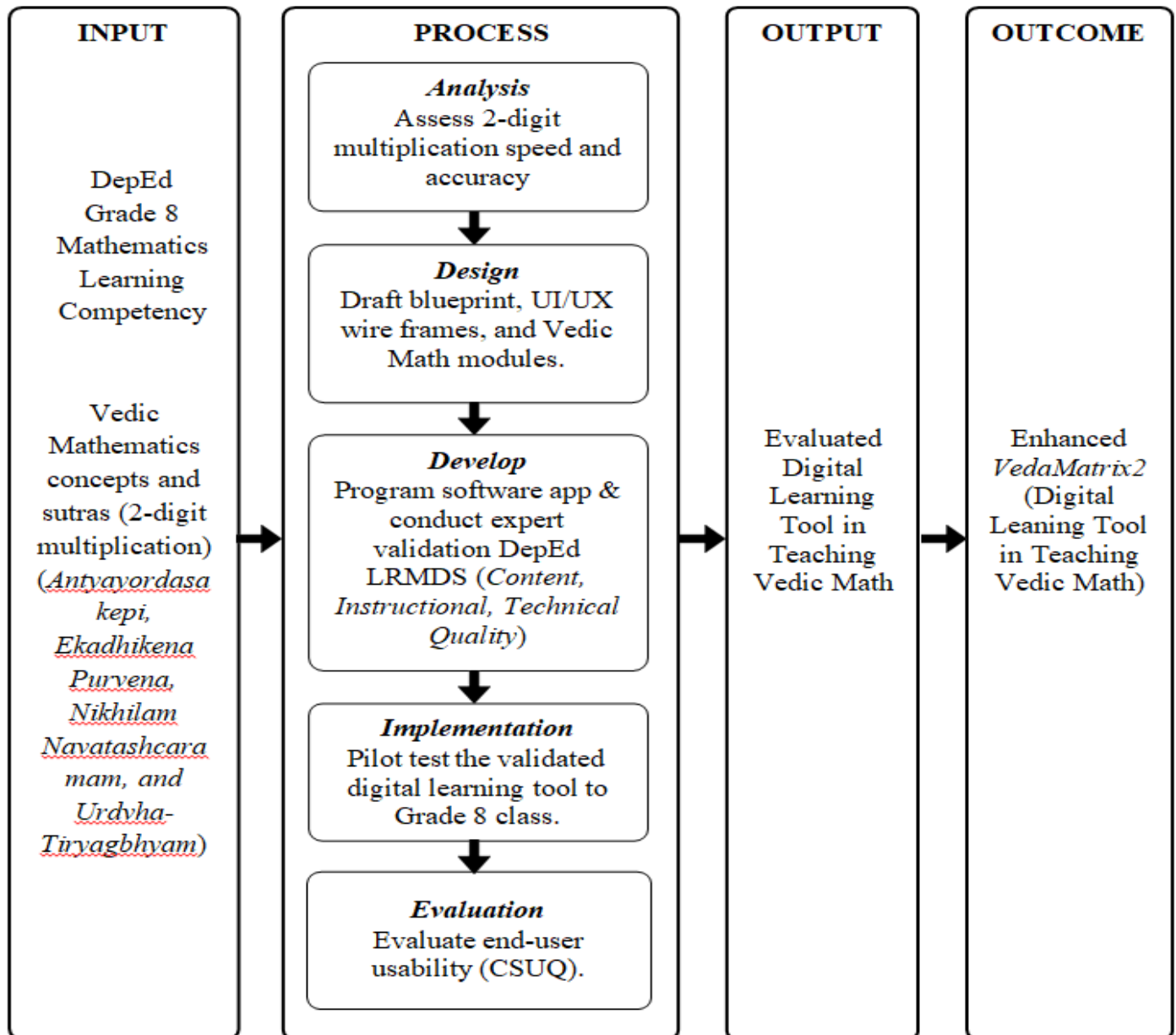
Figure 1 illustrates the conceptual framework of the study, which follows the Input-Process-Output-Outcome (IPOO) model to guide the development, validation, and evaluation of the mobile learning application. The Input phase comprises the core curricular and instructional foundations, specifically the Department of Education (DepEd) Grade 8 Mathematics Learning Competency alongside selected Vedic Mathematics concepts and sutras for two-digit multiplication, namely *Antyayordasakepi*, *Ekadhikena Purvena*, *Nikhilam Navatashcaramam*, and *Urdhva-Tiryagbhyam*.

The Process phase executes these inputs through the five sequential stages of the ADDIE framework. It starts with *Analysis* to establish student speed and accuracy in two-digit multiplication, followed by *Design* to create software blueprints, UI/UX wireframes, and module layouts. During *Development*, the application is programmed and evaluated by expert validators using the DepEd Learning Resource Management and Development System (LRMDS) framework across Content, Instructional, and Technical Quality. The

validated tool is then rolled out in *Implementation* to Grade 8 learners, followed by *Evaluation* to assess end-user usability using the Computer System Usability Questionnaire (CSUQ).

The direct Output resulting from this development process is the Evaluated Digital Learning Tool in Teaching Vedic Math, possessing established content validity, structural soundness, and high user acceptability. Finally, this leads to the long-term Outcome, represented as the Enhanced (VedaMatri2) Digital Learning Tool in Teaching Vedic Math an optimized, quality supplementary mobile tool engineered to build foundational mental arithmetic skills and improve computational performance.

Figure 1 Schematic Diagram of the Study Utilizing the Input-Process-Output-Outcome (IPOO) Model and ADDIE Framework for the Development and Evaluation of the Vedic Mathematics Digital Learning Tool



Scope and Delimitation of the Study

Utilizing a Design and Development Research methodology structured around the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework, this study focuses on the development, expert validation, and user acceptability evaluation of an Android-based mobile digital learning tool incorporating Vedic Mathematics principles for 2-digit multiplication, designed for Grade 8 learners in a public high school in northern Negros Occidental during the School Year 2026–2027. The instructional design of the application

integrates four specific Vedic Sutras, explicitly establishing *Urdhva-Tiryagbhyam* (Vertically and Crosswise) with corresponding to algebraic binomial expansion, *Ekadhikena Purvena* (Squaring ending in 5), *Antyayordasake'pi* (Multiplying by 11), and *Nikhilam Navatashcaramam* (Multiplying near base 10/100) with pattern-recognition prerequisites for foundational mental arithmetic.

The evaluation process involved three target participant groups: ten (10) expert validators (comprising Mathematics Content Experts, Educational Technology Specialists, and Information Technology Experts) selected to evaluate the level of validity in alignment with the DepEd LRMDs standards, the content quality, instructional quality, Technical quality, and Technical errors; five (5) Grade 8 Mathematics teachers selected as subject-matter implementers to evaluate the level of usability with the CSUQ standards; and forty (40) Grade 8 student-users selected as the primary target end-users to evaluate the level of computational accuracy and speed and the level of usability with the CSUQ standards.

Evaluation metrics were strictly confined to software content validity and technical compliance assessed through the Department of Education (DepEd) Learning

Resource Management and Development System (LRMDs) framework, alongside system usability evaluated via the Computer System Usability Questionnaire (CSUQ) and to determine the level of computational accuracy and speed 35-item test questionnaire was developed. Prior to administration, the research instruments underwent expert validation, achieving a Very High Content Validity rating with an overall Content Validity Index / validation score exceeding 0.90 and high internal consistency across sub-scales. Quantitative data collected were processed using descriptive statistical tools, specifically frequency (f) and percentage (%) to measure level of computational accuracy and speed levels, as well as weighted mean (M) and standard deviation (SD) to analyze LRMDs compliance ratings and CSUQ usability dimension scores across all participant groups.

To maintain a dedicated focus on software quality and user acceptability, several empirical and technological boundaries were established. The study deliberately excludes long-term classroom implementation, formal pre-test and post-test experimental control designs, student learning gain evaluations, academic achievement assessments, and measurements of long-term cognitive retention. Curriculum content is restricted solely to 2-digit multiplication and the four selected Vedic Sutras, excluding other arithmetic operations, multi-digit calculations beyond two digits, and broader Grade 8 algebraic topics outside the underlying pattern concepts for binomial expansion. Furthermore, technological deployment is limited exclusively to mobile devices running the Android operating system, thereby excluding iOS, web-based, and desktop software environments.

The interpretation of the findings remains subject to specific methodological limitations beyond the direct control of the researcher. Because participant sampling was confined to a single public high school in northern Negros Occidental, the generalizability of the user acceptability findings to private institutions or schools in other geographic regions with varying levels of technological access and digital literacy may be limited. Additionally, variations in screen size, processing power, and touch responsiveness across individual student-owned Android devices may have subtly affected individual user interaction experiences during usability testing. Finally, level of usability ratings derived from the CSUQ rely on self-reported perception measurements, which inherently carry the potential for subjective response bias.

Significance of the Study

By evaluating this interactive digital learning tool, this study offers empirical insights for educators and curriculum designers to enhance students' Vedic Mathematics skills and optimize digital math pedagogy.

Specifically, the study may benefit the following:

Learners

Learners may gain an engaging, interactive, and self-paced digital platform to explore alternative mental calculation strategies. By using this mobile application, learners may master 2-digit multiplication through

Vedic Mathematics, which reduces calculation anxiety, enhances computational speed and accuracy, and builds overall confidence in mental arithmetic.

Mathematics Teachers

Educators receive a ready-to-use, expert-validated digital supplementary resource aligned with DepEd Grade 8 learning competency specifically the multiplication of binomials grounded in 2-digit arithmetic. Teachers can leverage this innovative tool for remedial instruction, enrichment activities, and differentiated learning, allowing them to integrate technology seamlessly into their lessons without building digital media from scratch.

School Administrators

School principals and administrators may gain an officially screened, quality supplementary resource that advances institutional digital learning goals. Adopting and deploying this compliant tool may strengthen the school's secondary mathematics curriculum and supports overall academic performance metrics.

Curriculum Implementation Division (CID) Chief Personnel

Curriculum managers and education program supervisors obtain empirical data and a contextualized technological model supporting alternative mental math strategies. The findings provide concrete evidence for policy formulation, instructional supervision, and curriculum enhancement in secondary mathematics.

Learning Resource Management and Development Chief Personnel

Learning Resource Management and Development System officers may acquire an officially evaluated, compliant non-print learning resource that meets DepEd quality assurance criteria. The software may serve as a validated asset ready for cataloging, archiving, and division-wide repository distribution.

Parents

Parents may acquire a safe, cost-effective, and educational mobile resource that their children can use for productive home study. Because the software operates entirely offline after installation, parents can support their children's mathematical practice without incurring recurring cellular data expenses or requiring active home internet connections.

Researcher

This study serves as a practical platform for the researcher to apply and refine competencies in mobile app development, instructional design, and empirical data analysis. By bridging the gap between ancient mathematical theory and modern mobile technology, the researcher gains valuable insights as a contributor to the fields of ICT and mathematics education.

Future Researchers

Future scholars may receive a fully functional, expert-validated software artifact and an empirical usability. Researchers can utilize this foundation to conduct large-scale classroom implementation studies, perform quasi-experimental learning efficacy tests, or design further feature enhancements for educational mobile software.

Definition of Terms

The following terms are defined conceptually and operationally to provide a clearer understanding of the variables and processes involved in this study: **ADDIE Model**

The ADDIE model is a systematic five-phase instructional design framework, comprising Analysis, Design,

Development, Implementation, and Evaluation used to guide the structured creation, testing, and assessment of educational programs, software, and learning materials (Branch, 2009; Molenda, 2003)

Within the framework of this research, the ADDIE model is operationalized as the core developmental methodology used to analyze Grade 8 student computational needs, design the application interface, program the Android software, deploy the tool to target users, and evaluate system usability alongside expert compliance.

Computational Accuracy

Computational accuracy refers to the degree to which a learner executes mathematical operations without making procedural, factual, or arithmetic errors, yielding correct solutions that reflect sound procedural competence and numerical understanding (Kilpatrick et al., 2001; Baroody et al., 2016). In arithmetic learning, accuracy serves as a foundational dimension of computational fluency, ensuring that mental heuristics and algorithms consistently produce correct results (National Research Council, 2001; Geary, 2021).

In the context of this study, this term is defined as the total number or percentage of correctly solved mathematical problems (e.g., Vedic multiplication items) completed by students on the software application's pre-test, post-test, or interactive practice modules.

Computational Speed

Computational speed pertains to the execution efficiency or rate at which a learner processes mathematical algorithms and completes numerical operations within a given timeframe (National Research Council, 2001; Mahajan, 2023). It represents procedural automaticity, rapid cognitive retrieval, and reduced working memory load during mental calculation (Sweller, 2020; Awasthi et al., 2023).

This term refers to as the total time (recorded in seconds or minutes) taken by a student to complete a standardized set of mathematical exercises or interactive quiz modules within the digital learning tool.

Design and Development Research (DDR)

Design and Development Research (DDR) is a pragmatic research design focused on the systematic analysis, creation, testing, and evaluation of instructional products, media, and tools to establish an empirical basis for their effectiveness and design principles (Richey & Klein, 2007; Ellis & Levy, 2010).

In this study, DDR represents the overarching methodological framework applied to conceptualize, program, expert-validate, deploy, and evaluate the VedaMatrix2 mobile application within a secondary school learning environment. **Digital Learning Tool**

A digital learning tool is any software application, mobile program, or interactive digital media specifically designed to deliver, support, or enhance instructional content and learning experiences (Clark & Mayer, 2016; Sung et al., 2016).

For the scope of this study, Digital Learning Tool specifically denotes VedaMatrix2 a native Android mobile application (< 30 MB, running 100% client-side offline) built with Kotlin and custom XML layouts to provide Grade 8 learners with interactive tutorials, practice drills, retrospective reviews, and timed challenge speed runs in 2-digit Vedic multiplication.

Content Quality. Conceptually, content quality represents the extent to which instructional materials, explanations, practice exercises, and embedded mathematical rules are factually accurate, mathematically sound, free of bias, and aligned with grade-level learning standards and competencies (Clark & Mayer, 2016; Department of Education, 2020). *For the purpose of this investigation, this construct is operationally defined as the mean evaluation score awarded by subject matter experts (e.g., mathematics teachers and education program supervisors) using the Department of Education (DepEd) Learning Resource Management and*

Development System (LRMDS) non-print evaluation tool or a standardized four-point rating scale.

Instructional Quality. This denotes the degree to which educational software integrates effective pedagogical design, cognitive multimedia learning principles, structured scaffolding, responsive feedback mechanisms, and guided practice to facilitate effective skill acquisition (Spector, 2016; Mayer, 2021).

In this study, this is evaluated through the average rating obtained from expert evaluators and student end-users on structured evaluation questionnaires assessing lesson clarity, feedback responsiveness, step-by-step guidance, and self-paced navigation features of the application.

Technical Quality. This term reflects the software engineering standard concerning an application's visual interface design, system reliability, operational architecture, navigation efficiency, and user interface responsiveness (ISO/IEC, 2011; Lewis, 2018).

In this research, this term is determined by the mean usability score derived from expert evaluations and usability testing using the Computer System Usability Questionnaire (CSUQ) or DepEd LRMDS non-print rating sheet, focusing on interface aesthetics, system stability, button responsiveness, and navigation flow.

Technical Errors. This refers to system bugs, software glitches, application crashes, interface distortions, or functional defects encountered during execution that impede proper software performance or disrupt user interaction (IEEE, 2017; Pressman & Maxim, 2020).

This refers to as the total count, severity classification (e.g., minor layout misalignment versus full application crash), and documented log of software glitches identified during system testing, expert validation, and pilot testing of the digital learning tool.

Learning Resource Management and Development System (LRMDS)

The Learning Resource Management and Development System (LRMDS) is a national framework and web repository established by the Department of Education to oversee the identification, creation, quality-assurance evaluation, cataloging, and distribution of print and non-print basic education learning materials (DepEd, 2009; DepEd Order No. 76, s. 2011).

Within the study's evaluative scope, LRMDS refers to the official DepEd evaluation instrument for non-print materials used by expert evaluators to rate VedaMatrix2 across Content Quality (Factor A), Instructional Quality (Factor B), Technical Quality (Factor C), and Technical Errors (Factor D).

Multiplication of Binomials

Multiplication of binomials is an algebraic process involving the product of two algebraic expressions that each contain two terms, typically performed using distributive properties or the FOIL (First, Outer, Inner, Last) method (Larson & Boswell, 2019; DepEd, 2016).

Contextually in this research, multiplication of binomials represents the Grade 8 DepEd curriculum competency that serves as the mathematical foundation for this research, where learners apply 2-digit Vedic mental arithmetic techniques to simplify algebraic products.

System Usability

System usability is the degree to which a software product or digital tool allows specified users to achieve specified goals with effectiveness, efficiency, learnability, and satisfaction within a designated context of use (ISO, 2018; Lewis, 1995; Nielsen, 1993).

In this study, system usability refers to the quantitative level of user acceptance, functional quality, and satisfaction measured among Grade 8 learners and mathematics teachers using the Computer System Usability

Questionnaire (CSUQ), covering System Usefulness, Information Quality, Interface Quality, and Overall Satisfaction.

Vedic Mathematics

Vedic Mathematics is a system of mental calculation reconstructed from ancient Indian texts by Swami Bharati Krishna Tirthaji between 1911 and 1918, consisting of 16 main sutras and 13 sub-sutras that streamline arithmetic and algebraic operations into intuitive mental heuristics (Kapoor, 2006; Tirthaji, 1965).

For this research, Vedic Mathematics refers to the specific mental math framework and four 2-digit multiplication rules (*Antyayordasake'pi*, *Ekadhikena Purvena*, *Nikhilam*, and *Urdhva-Tiryagbhyam*) programmed into interactive lessons, practice drills, and speed challenges within the VedaMatrix2 software.

Antyayordasake'pi. *Antyayordasake'pi* is a Vedic Mathematics sub-sutra (corollary) translating to "when the last digits sum to ten and the remaining digits are the same," providing a high-speed mental shortcut for multiplying specific pairs of numbers (Tirthaji, 1965; Williams, 2000).

As applied in this study, *Antyayordasake'pi* designates one of the four mental multiplication algorithms embedded within the VedaMatrix2 application, utilized by Grade 8 learners to solve specialized 2-digit multiplication problems where the 2-digit number is multiplied by 11.

Ekadhikena Purvena. *Ekadhikena Purvena* is a Vedic Mathematics sutra translating to "by one more than the previous one," utilized to multiply specific number pairs or square numbers ending in 5 by multiplying the leading digit by its integer successor (Agarwal, 2018; Tirthaji, 1965).

Within the VedaMatrix2 application, *Ekadhikena Purvena* is defined as the second mental arithmetic strategy digitized into interactive modules, enabling Grade 8 learners to perform rapid 2-digit calculations by squaring 2-digit numbers ending in 5 and squaring numbers near 50.

Nikhilam Navatashcaramam Dashatah. This is a foundational Vedic Mathematics sutra translating to "all from 9 and the last from 10," which simplifies multiplication of numbers near a base power of ten through deviation arithmetic (Glover, 2014; Tirthaji, 1965).

In this study, *Nikhilam Navatashcaramam Dashatah* (shortened as *Nikhilam*) refers to the mental calculation algorithm digitized in VedaMatrix2 to assist Grade 8 learners in solving 2-digit multiplication items featuring numbers close to base 10 or 100.

Urdhva-Tiryagbhyam. It is a primary Vedic Mathematics sutra translating to "vertically and crosswise," providing a universal vertical-crosswise algorithm applicable to all multi-digit multiplication problems (Nicholas et al., 1999; Tirthaji, 1965).

Urdhva-Tiryagbhyam refers to the general 2-digit multiplication algorithm built into VedaMatrix2, offering Grade 8 learners a single-line mental calculation route that replaces traditional multi-step written calculations.

REVIEW OF RELATED LITERATURE

This literature review provides a comprehensive analysis of the academic landscape surrounding the development and implementation of digital learning tools for Vedic Mathematics. The review is organized into five critical themes: Landscapes of Mathematics Education, Vedic Mathematics: Philosophy and Pedagogy, Technology in Mathematics Instruction, and Instructional and ADDIE Model in mathematics Landscapes of Mathematics Education

The current landscape of mathematics education is characterized by a push toward competency-based learning and the integration of 21st-century skills, though significant disparities in student performance persist globally and locally. In the Philippines, the education system is navigating a complex transition to the MATATAG

curriculum to address long-standing issues in proficiency and curriculum congestion (Johnston, 2023), (Kilag & Ledesma, 2024), ((Insights, Challenges and Coping Strategies of the Mathematics Teachers on the MATATAG Curriculum, 2025).

The Philippine mathematics education landscape is marked by persistent challenges in student performance and resource adequacy. Albento (2023) conducted a descriptive-developmental study in the Candon City Division, involving 362 Grade 6 learners (Albento, 2023). The study identified that learners struggled most with dividing fractions, mixed fractions, and basic operations of integers. In response, remediated learning material was developed and validated, showing high adequacy and usefulness in improving mathematics proficiency. This highlights the need for targeted interventions to address specific learning gaps in elementary grades.

Similarly, Lagria and Pañares (2023) explored the difficulties faced by Grade IV pupils in the West 2 District of Gingoog City (Lagria & Pañares, 2023). Their descriptive-correlational research found that comprehension is the most challenging aspect for learners, particularly in visualizing operations with fractions and solving real-life problems involving GCF and LCM. The study noted a moderate correlation between student attitude and academic performance, suggesting that fostering a positive mindset is as crucial as technical instruction.

At the systemic level, Johnston (2023) analyzed the curricular context of statistics education in the Philippines (Johnston, 2023). The report describes the intended K to 12 curriculum for statistics and probability but emphasizes that implementation is hindered by a lack of resources and the need for continuous teacher professional development. This systemic view is complemented by a qualitative systematic review that assessed the broader mathematics education context in the Philippines (Charting a Course for Improvement: Assessing Mathematics Education in the Philippine Context, 2024). The review cited performance disparities in international assessments like PISA and TIMSS as evidence of persistent challenges in mathematical proficiency and problem-solving skills. It recommended innovative instructional strategies, such as technology integration and problem-based learning, to align classroom practices with 21st-century demands.

The resilience of teachers in this challenging environment was explored through the Theory of Pedagogical Resilience of Adaptive Mathematics Teachers (PRAM) (A Pyramid of Strength: The Pedagogical Resilience of Adaptive Mathematics Teachers (PRAM), 2025). This grounded theory study, involving elementary teachers in Iloilo, developed a dynamic "Pyramid Model" of resilience. It identified five domain cognitive, behavioral, supportive, emotional, and reflective strategies that teachers use to overcome instructional barriers, resource constraints, and technology integration difficulties. The findings suggest that professional development should not only focus on content but also on fostering this multidimensional resilience to ensure educational quality.

On a global scale, mathematics education is evolving toward more inclusive and technology-driven pedagogical models. Madi and Gusni (2025) provided a systematic review of 62 peer-reviewed studies, identifying innovative trends such as Universal Design for Learning (UDL), blended/HyFlex instruction, and ethnomathematics (Madi & Gusni, 2025). The review highlighted that while these models enhance student agency and achievement, their implementation remains geographically uneven, with high-income countries enjoying more institutional support than low- and middle-income countries.

The complexities of curriculum implementation were further analyzed by Ko (2023), who compared experiences across Denmark, France, China, and the Philippines (Ko, 2023). The study concluded that successful curriculum reform is a non-linear process that requires a harmonious combination of top-down and bottom-up strategies. It underscored the importance of high-quality materials, extensive teacher training, and aligned assessment methods to ensure that competency-based approaches reach the classroom.

The decline in mathematical competence was a major finding in the PISA 2022 results, particularly in Germany (Lewalter et al., 2023). The report noted a significant decrease in average scores compared to previous rounds and an increase in the proportion of low-achieving learners who struggle with basic tasks. This trend was attributed in part to the impact of the COVID-19 pandemic and the delayed integration of digital media into teaching, despite the availability of ICT resources. The findings emphasize the need for targeted support for

disadvantaged learners and a shift toward mathematical reasoning and real-world problem-solving.

Bibliometric analyses have also mapped the evolution of the field. Fernandez and Aclao (2025) reviewed 274 academic publications, identifying AI integration and personalized learning as dominant trends (Fernandez & Aclao, 2025). Their analysis suggests that the discourse in mathematics education is increasingly driven by international collaborations and a focus on gender equity and student motivation.

Similarly, Da and Pham (2025) focused on the landscape of AI integration from 2015 to 2025 (Da & Pham, 2025). Their systematic review identified emerging trends in AI-driven pedagogical models and the common challenges faced by developers and teachers in making AI a tool for quality improvement rather than just a replacement for traditional methods.

Vedic Mathematics: Philosophy and Pedagogy

Vedic Mathematics, rooted in ancient Indian knowledge systems, offers a unique pedagogical philosophy that emphasizes simplicity, mental agility, and creative reasoning through a system of 16 sutras and 13 sub-sutras (Kaur, n.d.), (Chaudhary & Gupta, 2025), (Sharma & Bakshi, 2025).

In the Philippine context, Vedic Mathematics is increasingly explored as an intervention to improve numeracy and computational speed. Daliva and Deita (2025) conducted a quasi-experimental study on Grade 7 learners, finding that the integration of Vedic techniques significantly improved both basic mathematical skills and learner engagement. The experimental group reached a higher level of proficiency compared to the control group, and learners demonstrated a notable increase in their on-task behavior and interest in the subject.

Taracina (2023) implemented Vedic Math techniques in a Grade 2 SPED (FL/GT) class at Don Emilio Salumbides Elementary School. The intervention targeted proficiency in the four fundamental operations. Over one month, the mean percentage score of the learners increased from 70.00% to 80.19%, exceeding the national cutoff. The study concluded that Vedic methods are effective tools for improving numeracy performance among elementary learners with diverse needs.

The application of Vedic Mathematics extends to higher-level concepts as well.

Bandala investigated the impact of Vedic Mathematics Techniques (VMT) on the performance of Grade 8 learners in factoring polynomials at Amas National High School (Luzano, 2024). The study showed that VMT provided a faster and more efficient approach to algebraic manipulation, which is traditionally a challenging area for learners.

In the early years, Babor et al. evaluated the effectiveness of a play-based Vedic approach on the numeracy skills of seventy kindergarten pupils in Misamis Oriental.

This study addressed a gap in the literature regarding the adaptation of Vedic methods for very young learners, suggesting that the philosophy of simple, logical patterns can be successfully introduced at pre-school level.

Finally, the philosophical relevance of such alternative mathematical approaches in the Philippines is supported by Balmaceda (2021), who discussed the value of mathematics appreciation courses (Balmaceda, 2021). Balmaceda argued that mathematics should be viewed as a dynamic human endeavor, and that courses designed to break down misconceptions and reveal the beauty of mathematical thinking, much like the Vedic system are vital for developing quantitative reasoning and a positive attitude toward the discipline.

The international literature on Vedic Mathematics is deeply rooted in the Indian Knowledge System (IKS). Kaur provided an analytical review of Vedic Mathematics in modern Indian education, describing it as both a computational tool and a pedagogical philosophy that fosters cognitive gains (Kaur, n.d.). This is echoed by Shrivastava et al., who explored Vedic Mathematics as a philosophy of learning that rethinks unity and simplicity in mathematical instruction (Shrivastava et al., n.d.).

Awasthi et al. (2023) compared Vedic and modern teaching approaches, noting that while the Vedic era focused on oral instruction and practical applications, modern methods emphasize abstract concepts and inclusive assessments (Awasthi et al., 2023). However, the study highlighted significant similarities, such as the shared emphasis on visualization, problem-solving, and collaboration. The authors suggested that reviving Vedic techniques could deepen student appreciation for the rich history of mathematical traditions.

The holistic nature of Vedic Mathematics was emphasized by Singh and Kumar, who proposed pathways for integrating these methods into school curricula (Singh & Kumar, n.d.). They argued that Vedic Mathematics encourages learners to think independently and discover solutions through logical reasoning, rather than rote memorization. This cognitive benefit was further explored in a 2025 review of the psychological benefits of Vedic Mathematics (The Cognitive and Psychological Benefits of Vedic Mathematics: A Review, 2025). The review found that Vedic methods enhance working memory, attention, and executive functioning, while simultaneously reducing math anxiety and building self-confidence.

Chaudhary and Gupta (2025) provided a comprehensive guide to Vedic Mathematics, tracing its origins to the sutras and sub-sutras reconstructed by Swami Bharati Krishna Tirtha (Chaudhary & Gupta, 2025). Their work highlights how these ancient mental strategies can enhance mental agility in modern competitive environments. Similarly, Sharma and Bakshi (2025) discussed the role of Vedic Mathematics in the revival of the Indian Knowledge System and its potential to transform modern education by providing faster techniques for complex problem-solving (Sharma & Bakshi, 2025).

Innovative tools like VedicViz have also been developed to visualize Vedic principles in mental arithmetic. An evaluation of VedicViz among high school learners and teachers in India showed strong agreement on the tool's usefulness and ease of use, with teachers noting its potential for self-learning (VedicViz: Towards Visualizing Vedic Principles in Mental Arithmetic, 2022). Furthermore, Mahajan (2023) conducted a quasi-experimental study involving 60 learners, observing statistically significant improvements in calculation speed and a reduction in errors among those trained in Vedic methods (Mahajan, 2023).

Technology in Mathematics Instruction

The integration of digital tools in mathematics instruction has transitioned from a pandemic-driven necessity to a fundamental component of modern pedagogy, enhancing visualization and personalized learning (Glewwe et al., 2025), (Fernandez & Aclao, 2025), (Da & Pham, 2025).

Nabayra (2022) explored teacher-created videos for university students, providing a flexible way to learn mathematics online. Espenosa et al. (2026) studied the impact of GeoGebra-assisted instruction on solid geometry achievement. Corpuz (2023) developed instructional materials using Google Sites, integrating the 7E learning cycle. Social media and video platforms have also been used, with YouTube playlists (Insorio et al., 2022) and Facebook Messenger (Insorio et al., 2023) showing significant increases in student performance and confidence. Finally, Glewwe et al. (2025) conducted a randomized controlled trial showing that tablet-based instruction significantly improved junior high school math learning.

Their findings aim to inform localized pedagogical strategies that leverage dynamic geometry software to help learners visualize 3D shapes and concepts.

Similarly, Corpuz (2023) developed instructional materials using Google Sites, integrating the 7E instructional learning cycle for General Mathematics (Enhancing Mathematics Education in the Philippines: Addressing Challenges and Improving Instructional Quality through Professional Development, 2024). The material was validated by experts as highly acceptable for both face-to-face and distance learning, effectively bridging the gap between national standards and technological integration.

The use of social media and video platforms has also been prominent. Insorio et al. (2022) implemented a YouTube video playlist as supplementary learning material for Grade 10 learners in San Pedro, Laguna (Cruz & Hernandez, 2023). The intervention resulted in a significant increase in academic performance and student

confidence. In another study, Insorio and colleagues (2023) utilized Facebook Messenger to deliver lectures and video lessons to Grade 7 learners under modular distance learning (Madi & Gusni, 2025). The experimental group showed significantly higher post-test scores, proving that accessible, low-bandwidth technologies can be effective interventions for struggling learners.

Finally, the most advanced application of technology was seen in a randomized controlled trial conducted by Glewwe et al. (2025) across 42 remote schools in the Philippines (Glewwe et al., 2025), (Bernas, 2023). The study found that tablet-based computer-assisted instruction improved junior high school math learning by 0.34 to 0.46 standard deviations. Notably, the effects were even more pronounced in the second year of implementation, reaching 1.6 standard deviations, which underscores the long-term potential of digital tools in rural education.

Globally, the use of digital educational content is widespread. An online survey of 261 teachers in Ukraine revealed that nearly 95% use digital content, with PowerPoint and Canva being the most popular tools for presentation and design (Albento, 2023). Specialized tools like Mathematica and GeoGebra were used by approximately a quarter of the participants, indicating a growing but still developing adoption of high-level mathematical software.

The importance of teacher training and standard procedures was highlighted by Gamit (2023), who implemented a learning management system in high school classrooms (Charting a Course for Improvement: Assessing Mathematics Education in the Philippine Context, 2024). The study found that learners often struggle with digital tools if there is no cohesive learning experience or if teachers overestimate student proficiency. The research suggested that technology is most effective when teachers use the resources themselves and provide early, thorough introductions to the tools.

Innovative assessment tools, such as digital interactive notebooks (dINB), have been shown to enrich the Technological Pedagogical Content Knowledge (TPACK) of instructors (Simbulas et al., 2023). Galanti et al. (2020) found that dINBs created a flexible assessment environment aligned with student-centered instruction in virtual classrooms. This aligns with the findings of Alshehri (2024), who argued that digital education has transformed the roles of learners and teachers, making subjects like mathematics more understandable through visual aids and individualized instruction (Glewwe et al, 2025).

However, challenges remain. A study in the southeastern United States by Martin et al. (2022) found that while digital technology use increased during the pandemic, certain activities like math games were perceived as equally or more useful in person (Kilag & Ledesma, 2024). The study suggested that the primary benefit of technology during remote teaching was in organization and formative assessment rather than just the delivery of content.

Instructional and ADDIE Model in Mathematics

This theme focuses on the systematic development of instructional materials using the ADDIE model, specifically for mathematics education. The model consisting of Analysis, Design, Development, Implementation, and Evaluation phases provides a rigorous framework for ensuring that learning tools are both pedagogically sound and effective.

Loyola, C. J. O., De Luna, L. R., Diloy, M. A., & Rivera, V. S. (2022) utilized the ADDIE model to design and develop a gamification tool aimed at enhancing mental computation in basic mathematics. In the *Analysis* phase, the researchers identified significant numeracy gaps among elementary learners, particularly in the speed and accuracy of fundamental operations. The *Design* phase focused on integrating interactive game elements, such as reward systems and timed challenges, to make mental math more engaging. During *Development*, the digital tool was built using a platform that allows for real-time feedback. The *Implementation* phase involved a pilot study with students, where the gamification elements were tested for usability. Finally, the *Evaluation* phase confirmed that the tool significantly increased student motivation and their ability to perform mental calculations rapidly. The study concludes that the systematic ADDIE approach

ensures the tool is tailored to the specific cognitive needs of Filipino learners while leveraging the psychological benefits of gaming.

Ronquillo, E. (2025) developed and validated a set of worksheets specifically designed to address the "Least Learned Competencies" in Mathematics 4. The researcher strictly followed the ADDIE framework, beginning with the *Analysis* of regional assessment data to pinpoint areas where students consistently failed to meet proficiency standards. In the *Design* phase, the worksheets were structured with scaffolded tasks, moving from simple recall to complex problem-solving.

During *Development*, content and language experts were consulted to ensure clarity and alignment with the Department of Education (DepEd) curriculum.

The *Implementation* phase allowed teachers to use the materials in a classroom setting, providing direct evidence of their impact. The *Evaluation* phase resulted in high acceptability ratings, with participants noting that the worksheets effectively bridge the gap between abstract concepts and practical mastery.

Arnado, A. (2023) explored the development and validation of Motivational Manipulative Learning Materials (MMLMs) for Grade 9 Trigonometry. Recognizing the abstract nature of trigonometry, the researcher *Analyzed* the specific conceptual barriers faced by students. The *Design* involved creating both physical and digital manipulatives that allow for tactile and visual exploration of triangles and circles. In the *Development* stage, the prototypes were refined based on initial feedback from subject matter experts. The *Implementation* demonstrated that students who used the MMLMs had a more profound understanding of the relationship between trigonometric ratios. The *Evaluation* phase confirmed that the materials were content-valid and pedagogically effective in sustaining learner interest, proving that structured instructional design can make advanced mathematics more accessible.

Elen, K. M. L. (2024) focused on "Interdisciplinary Contextualization" in the development of instructional materials for Grade 7 Mathematics. The study used the ADDIE model to bridge mathematical concepts with other subject areas, such as the natural sciences and social studies. During the *Analysis* phase, the researcher identified that students often struggle with the relevance of mathematics. The *Design* phase created problems centered on real-world local contexts, such as agriculture and environmental conservation. The *Development* stage involved drafting and peer-reviewing the interdisciplinary modules. The *Evaluation* showed that students found the contextualized materials more relevant and easier to understand, highlighting the model's effectiveness in curriculum integration and enhancing student interest through meaningful application.

Design and Development of a Numeracy Bridging Workbook (2025) (e-RuNT Based). This study, conducted in a large public secondary school in Central Philippines, aimed to design a numeracy bridging workbook for Grade 10 learners. The researchers started with a diagnostic needs analysis (*Analysis*) using the Enhanced Regional Unified Numeracy Test (e-RuNT), which identified subtraction as the operation with the lowest mastery level. The workbook was then *Designed* with a focus on learner-centered, scaffolded subtraction tasks. During the *Development* phase, reinforcement activities for addition, multiplication, and division were added to create a comprehensive tool. The *Evaluation* involved validating the workbook with a panel of experts, who confirmed its responsiveness and alignment with secondary education standards, ensuring that it provides a valid intervention for numeracy improvement.

Rohaeti, E. E., Evans, B. R., Prahmana, R. C. I., & Hidayat, W. (2023) developed the "SANTUY" mobile application in Indonesia to improve students' mathematical understanding and cognitive flexibility. The development followed the ADDIE stages, starting with an *Analysis* of the difficulties students face in understanding functions and relations. The *Design* of the SANTUY app allowed for "differential learning," where the software adapts to the user's current level of understanding. The *Development* phase utilized Android-based platforms to ensure widespread accessibility. The *Implementation* in high schools showed that the app significantly enhanced students' mathematical reasoning compared to traditional lecture-based methods. The *Evaluation* phase highlighted that the app's interactive and adaptive features are key to its success in fostering higher-order thinking skills.

Pujiastuti, H., & Haryadi, R. (2022) applied the ADDIE model to the development of Augmented Reality (AR) tools for mathematics learning in Indonesia. The study focused on 3D geometry, *Analyzing* the spatial visualization challenges faced by students. The *Design* phase created AR markers that project 3D geometric shapes onto mobile screens. During *Development*, the markers and app were tested for technical reliability. The *Implementation* involved small-group and large-group trials in high schools, where students interacted with the AR projections.

The *Evaluation* confirmed that the tool was highly effective in making abstract geometry concepts more concrete and improving students' spatial reasoning abilities, proving that AR can be a practical classroom intervention when designed systematically.

Abrar, A. I. P., et al. (2025) developed an Android-based mathematics learning application for sequences and series using iSpring Suite 11. The development process followed the ADDIE framework, ensuring that the app's media and material were validated by experts. In the *Analysis* phase, the team identified that students often find arithmetic and geometric sequences boring or difficult. The *Design* incorporated interactive quizzes and multimedia explanations. The *Development* phase resulted in a practical and validated app. The *Evaluation* phase showed that the app was not only highly valid but also extremely practical for use in high school mathematics classrooms, providing a modern, interactive alternative to traditional textbooks.

Adiastuty, N., Muparihah, L., & Riyadi, M. (2025) investigated the effectiveness and validity of differentiated mathematical learning media based on the Smart App Creator application. The study aimed to develop students' "thinking creativity." Following the ADDIE model, the researchers *Analyzed* the diverse learning styles of students. The *Design* phase allowed for multiple paths through the content, catering to different creative approaches. The *Development* phase created a versatile digital platform. The *Evaluation* phase involved testing the media's validity and effectiveness, with results indicating that the tool is both a reliable instructional resource and a powerful motivator for fostering creative problem-solving in mathematics.

Silaen, E. O., Susanti, E., & Aisyah, N. (2025) developed STEM-based E-LKPD (Electronic Student Worksheets) focused on the Pythagorean Theorem. The development followed the ADDIE stages, integrating Science, Technology, Engineering, and Mathematics principles. The *Analysis* phase explored how the theorem is used in various STEM careers. The *Design* of the worksheets focused on problem-based learning scenarios. The *Development* phase produced digital worksheets that can be used on tablets. The *Evaluation* phase measured the impact on students' problem-solving ability, finding a significant improvement in their capacity to apply mathematical theorems to real-world scenarios, thereby demonstrating the power of the ADDIE model in creating modern, interdisciplinary math materials.

Synthesis

The literature review across the four themes Landscapes of Mathematics Education, Vedic Mathematics: Philosophy and Pedagogy, Technology in Mathematics Instruction, and the Instructional and ADDIE Model in Mathematics reveals a clear and compelling path for the development of a digital Vedic Mathematics tool. The Landscapes theme highlights a critical need for reform, as students in the Philippines and globally struggle with traditional mathematical models and resource constraints. Vedic Mathematics provides the pedagogical solution, offering a system that simplifies computation and fosters mental agility through ancient *sutras* that are remarkably relevant to modern mental math. Technology provides the necessary vehicle for this solution, with evidence showing that digital tools from mobile apps to AR can significantly enhance visualization and student engagement. Finally, the Instructional and ADDIE Model theme provides the methodology to execute this vision. The local and foreign studies reviewed in this section demonstrate that a systematic, evidence-based approach to tool development ensures validity, practicality, and effectiveness. Whether it is a gamified tool in the Philippines (Loyola, 2022) or an AR app in Indonesia (Pujiastuti, 2022), the ADDIE model ensures that the resulting product is directly responsive to the needs of the learners identified in the initial landscape analysis. The synthesis of these themes suggests that the development of a digital learning tool for Vedic Mathematics is not merely an addition of technology to an old system, but a strategic integration of ancient wisdom and modern instructional design. By grounding the tool in the ADDIE model, the research addresses the "Least

Learned Competencies" (Ronquillo, 2025) while simultaneously promoting "thinking creativity" (Adiastuty, 2025). Ultimately, this multi-thematic foundation supports the creation of a tool that can bridge the achievement gap, reduce math anxiety, and equip 21st-century learners with the computational speed and conceptual clarity needed for future success.

METHODOLOGY

This Chapter presents the Research Design, Software Lifecycle Model, Software Development Phases, Research Instrument, Requirement Phases, Data Analysis Procedure, and Ethical Consideration that guide the conduct of the study.

Research Design

This study utilized the Design and Development Research research design alongside with the ADDIE model as the structural framework for the systematic creation and validation of the digital learning tool.

Developmental research, as characterized in recent literature, is defined as the methodical investigation of design, development, and evaluation procedures aimed at producing an educational product (McKenney & Reeves, 2018). The study addresses the contemporary need for specialized instructional products when existing resources are insufficient or fail to leverage modern technological affordances. By following the sequential phases of Analysis, Design, Development, Implementation, and Evaluation, the study ensures a rigorous transition from conceptualization to a functional educational tool.

The researcher employs the ADDIE Model (Analysis, Design, Development, Implementation, and Evaluation) as the primary methodological framework.

According to recent scholarship by Kurt (2018), the ADDIE model remains the gold standard for creating instructional resources, offering an organized and iterative process that ensures learner needs and specific pedagogical objectives inform every stage of creation. Furthermore, the model's flexibility allows for the integration of modern digital pedagogies, making it ideal for the development of niche mathematical software (Shelton & Saltsman, 2016).

By integrating the ADDIE model within a developmental research framework, the creation of the digital tool for teaching Vedic Mathematics moves beyond simple software development. It transforms into a scholarly process where the Analysis phase pinpoints computational challenges in conventional mathematics (Hess & Greer, 2016). The Design and Development phases convert Vedic Sutras into interactive digital formats. The Evaluation phase employs expert validation and formative assessment as emphasized by Trust and Pienta (2020) to guarantee the tool's efficacy, user experience, and mathematical precision.

Software Lifecycle Model

The development of the VedaMatrix2 mobile application follows the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model integrated with an iterative prototyping approach as its primary Software Development Life Cycle (SDLC) framework. The initial Analysis phase established the educational, technical, and operational parameters by investigating the computational accuracy and speed of forty (40) Grade 8 learners and five Mathematics teachers. During this phase, Department of Education (DepEd) Grade 8 Mathematics competencies focusing on 2-digit multiplication and pattern recognition related to binomial expansion were mapped directly to four Vedic Sutras: *Urdhva-Tiryagbhyam*, *Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam*. Additionally, core technical parameters were established, mandating that the application operate entirely client-side, remain 100% offline, maintain a lightweight installation footprint of under 30 megabytes, and perform reliably across Android operating system environments.

Transitioning into the Design phase, these curricular and technical requirements were translated into interactive wireframes, screen-flow architectures, and UI/UX design blueprints across four distinct application modes: Interactive Tutorials, Practice Drills, Retrospective Reviews, and Timed Challenge Speed Runs. The

pedagogical structure strictly distinguished *Urdhva-Tiryagbhyam* (Vertically and Crosswise) as the universal general method corresponding directly to algebraic binomial expansion $(ax + b)(cx + d)$, while framing *Ekaadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam* as specialized pattern-recognition prerequisites to build foundational mental arithmetic fluency.

Interface layouts, high-contrast visual assets, scaled typography, and real-time feedback mechanisms were meticulously designed to optimize user engagement on mobile screens. During the Development phase, the functional software package was engineered using Kotlin for back-end application logic and custom XML layouts for front-end presentation within Android Studio. Development efforts encompassed building local scoring algorithms, automated hint generators, interactive step-by-step solution guides, and offline performance logging mechanisms without server dependencies. Internal alpha testing and rigorous code debugging were conducted across varying screen resolutions to resolve system crashes, layout overflows, and memory bottlenecks prior to participant deployment.

In the Implementation phase, the compiled standalone Android package (.apk, < 30 MB) was installed directly onto the mobile devices of the forty (40) Grade 8 student-users and five (5) Grade 8 Mathematics teachers. To ensure seamless operation, guided orientation sessions were conducted to familiarize participants with the navigation menus, tutorial features, and interactive drill modes, enabling independent user interaction with the application.

Finally, the Evaluation phase measured technical quality, content validity, and user acceptability using standardized appraisal instruments. A ten (10) member panel of expert validators, comprising five (5) Mathematics Content Experts and five (5) Information Technology Experts appraised the application using the DepEd Learning Resource Management and Development System (LRMDS) framework across Content Quality (Factor A), Instructional Quality (Factor B), Technical Quality (Factor C), and Technical Errors (Factor D). Concurrently, system usability and acceptability were assessed among the student-users and teachers using the Computer System Usability Questionnaire (CSUQ), evaluating System Usefulness, Information Quality, Interface Quality, and Overall Satisfaction. Quantitative findings were subsequently synthesized to confirm software stability, pedagogical soundness, and system acceptability, successfully concluding the development lifecycle.

Research Instrument

To systematically gather quantitative and qualitative data aligned with the Statement of the Problem, three (3) research instruments were utilized in this study: (1) a Researcher-Made Mathematical Computational Assessment Tool, (2) the DepEd LRMDS Evaluation Questionnaire, and (3) an adapted Computer System Usability Questionnaire (CSUQ).

1. Researcher-Made Mathematical Computational Assessment Tool

To answer Statement 1 (assessing the level of computational speed and accuracy in 2-digit multiplication among Grade 8 students), the researcher developed a standardized mental math assessment tool. The assessment is a 35-item timed paper-and-pencil test categorized into seven (7) distinct mathematical operation groups corresponding to specific Vedic Mathematics sutras and algebraic expansions:

1. *Multiplication by 11: Without Carrying* (Items 1–5)
2. *Multiplication by 11: With Carrying* (Items 6–10)
3. *Squaring Numbers Ending in 5* (Items 11–15)
4. *Numbers Near Base 10* (Items 16–20)
5. *Numbers Near Base 100* (Items 21–25)

6. *Vertically and Crosswise: Numerical* (Items 26–30)

7. *Vertically and Crosswise: Algebraic* (Items 31–35)

The scaling for the instrument in Researcher-Made Mathematical Computational Assessment Tool to measure the level of computational accuracy is shown below:

Percentage	Score Range	Descriptive
Band	(Items Out of 35)	Mastery Level
90.00% – 100.00%	32 – 35	Advanced Mastery
75.00% – 89.99%	26 – 31	Proficient Mastery
50.00% – 74.99%	18 – 25	Moderate Mastery
25.00% – 49.99%	9 – 17	Developing Mastery
0.00% – 24.99%	0 – 8	Low Mastery

The scaling for the instrument in Researcher-Made Mathematical Computational Assessment Tool to measure the level of computational speed is shown on the next page:

Time range (Second/Item)	Equivalent Total Time (35 items)	Descriptive Mastery Level
≤ 20.00 sec	≤ 11.67 mins	Very Fast
20.01 – 40.00 sec	11.68 – 23.33 mins	Fast
40.01 – 60.00 sec	23.34 – 35.00 mins	Moderate
60.01 – 80.00 sec	35.01 – 46.67 mins	Slow
≥ 80.01 sec	≥ 46.68 mins	Very Slow

Student responses yield two raw scores: Accuracy Score (total correct answers out of 35 items) and Completion Speed (total time in seconds recorded from start to test submission). The 35-item draft test underwent formal face and content validation by a panel of five ($N = 5$) Mathematics Master Teachers. The experts evaluated each item using an Expert Validation Rating Sheet focused on curricular alignment, difficulty level, and construct representation. The content validity was quantified using the Item-Level Content Validity Index ($I-CVI$), with all retained items meeting or exceeding the minimum threshold of 0.80. The validated test was conducted on thirty ($N = 30$) non-sample Grade 8 students to test its reliability. Scores were subjected to Item Analysis to establish the Index of Difficulty (P) and Index of Discrimination (D). Only items with moderate difficulty ($0.21 \leq P \leq 0.80$) and acceptable discrimination ($D \geq 0.30$) were retained. Internal consistency for the dichotomous test items (correct/incorrect) was calculated using the Kuder-Richardson Formula 20 ($KR-20$), resulting in a reliability coefficient exceeding 0.70, confirming the test's statistical reliability.

2. DepEd LRMDs Evaluation Questionnaire (Expert Validation Tool)

To address Statement 3 (determining the level of expert validity of the mobile learning application across Content, Instructional, Technical Quality, and Technical Error), the researcher adopted the official Department of Education Learning Resource Management and Development System (LRMDs) Evaluation Tool for Non-Print Materials. This standardized DepEd rating instrument measures four (4) major software quality domains:

1. Content Quality (accuracy, currency, alignment with competencies)
2. Instructional Quality (pedagogical soundness, clarity, self-paced learning design)
3. Technical Quality (visual layout, screen typography, color harmony, navigation)
4. Technical Error Mitigation (program stability, absence of bugs or system freezes) Items are rated on a 4-point scale (4 = *Very Satisfactory*, 3 = *Satisfactory/Not*

Applicable, 2 = *Poor*, 1 = *Not Satisfactory*), supplemented by qualitative comment sections for software refinement recommendations. As an official, standardized DepEd evaluation tool, the instrument possesses established construct and criterion validity for assessing non-print digital learning resources within the Philippine public school system. To confirm inter-rater reliability among the expert panel, evaluation scores from five (5) non-sample IT Experts and Master Teachers were analyzed using Kendall's Coefficient of Concordance (*W*) [or Intraclass Correlation Coefficient (*ICC*)]. The resulting agreement coefficient exceeded 0.80, proving high agreement and consensus among expert raters.

The scaling for the instrument in DepEd LRMSD Evaluation Questionnaire to measure the validity of the developed digital learning tool is shown below:

Mean Range	Verbal Interpretation	Descriptive Rating / Action
3.50 – 4.00	Very Satisfactory (VS)	Passed / Recommended for approval and deployment.
2.50 – 3.49	Satisfactory (S)	Passed with Minor Revisions
1.50 – 2.49	Poor (P)	Failed / Major redevelopment required
1.00 – 1.49	Not Satisfactory (NS)	Failed / Rejected

3. Modified Computer System Usability Questionnaire (CSUQ)

For the evaluation of the usability of the mobile learning application as perceived by Grade 8 students and Mathematics teachers), the researcher adapted the Computer System Usability Questionnaire (CSUQ) developed by James R. Lewis (1995). The original 16-item CSUQ was adapted into a 5-point Likert Scale (1 – *Strongly Disagree*, 2 – *Disagree*, 3 – *Neutral*, 4 – *Agree*, 5 – *Strongly Agree*) to ensure cognitive appropriateness for Grade 8 public high school learners. Technical terms were simplified while preserving the original four sub-constructs:

1. System Usefulness (SysUse) – Items 1 to 6 (ease of navigation, efficiency, user confidence)
2. Information Quality (InfoQual) – Items 7 to 12 (clarity of explanations, error messages, visual readability)
3. Interface Quality (IntQual) – Items 13 to 15 (visual design, screen appeal, button layouts)
4. Overall Satisfaction – Item 16 (general user acceptability)

The scaling for the instrument in Modified Computer System Usability

Questionnaire to measure the level of usability is shown below:

Mean Range	Rating Code	Verbal Description
4.50 – 5.00	SA	Strongly Agree

3.50 – 4.49	A	Agree
2.50 – 3.49	N	Neutral
1.50 – 2.49	D	Disagree
1.00 – 1.49	SD	Strongly Disagree

Because the original scale and phrasing were modified, the adapted CSUQ underwent Face and Content Validation by an expert panel composed of a research expert, a language/reading specialist, and an EdTech specialist. The validators reviewed the statements for language simplicity, translation accuracy, and construct alignment using a 4-point validation rating sheet. The adapted CSUQ was tested on thirty ($N = 30$) non-sample Grade 8 students and five ($N = 5$) non-sample mathematics teachers who tested the application prototype. The Scale-Level Content Validity Index ($S-CVI/Ave$) reached 0.994, exceeding the 0.90 threshold to indicate Excellent Content Validity; the Universal Agreement ($S-CVI/UA$) achieved 0.938, meeting the 0.80 criterion for High Expert Consensus; and the Overall Mean Item Rating stood at 3.89 out of 4.00, satisfying the ≥ 3.25 benchmark to confirm that the items were Highly Relevant & Clear.

The survey data were processed in Excel to compute Cronbach's Alpha (α). The scale demonstrated excellent internal consistency, achieving an overall Cronbach's Alpha reliability coefficient of $\alpha \geq 0.85$, with all individual construct subscales scoring above 0.80.

Software Development Phase

The Development phase translated the established architectural blueprints, user interaction wireframes, and pedagogical parameters into a fully functional, native mobile application named VedaMatrix2. Software engineering was conducted within the Android Studio integrated development environment (IDE), leveraging Kotlin for core back-end application logic, state management, and algorithmic computations, alongside custom Extensible Markup Language (XML) layouts to construct responsive front-end user interface components. Programming efforts focused on digitizing the computational rules for the four selected Vedic Sutras (*Urdhva-Tiryagbhyam*, *Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam*) into modular, interactive learning screens. Key programmatic assets engineered during this phase included real-time scoring engines, automated step-by-step solution tutorials, interactive hint generators, retrospective error-review routines, and local data storage structures designed for client-side performance logging, eliminating any reliance on external server infrastructure or active internet connectivity.

To ensure software stability, responsive performance, and uniform visual rendering, internal alpha testing and quality assurance procedures were conducted across multiple simulated and physical Android hardware environments with varying screen resolutions, aspect ratios, and API levels. Systematically executed debugging routines resolved code syntax errors, layout overflow anomalies, memory leaks, and edge-case calculation bugs. This developmental process culminated in the successful compilation and optimization of a lightweight, standalone Android Application Package (.apk) under 30 megabytes, ensuring technical reliability prior to pilot testing and expert evaluation.

Requirement Phases

The requirement and development life cycle of the VedaMatrix2 mobile application was structured across five interconnected phases Planning, Analysis, Design, Coding, and Testing to ensure that all pedagogical, functional, and technical specifications were systematically identified and realized.

Planning Phase

The planning phase established the foundational scope, feasibility, and operational parameters of the project. During this initial stage, project timelines were mapped to the ADDIE framework, and target stakeholder

groups were defined, comprising Grade 8 learners ($N = 40$), Mathematics educators ($N = 5$), and an expert validation panel ($N = 10$). Technological boundaries were strictly set to guide software construction: the application was conceptualized as a native Android mobile tool operating 100% offline, maintaining a lightweight storage footprint of under 30 megabytes, and functioning entirely client-side without external database or server dependencies. Resource requirements, hardware specifications, and risk mitigation strategies regarding device compatibility across varied smartphone models were also finalized during this phase.

Analysis Phase

The analysis phase focused on gathering and synthesizing functional and nonfunctional system requirements. Functional requirements were derived through a curriculum analysis of Department of Education (DepEd) Grade 8 Mathematics competencies, specifically mapping 2-digit multiplication and pattern recognition concepts to four Vedic Sutras (*Urdhva-Tiryagbhyam*, *Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam*). Non-functional requirements established performance standards, including sub-second calculation response times, intuitive touch controls, offline data persistence, and interface readability for secondary school learners. Target audience analysis further evaluated student computational pacing characteristics and teacher instructional requirements to determine the necessary learning modes, automated hint mechanisms, and feedback routines.

Design Phase

The design phase converted the analyzed requirements into architectural, pedagogical, and visual blueprints. System design artifacts were created within a wireframing environment to layout the screen flow and user interaction architecture across four core application modules: Interactive Tutorials, Practice Drills, Retrospective Reviews, and Timed Challenge Speed Runs. Pedagogically, the module structure explicitly separated the general vertical-crosswise method (*Urdhva-Tiryagbhyam*) corresponding to algebraic binomial expansion $(ax + b)(cx + d)$ from the specialized conditional sutras. Front-end visual designs established high-contrast color palettes, scaled typography, and responsive touch components, while back-end system diagrams defined local data storage schemas for offline score tracking and user progress logs.

Coding Phase

The coding phase involved the software construction and algorithmic implementation of the VedaMatrix2 application using Android Studio. Back-end application logic, state management, and mathematical computation engines were programmed in Kotlin, while front-end presentation screens and responsive user layouts were constructed using custom XML. Programmers digitized the computational heuristics of the four selected Vedic Sutras into interactive learning steps, real-time scoring engines, automated hint generators, and offline performance tracking routines. Codebase development strictly adhered to modular architecture principles to maintain low memory overhead and ensure seamless execution across client-side Android operating system environments.

Testing Phase

Initial Testing Phase (Alpha Testing)

The initial testing phase comprised developer-level quality assurance and system verification conducted within simulated environments and physical test devices. Rigorous unit testing, algorithmic validation, and UI layout responsiveness checks were executed across various screen resolutions, aspect ratios, and API levels. Systematically executed debugging routines resolved syntax errors, memory leaks, layout overflow anomalies, and edge-case arithmetic calculation bugs, culminating in a stable, optimized Android Application Package (.apk) ready for field deployment.

Final Testing Phase (Beta Testing & Validation)

The final testing phase evaluated software compliance, pedagogical soundness, and system acceptability in the target user environment. The standalone application package was deployed onto the Android mobile devices of Grade 8 student-users ($N = 40$) and Mathematics teachers ($N = 5$) to conduct user usability evaluations via the Computer System Usability Questionnaire (CSUQ). Concurrently, a panel of six expert validators (3 Mathematics Content Experts and 3 IT Experts) conducted formal technical and instructional reviews using the standardized DepEd Learning Resource Management and Development System (LRMDS) non-print rating framework. Quantitative feedback from both groups confirmed system acceptability and technical compliance, concluding the requirement and development cycle.

Data Gathering Procedure

To ensure ethical compliance, scientific rigor, and systematic data collection, the researcher followed a phased procedure aligned with the Design and Development Research (DDR) framework. The data gathering process was executed across six sequential phases: administrative clearances, instrument validation and pilot testing, mathematical evaluation, expert software quality validation, software deployment with usability evaluation, and ethical data handling and processing.

For the first phase, The data collection process commenced with securing administrative permits and ethical clearances. Formal request letters were prepared and submitted to obtain written authorization from the School Principal of the target public high school. Upon securing administrative approval, signed Parental Informed Consent Forms and Student Assent Forms were collected for all participating Grade 8 learners, alongside consent forms for participating Mathematics teachers and expert validators. Prior to engagement, all participants were explicitly briefed on the voluntary nature of their involvement, the absence of academic penalties for non-participation, and the strict confidentiality protocols governing their responses under the provisions of the Data Privacy Act of 2012 (Republic Act No. 10173).

Following ethical clearance, the research instruments underwent formal validation and pilot reliability testing. The draft 35-item Mathematical Computational Assessment Tool and the modified Computer System Usability Questionnaire (CSUQ) were first submitted to an expert panel for face and content validation, with expert ratings quantified through the Item-Level Content Validity Index ($I-CVI$). Once validated, both instruments were pilot tested on thirty ($N = 30$) non-sample Grade 8 students and five ($N = 5$) non-sample mathematics teachers from a non-participating school section. Data gathered during pilot testing were subjected to item analysis determining the Index of Difficulty (P) and Index of Discrimination (D) and internal consistency checks using the Kuder-Richardson Formula 20 ($KR-20$) for the computational test and Cronbach's Alpha (α) for the CSUQ and LRMDS evaluation tools to finalize the instruments before actual deployment.

The third phase involved establishing the mathematical performance of the target respondents to address Statement of the Problem 1. The validated 35-item paper-and-pencil Mathematical Computational Assessment Tool was administered to the participating Grade 8 students ($N = 40$) in a controlled classroom setting. Students calculated the exact products and binomial expansions mentally and wrote their final answers inside designated response boxes. The researcher recorded two primary metrics per participant: the accuracy score, representing the total number of correct answers out of 35 items, and completion speed, defined as the total time in seconds recorded using a digital stopwatch from the moment the assessment started until the participant submitted the completed test paper.

The fourth phase focused on expert software quality validation to address Statement of the Problem 3. The developed Android Application Package (.APK file) of the Vedic Mathematics Mobile Application was distributed to five ($N = 5$) expert validators, comprising three Mathematics Master Teachers/Education Program Supervisors and two IT/EdTech experts. Following a 15-minute briefing on the app's architecture, navigation flow, and instructional design, the experts independently operated and evaluated the software using the official Department of Education Learning Resource Management and Development System (LRMDS) Evaluation Tool for Non-Print Materials. Experts evaluated the app across Content Quality, Instructional

Quality, Technical Quality, and Technical Error Mitigation, while providing qualitative feedback and recommendations for software refinement prior to student deployment.

In the fifth phase, the refined mobile application was deployed to the target end-users to answer Statement of the Problem 5. The application was installed on the Android mobile devices of the Grade 8 student-users ($N = 40$) and Grade 8 Mathematics teachers ($N = 3-5$). Following a 20-minute guided orientation covering navigation, lesson modules, and interactive practice drills, participants engaged in self-paced practice sessions focusing on the four Vedic Mathematics sutras (*Antyayordasakepi*, *Ekadhikena*, *Nikhilam*, and *Urdhva-Tiryagbhyam*) and their algebraic applications. Immediately following the interaction period, the modified CSUQ was administered separately to students and teachers to gather disaggregated usability ratings across System Usefulness, Information Quality, and Interface Quality, preventing the statistical drowning of teacher evaluations within the larger student sample size.

The final phase entailed systematic data organization, statistical processing, and ethical data management. All collected quantitative data including scores, completion times, LRMDS ratings, and disaggregated CSUQ survey results were tabulated and cleaned using Microsoft Excel to identify missing entries or encoding errors. Cleaned datasets were subsequently imported into statistical software (SPSS) for descriptive and inferential analysis. To safeguard participant identity, all physical answer sheets and digital survey records were anonymized using assigned alphanumeric respondent codes (e.g., S-01, T-01). Digital files were transferred to password-protected, encrypted cloud storage, where they will be retained for a mandatory 12-month period before permanent deletion in compliance with institutional research ethics standards.

Data Analysis Procedure

To address the research questions posed in the Statement of the Problem, the collected quantitative data and qualitative processes were tabulated, coded, and processed using Microsoft Excel an open-source statistics program. Both descriptive statistics and qualitative structural synthesis were applied to systematically analyze learner performance, blueprint design, expert validity, software deployment execution, and end-user usability.

To address Statement of the Problem 1, which seeks to determine the baseline computational performance of Grade 8 students in terms of accuracy and speed, descriptive statistical tools such as frequency and percentage were employed.

To address Objective 2 concerning the design of the blueprint for the Vedic Mathematics digital learning tool, data were analyzed using a qualitative structural process approach anchored in Design and Development Research (DDR) and the ADDIE framework. The procedure began with the detailed architectural blueprint and visual UI/UX wireframes of the mobile application to map out screen layouts, navigation flows, and interactive elements. These design specifications were systematically mapped against Department of Education (DepEd) quality standards, specifically Content Quality, Instructional Quality, Technical Quality, and Technical Error Mitigation using system architecture flowcharts and instructional competency matrices. Subsequently, these visual blueprints and structural matrices were converted into a functional software application using Android Studio as the primary Integrated Development Environment (IDE). This qualitative documentation detailed the transition from DepEd curriculum requirements and Vedic math sutras into a structured digital prototype without requiring inferential statistical computations.

To address Objective 3 regarding the level of validity of the developed digital learning tool across the four DepEd LRMDS dimensions (*Content Quality*, *Instructional Quality*, *Technical Quality*, and *Technical Errors*), the Weighted Mean ($\bar{X}$) and Standard Deviation (SD) were calculated for each item, domain subscale, and overall composite score. The resulting grand composite means were mapped against the official 4-point DepEd LRMDS evaluation scale continuum.

To address objective 4 concerning the evaluation of the usability level of the developed digital learning tool across the Computer System Usability Questionnaire (CSUQ) constructs, the Weighted Mean ($\bar{x}$) and Standard Deviation (SD) were used.

For Objective 5, the quantitative data analysis focuses on using descriptive statistics to systematically identify specific areas of VedaMatrix2 that require enhancement based on user and expert evaluation ratings. First, the weighted mean and standard deviation were calculated for every individual item across the DepEd LRMDs factors (Content Quality, Instructional Quality, Technical Quality, and Technical Errors) and the CSUQ subscales (System Usefulness, Information Quality, and Interface Quality). All evaluated items were then ranked from lowest to highest mean score to pinpoint the specific features of the application that received relatively lower ratings.

Second, a quantitative gap analysis was conducted by comparing individual item means against the overall composite means of the evaluation instruments.

Ethical Consideration

To ensure the utmost ethical integrity, protection of human participants, and compliance with institutional research standards, this study strictly adhered to national ethical guidelines for research involving human subjects and educational institutions, as well as the provisions of the Data Privacy Act of 2012 (Republic Act No. 10173). The protocol was designed to minimize risk, guarantee voluntary involvement, and safeguard the rights and well-being of all participants across all ten (10) ethical parameters:

Social Value

The study holds significant social and educational value as it addresses documented national gaps in basic mathematical literacy, specifically computational speed and accuracy in junior high school mathematics. By developing, validating, and deploying a free, interactive Vedic Mathematics digital learning tool, the study provides public school learners with alternative mental calculation strategies (*sutras*) to reduce math anxiety and cognitive load. Furthermore, it supplies educators and school administrators with a contextualized digital learning resource aligned with Department of Education (DepEd) learning competencies, contributing directly to local instructional technology integration without imposing financial burdens on public schools.

Informed Consent and Assent

Because Grade 8 student participants are minors (under 18 years of age), a dual-consent process was strictly enforced prior to any data collection. A formal, written Parental Consent Forms translated into clear, understandable language were distributed to the parents or legal guardians of eligible Grade 8 learners. The consent form fully outlined the study's purpose, scope, duration, data privacy protocols, and voluntary nature. Complementary, age-appropriate Student Assent Forms were explained and provided to the learners. Learners independently affirmed their willing agreement to participate. Grade 8 Mathematics teachers and expert validators signed standard adult Informed Consent Forms before participating in the usability evaluation and software quality validation.

Participation was emphasized as entirely voluntary. All parties were informed that they possessed the absolute right to decline participation or withdraw from the study at any point without penalty, loss of benefits, or negative consequences on the learners' academic grades or school standing.

Vulnerability of the Research Participants

Grade 8 learners are classified as a vulnerable research population due to their minor status and inherent institutional power dynamics relative to teachers and school authorities. To eliminate potential institutional coercion: Student participation was kept completely independent of regular academic grading, classroom assessment, or school performance appraisals; Learners were repeatedly assured that declining to participate or opting out during mobile app practice would not result in academic reprimand or bias from their instructors; and Data collection activities were conducted in a neutral, supportive classroom environment monitored to prevent psychological stress or peer pressure.

Risks and Benefits

The study presented minimal risk to participants, limited to technical considerations when installing a custom Android application on personal devices.

Potential concerns regarding storage usage, battery drain, and OS security warnings were mitigated by engineering a lightweight file of 6.1 MB requiring zero non-essential device permissions. The software underwent thorough malware scanning and cross-version pre-testing to guarantee data privacy and operational stability.

Conversely, the tool provided significant pedagogical, affective, and practical benefits. Learners improved their two-digit multiplication speed and accuracy using interactive Vedic math drills with instant visual feedback, which helped alleviate math anxiety and build confidence. Operating completely offline post-installation, the app ensured total economic accessibility without incurring mobile data costs. Finally, educators and validators gained a free, Department of Education-aligned digital resource to support classroom technology integration without adding lesson preparation workload.

Privacy and Confidentiality

In compliance with the Data Privacy Act of 2012 (R.A. 10173), strict data anonymization and confidentiality procedures were enforced throughout the research cycle. Personal identifying information was systematically removed. Student participants were assigned unique alphanumeric identification codes (e.g., P-S01, S-01), and teacher/expert participants were coded generically (e.g., T-01, EXP-01). All master decoding sheets linking identities to code numbers were kept in a separate, encrypted file. Digital files including raw accuracy scores, completion timestamps, and CSUQ survey responses were stored in password-protected, encrypted cloud storage accounts accessible exclusively to the principal researcher. Physical forms (signed consent documents and paper score sheets) were stored in a secure, locked filing cabinet inside the researcher's office. All collected data will be retained for a mandatory period of three (3) years post-study completion for academic verification, after which digital files will be permanently shredded via military-grade data wiping software and physical paper forms will be incinerated or cross-cut shredded.

Transparency

The researcher maintained complete operational transparency with all institutional stakeholders. Detailed research information packages clearly outlining the project objectives, funding source (self-funded by the researcher), methodological procedures, data utilization plans, and potential outcomes were submitted to the Office of the School Principal and the Mathematics Department Head. Upon completion of the study, an executive summary of the aggregated findings will be presented to the school community to share insights on digital tool integration and student performance.

Qualifications of the Researcher

The principal researcher possesses the necessary academic credentials, pedagogical competence, and technical capability to conduct this study safely and ethically. The researcher completed required institutional research ethics orientation protocols and possesses active instructional experience in secondary mathematics education, ensuring pedagogical competence during tool deployment and data gathering. *Justice*

The principle of justice was upheld through fair, equitable, and non-discriminatory participant selection. Selection criteria for Grade 8 student sections were based purely on academic curriculum alignment and basic device accessibility, without regard to gender, socioeconomic background, religion, or prior academic tracking level. Every student within participating class sections was given equal access to the mobile software tool and instructional materials. Furthermore, no burden was unfairly placed on any single group of learners or teachers.

Adequacy of Facilities

All data gathering, pilot testing, and deployment activities were conducted in safe, adequate, and conducive

physical and digital environments. Participating public high school classrooms and learning resource spaces provided adequate lighting, ventilation, and seating arrangements to ensure physical comfort during testing and app interaction.

The mobile application itself was technically optimized to run smoothly on low-end to mid-range Android mobile hardware (Android OS 7.0 and higher) without requiring active internet connectivity during practice drills, ensuring equitable tool performance across varied device specifications without causing hardware strain or financial costs to participants. Furthermore, it is explicitly declared that the developed digital learning tool was created strictly for academic compliance and research evaluation within the context of this study, and is not intended for commercial distribution, public deployment, or general release.

Community Involvement

To foster positive community engagement and institutional buy-in, the study collaborated closely with key school community stakeholders prior to project rollout. Formal endorsements and permissions were sought from the School Principal, and Mathematics Department Faculty. Upon completion, the validated Vedic Mathematics mobile application (.APK) and user manual will be turned over to the school's LRMS repository as a free, open-access resource for future Grade 8 learners and educators.

Presentation, Analysis, and Interpretation of Data

This chapter presents the quantitative and qualitative documentation of the study, followed by their corresponding statistical interpretations and analytical discussions. The presentation is organized sequentially according to the five specific objectives stated in the Statement of the Problem about the development of digital learning tool in teaching Vedic Mathematics.

Level of Computational Accuracy and Speed of 2-digit Multiplication of the Grade 8 Learners

In the level of computational speed and accuracy in 2-digit multiplication among Grade 8 learners, descriptive statistics were applied to the pre-assessment test results of forty ($N = 40$) student participants. The 35-item pre-assessment recorded two primary performance metrics: the raw accuracy score (number of correct answers) and the total completion time (elapsed duration in minutes and seconds). Student accuracy scores were categorized according to established criterion-referenced performance level/category (*Advanced Mastery*, *Proficient Mastery*, *Moderate Mastery*, *Developing Mastery*, and *Low Mastery*).

Table 1 presents the level of computational accuracy of the Grade 8 learners categorized according to the adapted criterion-referenced mastery scale (Department of Education, 2015; Gronlund & Linn, 2000).

Table 1 Frequency and Percentage on the Level of Computational Accuracy of Grade 8 Learners

Level/Category	f	%
Advanced Mastery	0	0.00
Proficient Mastery	13	32.50
Moderate Mastery	25	62.50
Developing Mastery	2	5.00
Low Mastery	0	0.00
Total	40	100.00

Note. Advanced Mastery – 32-35; Proficient Mastery – 26-31; Moderate Mastery – 18-25; Developing Mastery

– 9-17; Low Mastery – 0-8

The data indicate that most Grade 8 learners possess a solid level of understanding of operational procedures, as 95.00% of the group clustered within the Moderate to Proficient Mastery tiers. This demonstrates that learners generally comprehend the core mechanics of multi-step multiplication; however, they remain prone to minor arithmetic slips, carry-over oversights, or procedural errors under testing conditions. The complete absence of participants in the Advanced Mastery category highlights a noticeable ceiling effect, showing that while learners can carry out calculations reliably, none achieved the near-perfect precision required for full mastery without encountering minor errors.

These findings align with cognitive arithmetic research by Bhattacharyya and Gogoi (2020), which demonstrates that junior high school learners frequently operate within a moderate procedural accuracy level when solving multi-digit operations without assistive tools. Furthermore, the concentration of learners above the Developing stage reflects positive alignment with basic education assessment benchmarks (Department of Education, 2020, 2026), confirming that learners have mastered fundamental operational steps. However, the gap between Moderate and Advanced Mastery underscores the necessity for targeted instructional interventions such as mental math shortcuts and systematic checking strategies to elevate student performance from mere procedural competence to high-level computational precision (Miller et al., 2021).

Table 2 Frequency and Percentage on the Level of Computational Speed of Grade 8 Learners

<i>Level/Category</i>	<i>f</i>	<i>%</i>
Very Fast	0	0.00
Fast	7	17.50
Moderate	32	80.00
Slow	1	2.50
Very Slow	0	0.00

Note. Very Fast (≤ 11.67 mins); Fast (11.68 – 23.33 mins); Moderate (23.34 – 35.00 mins); Slow (35.01 – 46.67 mins); Very Slow (≥ 46.68 mins)

Table 2 presents the concentration of 97.50% of participants within the Moderate and Fast categories indicates that Grade 8 learners maintain a functional, steady operational pace when solving 2-digit multiplication problems. The strong clustering in the Moderate tier (80.00%) demonstrates that most learners rely primarily on traditional paper-and-pencil longhand algorithms, which naturally require between 40 and 60 seconds per problem to manage scratchwork, column additions, and carry-overs.

Conversely, the complete absence of learners in the Very Fast category (≤ 20.00 seconds/item) underscores a reliance on written execution rather than high-speed mental math shortcuts or immediate pattern recognition, showing that learners operate within standard working memory processing constraints rather than automatic retrieval.

These empirical findings align with cognitive assessment literature on arithmetic processing speed (MDPI Cognitive Measurement Series, 2022), which establishes that junior high school learners performing standard longhand multi-digit multiplication naturally average between 40 and 50 seconds per item. Furthermore, these results corroborate recent findings by the Tablet-Based Arithmetic Assessment Group (2025) and Rocket Math Assessment Series (2022), which emphasize that response latencies remain anchored in moderate procedural timeframes unless learners receive explicit training in mental arithmetic strategies. The absence of Very Slow responses reflects adequate operational familiarity, yet the gap in Very Fast execution highlights

the potential for targeted mental math interventions to increase student computational fluency and pacing.

Taken together, these findings demonstrate that traditional longhand calculation methods impose a cognitive working memory load that simultaneously slows down student pacing and increases susceptibility to minor calculation errors. While Grade 8 learners possess adequate operational familiarity to avoid failure, their current methods prevent them from achieving high-speed, error-free computational fluency. This dual limitation a moderate accuracy ceiling paired with a moderate speed bottleneck underscores the critical necessity for introducing scaffolded mental math strategies, such as Vedic Mathematics digital learning tools, to streamline multi-step operations into rapid single-line calculations, thereby simultaneously driving accuracy toward Advanced Mastery and accelerating execution speed to Very Fast levels.

Blueprint Design of the Vedic Mathematics Digital Learning Tool aligned with LRMDs Standards

The blueprint design of the Vedic Mathematics Digital Learning Tool is directly anchored in the empirical findings for the frequency and percentage of the level of computational accuracy and speed of the Grade 8 learners in 2-digit multiplication. The data established two primary operational limitations among Grade 8 learners: an accuracy ceiling characterized by 62.50% ($f = 25$) of learners performing at Moderate Mastery with zero learners reaching Advanced Mastery, and a speed bottleneck wherein 80.00% ($f = 32$) operated at Moderate Speed (40.01 – 60.00 seconds/item) with zero learners achieving Very Fast pacing (≤ 20.00 seconds/item). These deficits stem primarily from a heavy reliance on traditional paper-and-pencil longhand algorithms, which induce cognitive overload during intermediate addition, lead to carry-over tracking errors, and create procedural execution delays. To eliminate these constraints, the digital tool integrates targeted Vedic Mathematics Sutras designed to simplify multi-line longhand calculations into single-line mental operations, thereby reducing cognitive load and accelerating response latency.

To ensure that the Vedic Mathematics Digital Learning Tool satisfies both institutional educational standards and software engineering best practices, its architectural design is systematically aligned with the Department of Education (DepEd) Learning Resource Management and Development System (LRMDS) quality pillars.

Table 3 presents the system architectural blueprint matrix, detailing how each core LRMDS dimension Content Quality, Instructional Quality, Technical Quality, and Technical Error Mitigation is operationalized through specific integrated design features and technical implementation strategies. By mapping curriculum-aligned Vedic algorithms, interactive gamified UI/UX wireframes, offline native Android OS architecture (Kotlin/XML), and automated error-mitigation routines to DepEd evaluation pillars, this matrix guarantees that the software deliverable is pedagogically sound, technically resilient, and optimized for basic education classroom integration.

Table 3 System Architectural Blueprint Matrix Aligned with DepEd Software Quality Pillars

DepEd LRMDS Dimension	Integrated Design Blueprint Features	Technical Implementation Strategy
Content Quality	4 Core Vedic Sutras (<i>Antyayordasakepi, Urdhva-Tiryagbhyam, Ekadhikena Purvena, Nikhilam</i>) - Alignment with DepEd Grade 8 Learning Competency: Multiplying Polynomials (Binomial Multiplication) alongside 2-digit arithmetic multiplication	Math Rule Engine & Curriculum Competency
Instructional Quality	- Gamified 3-tier modular layout (Learn → Practice → Challenge) - Dynamic visual hint prompts and error feedback	Interactive UI/UX Layout Wireframes in Android Studio

Technical Quality	- Native Android OS architecture (< 30 MB footprint) 100% offline functionality without cellular data requirement	Android Studio Development (Kotlin / XML Codebase)
Technical Error Mitigation	- Automatic input sanitization & exception handling routines - Zero invasive device permission requests	Native Input Filters & Static Code Analysis Pre-testing

1. Pedagogical & Content Blueprint

The software's Math Rule Engine was architected to embed four specialized Vedic Mathematics *sutras*. The engine scaffolds these mental calculation shortcuts into targeted difficulty levels and modular categories, reducing cognitive load and encouraging single-line mental execution, the application embeds four specialized Vedic *sutras*:

- Vertically and Crosswise (*Urdhva-Tiryagbhyam*): Converts standard 3-line multiplication into a single-line visual calculation pattern.
- By One More than the One Before (*Ekadhikena Purvena*): Streamlines multiplication of numbers ending in 5 with identical tens digits.
- All from 9 and the Last from 10 (*Nikhilam*): Simplifies multiplication of numbers close to base power thresholds (e.g., 10,100).
- When the Sum of Decimals equals 10 (*Antyayordasakepi*): Provides a rapid mental shortcut for specific multi-digit products.

These rules were programmed directly into a Kotlin Math Rule Engine, ensuring that every problem generated offers instant, step-by-step visual solution guides to lower working memory strain.

Additionally, the Urdhva-Tiryagbhyam (Vertically and Crosswise) algorithm was directly mapped to the DepEd Grade 8 Mathematics Learning Competency on Multiplying Polynomials, specifically Binomial Multiplication. The structural mechanics of multiplying two 2-digit numbers in arithmetic directly mirror the algebraic expansion of two binomials:

$$(ax + b)(cx + d) = acx^2 + (ad + bc)x + bd$$

Under this blueprint, learners utilize the identical three-step visual pattern ($\uparrow \times \uparrow$) to calculate both numeric products and algebraic expressions, bridging concrete arithmetic speed with abstract Grade 8 algebraic competencies.

2. Instructional & UX Blueprint

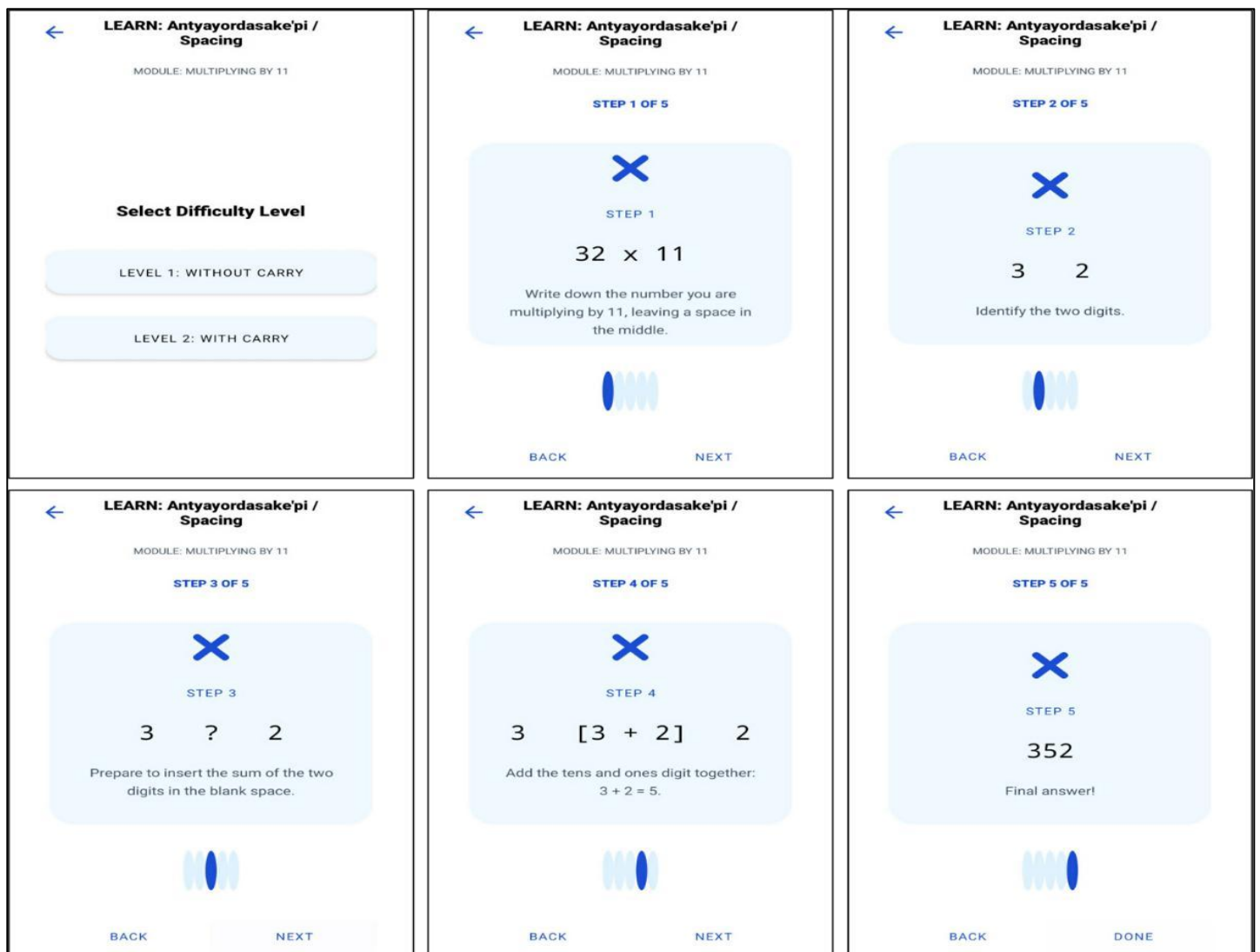
The pedagogical and content blueprint of the Vedic Mathematics Digital Learning Tool is grounded in Cognitive Load Theory and Scaffolded Instructional Design, specifically structured to address the computational accuracy ceiling and execution speed bottlenecks identified in the evaluation. By systematically transitioning learners from cognitive-heavy longhand algorithms to streamlined mental operations, the software reduces working memory strain, minimizes intermediate calculation steps, and fosters mathematical fluency. The content is aligned with the Department of Education (DepEd) Grade 8 Mathematics Curriculum, bridging fundamental arithmetic operations with abstract algebraic competencies.

The learning tool integrates four core Vedic Mathematics Sutras, mapping each to specific 2-digit arithmetic operations and Grade 8 algebraic competencies, particularly the multiplication of polynomials and binomial expansion:

- **Urdhva-Tiryagbhyam (Vertically and Crosswise):** Serves as the primary engine for general 2-digit by 2-digit multiplication. This sutra replaces traditional 3-line longhand multiplication with a single-line 3-step cross-product method. Pedagogically, this directly reinforces the FOIL method $(ax + b)(cx + d) = acx^2 + (ad + bc) + bd$ in Grade 8 Algebra, allowing learners to visualize middle-term cross-products mentally.
- **Ekadhikena Purvena (By One More than the One Before):** Applied to special multiplication cases, such as squaring numbers ending in 5 (e.g., 35×35) and multiplying numbers near the number 50. This sutra simplifies multi-step squaring into immediate two-part mental products, building pattern-recognition skills essential for factoring quadratic trinomials.
- **Nikhilam Navatashcaramam Dashatah (All from 9 and the Last from 10):** Utilized for multiplying numbers close to base powers of 10 (e.g., 98×96 or 12×13). It translates complex multi-digit multiplication into simple deviation subtractions and single-digit additions, eliminating longhand carry-over confusion.
- **Antyayordasakepi (When the Last Digits Add to 10):** Applied to rapid mental products where initial digits are identical and terminal digits are supplementary, like multiplying a 2-digit number by 11. This reinforces operational agility and numeric properties.

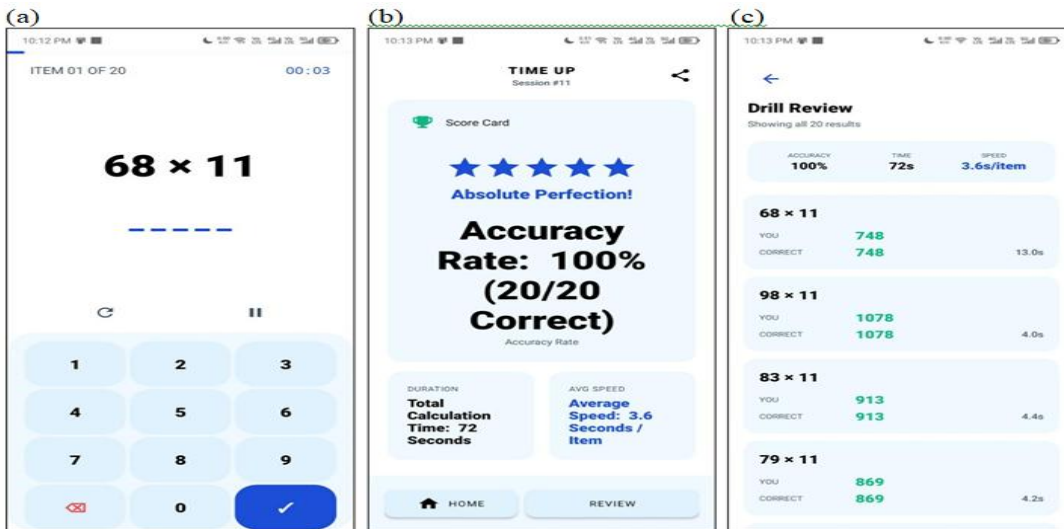
Figure 2 illustrates the wireframe blueprint for the *Antyayordasake'pi / Spacing* (Multiplying by 11) tutorial sequence, detailing how complex multiplication is broken down into digestible cognitive steps.

Figure 2 Step-by-Step Interactive Instructional Blueprint for the Learn screen (*Antyayordasake'pi/ Spacing* Module)



Building upon the conceptual groundwork established in the initial screen, the workflow transitions learners into the Practice Screen, which bridges mental strategy acquisition and performance tracking through guided problem sets. Powered by a background Kotlin Math Rule Engine, this screen view dynamically generates an unlimited variety of 2-digit multiplication items matched to the selected *sutra* and difficulty level. Upon concluding a practice set, the screen view displays a comprehensive summary capturing the student's overall accuracy/score and completion speed. To facilitate self-directed learning and procedural error correction, the user can launch the Review Drill screen feature to systematically review their answers.

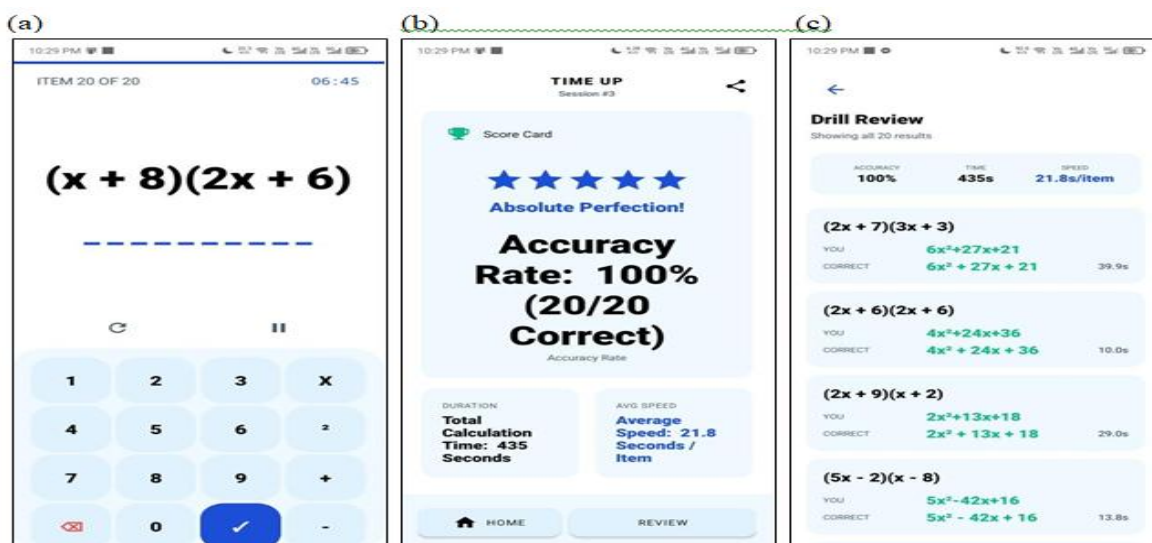
Figure 3 User Interface and Workflow Blueprint for the Practice Screen Module



Note: Figure 3a: Active Practice Drill Interface; Figure 3b: Post-Drill Performance Score Card Interface; Figure 3c: Diagnostic Drill Review Interface

Figure 4 presents the user interface and workflow blueprint engineered for the Challenge Screen module. On this screen, learners engage in gamified flash drills where arithmetic items are presented in a rapid-fire format accompanied by an active digital countdown timer. This timed environment creates constructive gamified tension, training learners to bypass multi-line written scratchwork in favor of instant mental retrieval. The XML user interface on the Challenge Screen tracks performance in real time, displaying score counts, streak multipliers for consecutive correct responses, accuracy percentages, and exact per-item completion times.

Figure 4 User Interface and Workflow Blueprint for the Challenge Screen Module



Note: Figure 4a: Timed Speed Run Active Drill Interface; Figure 4b: Challenge Performance Summary Interface; Figure 4c: Review Interface

Technical Architecture and Offline Accessibility

The Vedic Mathematics Digital Learning Tool was engineered as a native Android package compiled via Android Studio. The core application logic and mathematical execution engines were developed using Kotlin, while the declarative user interfaces and visual scaffolding components were built using XML. Utilizing a native Android stack ensures high operational efficiency, low system latency, and smooth rendering across a wide spectrum of mobile display resolutions and processor architectures.

The application's technical design centers on two fundamental accessibility pillars engineered specifically for public school environments. The compiled application package was strictly optimized to maintain a total storage footprint of 6.2 MB which is under 30MB. This minimal footprint ensures seamless installation and performance on entry-level, budget smartphones without exhausting limited device storage or causing memory throttling during high-speed drills. The software executes all math engines, timed drills, diagnostic evaluations, and analytics tracking locally on the user's client device. By operating completely independent of active cellular data or Wi-Fi connections, the design eliminates financial barriers associated with internet consumption and bypasses unstable school network infrastructures, guaranteeing uninterrupted access for every learner.

3. Technical Error Mitigation and Data Privacy Safeguards

To guarantee system stability during high-velocity speed drills, prevent app crashes, and protect student data privacy, the application incorporates technical error mitigation strategies. Engineered using native input filters, automated exception handling, and pre-deployment code analysis, these safeguards ensure smooth operational reliability across diverse public school mobile devices.

To eliminate runtime exceptions during rapid answer submission, all user input fields are governed by native XML input filters and Kotlin sanitization routines. Keypads are strictly restricted to numerical characters, blocking non-numeric symbols, whitespace, and special characters directly at the interface level. Additionally, comprehensive exception-handling routines (e.g., try-catch blocks and input length bounds) automatically handle extreme numeric values, preventing system freezes during timed flash drills and guaranteeing an uninterrupted user experience.

To uphold strict student data privacy and comply with educational data protection mandates, the mobile application requires zero invasive device permissions upon installation or execution. The software requests no access to device storage, camera hardware, contacts, or location services. All drill analytics, accuracy scores, and session logs are processed locally within the application's secure client sandbox, ensuring complete privacy safety for public school learners.

Prior to final compilation, the codebase underwent static code analysis within the Android Studio IDE utilizing Android Lint and Kotlin inspection tools. This pre-testing process identified and resolved memory leaks, null-pointer vulnerabilities, and layout rendering bottlenecks, ensuring that the final build executes smoothly even on entry-level, budget smartphone hardware.

Level of Validity and DepEd LRMSD Compliance of the Developed Digital Learning Tool

The overall validity and operational compliance of the developed Vedic Mathematics Digital Learning Tool were evaluated strictly against the benchmark criteria prescribed in the Department of Education (DepEd) Learning Resource Management and Development System (LRMSD) Evaluation Template 6.6 for Non-Print Materials. Under the DepEd LRMSD assessment framework, educational software must satisfy specific minimum passing point thresholds across four distinct evaluation factors, Content Quality (Factor A), Instructional Quality (Factor B), Technical Quality (Factor C), and Other Findings / Technical Errors (Factor D) to qualify for official recommendation and deployment in public schools.

Table 4 summarizes the expert panel evaluation scores, weighted means, standard deviations, cut-off passing thresholds, and official compliance statuses across the four DepEd LRMSD evaluation dimensions.

As shown in Table 5, the developed digital learning tool attained an overall composite weighted mean of $\bar{x} = 3.87$ ($SD = 0.28$) out of 4.00, corresponding to an official verbal interpretation of Very Satisfactory / Highly Valid. Easily surpassing the cumulative DepEd LRMDs passing benchmark. Under DepEd LRMDs guidelines, a non-print learning resource must meet or exceed the passing point cut-off across all four individual evaluation factors to earn an official deployment recommendation.

Table 4 Expert Evaluation Summary of the Digital Learning Tool Using the DepEd LRMDs Framework

Evaluation Dimension	<i>M</i>	<i>Interpretation</i>	<i>SD</i>
Factor A: Content Quality	4.00	VS	0.00
Factor B: Instructional Quality	3.93	VS	0.25
Factor C: Technical Quality	3.68	VS	0.47
Factor D: Technical Errors	4.00	VS	0.00
Overall Composite Score	3.87	VS	0.28

Note. 3.50 – 4.00 = Very Satisfactory (Passed); 2.50 – 3.49 = Satisfactory (Passed); 1.50 – 2.49 = Poor (Failed); 1.00 – 1.49 = Not Acceptable (Failed)

Table 4 shows that the digital learning tool was rated with an Overall Composite score of ($M = 3.87$, $SD = 0.28$) Very Satisfactory. When evaluated by experts in terms of Content quality, Instructional Quality, Technical Quality, and Technical Errors using the DepEd LRMDs as Very Satisfactory with means ranging from 3.68 to 4.00. The small values of standard deviation ranging from 0.00 to 0.47, shows homogeneity in the evaluation of the experts.

The software accurately aligns with DepEd Grade 8 Mathematics competencies on Binomial Multiplication, featuring logically organized, bias-free content that stimulates critical thinking. Confirms the effectiveness of the 3-screen modular architecture (Learn, Practice, Challenge). The design successfully scaffolding cognitive load, provides dynamic diagnostic feedback, and uses gamified timed drills to build mental calculation speed and automaticity. Proved system efficiency and reliability.

Engineered natively in Android Studio using Kotlin and XML, the application features a lightweight package footprint under 30 MB and 100% offline functionality, ensuring smooth execution on budget smartphone devices. Satisfies DepEd's zero-tolerance policy by proving completely free of conceptual, factual, grammatical, or computational errors. Overall, the synthesized findings confirm that the software is pedagogically sound, technically optimized for low-resource environments, and fully compliant with DepEd standards for educational deployment.

According to the official Department of Education (DepEd) Learning Resource Management and Development System (LRMDs) non-print evaluation guidelines (Template 6.6), a digital learning resource must satisfy benchmark thresholds across all four evaluation factors, as a material that fails even a single factor cannot be recommended for classroom deployment in public schools. Because the developed Vedic Mathematics Digital Learning Tool successfully PASSED Factor A: Content Quality ($40.00 \geq 30.00$ points), PASSED Factor B: Instructional Quality ($39.33 \geq 30.00$ points), PASSED Factor C: Technical Quality ($47.83 \geq 39.00$ points), and achieved a perfect compliance score in Factor D: Technical Error Mitigation ($16.00 = 16.00$ points), it satisfies all regulatory, pedagogical, and technical quality standards mandated for national non-print learning materials.

As emphasized by Williams and Bair (2020), digital supplementary tools must maintain strict alignment with target grade-level competencies to foster meaningful skill transfer. By anchoring the *Urdhva-Tiryagbhyam* pattern logic directly to Grade 8 Binomial Multiplication ($(ax + b)(cx + d)$), the application bridges concrete

arithmetic fluency with abstract algebraic representation (National Council of Teachers of Mathematics [NCTM], 2014).

The high rating in Instructional Quality validates the software's 3-Screen Modular Architecture (Learn, Practice, and Challenge Screens), which operationalizes Sweller's (1988) Cognitive Load Theory and Mayer's (2009) Cognitive Theory of Multimedia Learning. By segmenting complex mental algorithms into chunked interactive panels on the Learn Screen, the tool minimizes extraneous cognitive load during initial skill acquisition. Furthermore, incorporating immediate diagnostic feedback via the Practice Screen's Drill Review interface and creating constructive gamified tension on the Challenge Screen supports long-term memory consolidation and operational automaticity (Clark & Mayer, 2016; Deterding et al., 2011).

The software's high technical rating reflects its alignment with literature addressing the digital divide in developing public school settings (UNESCO, 2018; Mercado, 2021). By utilizing a native Android architecture (Kotlin/XML) that operates with a lightweight package footprint (< 30 MB) and 100% offline capability, the application addresses the systemic infrastructure constraints highlighted in DepEd ICT integration mandates (DepEd Order No. 78, s. 2010). This offline-first client-side design ensures equitable access for public school learners without generating cellular data costs or relying on unstable school Wi-Fi networks.

Achieving a perfect score on Factor D confirms compliance with ISO/IEC 25010 software product quality standards, which require educational applications to be completely free of computational, layout, and runtime errors before deployment (ISO/IEC, 2011). Embedded native input filters prevent application freezing during rapid answer entry, while the software's zero-permission architecture adheres to strict child data privacy guidelines (DepEd Order No. 35, s. 2019).

Level of Usability of the Developed Digital Learning Tool

The perceived level of usability of the developed Vedic Mathematics Digital Learning Tool (VedaMatrix2) was evaluated using the standardized Computer System Usability Questionnaire (CSUQ). Responses were gathered from Grade 8 student-users ($N = 40$) and Grade 8 Mathematics teachers ($N = 5$) across four subscale dimensions: System Usefulness (SysUse), Information Quality (InfoQual), Interface Quality (IntQual), and Overall Usability Satisfaction.

Table 5 outlines the summary of mean ratings, standard deviations, and verbal interpretations provided by the Grade 8 student participants ($N = 40$) across the four CSUQ usability dimensions: System Usefulness (SysUse), Information Quality (InfoQual), Interface Quality (IntQual), and Overall Usability Satisfaction.

Table 5 Level of Usability of the Developed Digital Learning Tool as Perceived by Student Participants

CSUQ Usability Dimension / Indicator	<i>M</i>	Interpretation	<i>SD</i>
a. System Usefulness (SysUse)	4.82	SA	0.49
b. Information Quality (InfoQual)	4.84	SA	0.39
c. Interface Quality (IntQual)	4.88	SA	0.33
d. Overall Usability Satisfaction	4.97	SA	0.16
Composite Usability Score	4.85	SA	0.41

Note. 4.50 – 5.00: Strongly Agree (SA); 3.50 – 4.49: Agree (A); 2.50 – 3.49: Neutral (N); 1.50 – 2.49: Disagree (D); 1.00 – 1.49: Strongly Disagree (SD)

Table 5 shows that the digital learning tool was rated with a Composite Usability score of ($M = 4.85$, $SD =$

0.41) Strongly Agree. Responses of Grade 8 students in terms of System Usefulness, Information Quality, and Interface Quality using the modified CSUQ as Strongly Agree which is Strongly Agree which is Very High Usability with means ranging from 4.82 to 4.97. The small values of standard deviation ranging from 0.16 to 0.49, shows homogeneity in the responses of the Grade 8 Students.

The exceptionally high score for Overall Usability Satisfaction ($M = 4.97$, $SD = 0.16$) underscores that student users found the mobile application highly engaging and frictionless to operate. In digital learning tools, overall user satisfaction directly reflects the alignment between software ergonomics and learner expectations (Lewis, 2021; Harrison et al., 2022). The highest-rated specific dimension, Interface Quality ($M = 4.88$, $SD = 0.33$), demonstrates that the native Android UI/UX design featuring touch-friendly navigation, structured wireframe layouts, and color-coded visual cues effectively minimized visual clutter. As highlighted in mobile application usability literature, intuitive visual hierarchy and responsive interactive elements prevent split-attention effects, allowing middle school learners to direct their cognitive capacity toward problem-solving rather than software navigation (Alqahtani & Rajkhan, 2021; Nielsen, 2023).

Similarly, the strong rating for Information Quality ($M = 4.84$, $SD = 0.39$) highlights the clarity and pedagogical value of the app's instructional contents, dynamic hint prompts, and immediate error feedback. By instantly notifying students of specific carry-over slips or intermediate cross-product errors during the Practice module, the application operationalizes principles of multimedia learning that reduce extraneous cognitive load and reinforce self-regulated error correction (Mayer, 2021; Sweller et al., 2019). Finally, System Usefulness ($M = 4.82$, $SD = 0.49$) confirms that learners recognized the practical utility of the tool in accelerating their mental calculation speed and simplifying complex longhand multiplication. This high perceived usefulness is critical for technology adoption in basic education, as learners are far more likely to integrate digital tools into their study habits when they experience immediate gains in operational speed and accuracy (Venkatesh et al., 2020; Naval & Langam, 2026).

Overall, these empirical metrics substantiate that the mobile application successfully fulfills the usability standards established by the Department of Education (DepEd) LRMS framework, serving as a highly effective digital scaffold for mental arithmetic enrichment.

Table 6 Level of Usability of the Developed Digital Learning Tool as Perceived by Mathematics Teachers

CSUQ Usability Dimension / Indicator	<i>M</i>	Interpretation	<i>SD</i>
a. System Usefulness (SysUse)	4.97	SA	0.18
b. Information Quality (InfoQual)	4.90	SA	0.31
c. Interface Quality (IntQual)	4.80	SA	0.41
d. Overall Usability Satisfaction	5.00	SA	0.00
Composite Usability Score	4.91	SA	0.28

Note: 4.50 – 5.00: Strongly Agree (SA); 3.50 – 4.49: Agree (A); 2.50 – 3.49: Neutral (N); 1.50 – 2.49: Disagree (D); 1.00 – 1.49: Strongly Disagree (SD)

Table 6 shows that the digital learning tool was rated by Grade 8 Math Teachers with a Composite Usability score of ($M = 4.91$, $SD = 0.28$) Strongly Agree. When rated by the Grade 8 Math teachers in terms of System Usefulness, Information Quality, and Interface Quality using the modified CSUQ as Very High Usability with means ranging from 4.80 to 5.00. The small values of standard deviation ranging from 0.16 to 0.49, shows homogeneity in the responses of the Grade 8 Math Teachers.

A mean of 5.00 accompanied by a standard deviation of 0.00 in Overall Usability Satisfaction indicates

complete, unanimous agreement among the teacher evaluators. In statistical terms, a standard deviation of zero confirms there was no variance in the data every respondent independently awarded the maximum possible rating of 5.00. The unanimous satisfaction indicates that the digital tool directly fulfilled teachers' instructional needs by providing a practical, effective method to support Vedic Mathematics lessons without adding extra workload or requiring technical training.

Teachers validated that the mathematical presentation of the four Vedic algorithms (*Antyayordasake'pi*, *Urdhva-Tiryagbhyam*, *Ekadhikena Purvena*, and *Nikhilam Navatashcaramam*) was pedagogically accurate, clear, and structured systematically for secondary mathematics instruction. Teachers commended the functional completeness and minimalist design, which minimized non-instructional cognitive distractions for learners during timed speed runs. This indicates a complete professional endorsement of the digital learning tool as a viable supplementary resource for secondary mathematics.

The unanimous rating recorded for Overall Usability Satisfaction alongside the near-perfect evaluation for System Usefulness, highlights that educators view the mobile application as a highly practical, reliable, and pedagogically sound instructional tool. In secondary educational technology adoption, teacher endorsement is heavily driven by perceived utility specifically, how seamlessly a software tool integrates into existing curricula to alleviate instructional burdens and address procedural skill deficits (Scherer et al., 2021; Harrison et al., 2022). The teachers' feedback confirms that digitizing Vedic Mathematics into an offline mobile platform provides an effective scaffold for reinforcing mental arithmetic without imposing unnecessary technical or operational overhead on classroom instruction (Naval & Langam, 2026).

Similarly, the high score achieved in Information Quality ($M = 4.90$, $SD = 0.31$) underscores the mathematical accuracy, clear step-by-step tutorial delivery, and real-time error-feedback mechanisms engineered into the application. Subject-matter experts emphasize that clear instructional formatting and immediate line-item feedback are vital for preventing cognitive overload and stopping procedural calculation errors before they become habituated (Mayer, 2021; Sweller, 2021). Lastly, the strong rating for Interface Quality ($M = 4.80$, $SD = 0.41$) confirms that the app's user interface design, mobile layout, visual contrast, and navigation paths meet high technical standards. Responsive and intuitive interface design ensures that both educators and junior high school learners can operate the application effortlessly, directing full cognitive focus toward mathematical problem-solving (Lewis, 2021; Nielsen, 2023).

The positive ratings for Interface Quality ($\bar{x}_{\text{student}} = 4.88$; $\bar{x}_{\text{teacher}} = 4.80$) and Overall Usability Satisfaction ($\bar{x}_{\text{student}} = 4.97$; $\bar{x}_{\text{teacher}} = 5.00$) corroborate human-computer interaction (HCI) principles advanced by Nielsen (1994) and Shneiderman et al. (2016). Nielsen (1994) stressed that intuitive user interface design, marked by visual clarity, logical hierarchy, consistent layouts, and responsive controls directly enhances user engagement and reduces operational errors. The minimalist visual layout and custom numeric keypads incorporated into the software minimized interaction overhead, ensuring that learners remained focused on speed-based calculation rather than software navigation. The complete consensus among teachers ($\bar{x} = 5.00$) regarding overall satisfaction further underscores that when a mobile learning application successfully harmonizes sound pedagogical strategy with standardized user-experience best practices, it yields a highly effective, acceptable, and viable supplementary tool for modern mathematics education (Nielsen, 1994; Shneiderman et al., 2016).

Enhancements on the Digital Learning Tool

Based on the evaluation results, a practical software enhancement plan was designed to upgrade the Vedic Mathematics Digital Learning Tool (*VedaMatrix2*). Even though the application earned strong approval from experts with an overall DepEd LRMSDS score of $M = 3.87$ ($SD = 0.28$) and achieved Very High Usability ratings from both Grade 8 students ($M = 4.85$, $SD = 0.41$) and Mathematics teachers ($M = 4.91$, $SD = 0.28$), the initial testing revealed clear areas for improvement. Specifically, the pre-assessment showed an accuracy ceiling where 62.50% of students performed at Moderate Mastery and 0.00% reached Advanced Mastery. It also showed a speed bottleneck where 80.00% calculated at Moderate Speed (taking 40 to 60 seconds per item) and 0.00% reached Very Fast pacing. Additionally, lower ratings in expert Technical Quality (3.68) and teacher Interface Quality (4.80) pointed to layout and design features that could be improved. To address these

findings, four clear software enhancements were identified.

First, to help students move from Moderate Mastery to Advanced Mastery, the app's *Learn* and *Practice* screens will be upgraded with an adaptive error-checking feature. Right now, the app only shows whether an answer is correct or incorrect. The upgraded app will analyze wrong answers and show students exactly where they made a mistake. For example, it will point out if a student forgot to add a carried number or made a simple addition slip during cross-multiplication in the *Urdhva-Tiryagbhyam* method. It will also suggest the best shortcut to use, such as prompting *Ekadhikena Purvena* when multiplying two-digit numbers that end in 5 and have the same tens digit. By showing step-by-step visual corrections, the app helps students fix minor calculation slips and improve their accuracy.

Second, to help students break through the Moderate Speed bottleneck and solve problems much faster, the *Challenge Screen* will include customizable timed speed-runs. Because 80.00% of students currently take 40 to 60 seconds per item due to writing down multi-step paper scratchwork, the app will introduce dynamic countdown timers ranging from 30 seconds down to 5 seconds per problem. Adding fun game features such as score multipliers for correct answer streaks, instant sound effects, and visual badges will encourage students to skip long written steps and rely on single-line mental calculations instead. This continuous practice helps increase calculation speed toward Very Fast levels.

Lastly, to address expert feedback on Technical Quality (3.68) and teacher feedback on Interface Quality (4.80), the visual design and user interface will be made clearer and easier to use. The keypad buttons on the screen will be made larger, so students do not accidentally press the wrong numbers during timed drills. The app will also include high-contrast color themes and adjustable text sizes. These visual updates ensure the screen is clear, easy to read, and comfortable to navigate, especially for students using budget or entry-level smartphones with smaller display screens.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents the summary of empirical findings, the conclusions derived from the analyzed data, and the corresponding recommendations formulated from the results of the study.

Summary

This study focused on the development, validation, and evaluation of pedagogical alignment and user acceptability of an Android-based mobile digital learning tool designed to teach Vedic Mathematics principles for two-digit multiplication to Grade 8 learners. Grounded in the need to address computational bottlenecks, lower cognitive load, and transition learners away from sole reliance on multi-step paper-and-pencil longhand calculations, the project targeted foundational mental arithmetic skills and operational fluency.

The study utilized a Design and Development Research (DDR) design structured around the ADDIE (Analysis, Design, Development, Implementation, Evaluation) framework and the Input-Process-Output-Outcome (IPOO) model. The instructional design and software architecture integrated Constructivist Learning Theory, Mayer's Cognitive Theory of Multimedia Learning (CTML), and Technological Pedagogical Content Knowledge (TPACK).

The software artifact, *VedaMatrix2*, was engineered as a native Android package compiled using Kotlin and custom XML layouts, designed to operate 100% offline client-side with a lightweight storage footprint. The tool digitized four core Vedic Sutras *Urdhva-Tiryagbhyam*, *Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam*

Navatashcaramam explicitly connecting the general vertical-and-crosswise method to Department of Education (DepEd) Grade 8 competencies in algebraic binomial expansion. The interface features a three-screen modular structure: Learn Screen, the Interactive visual tutorials for step-by-step concept acquisition. Practice Screen is the Dynamic problem generation paired with real-time error feedback and diagnostic review

features. Challenge Screen is the Latency-timed flash drills designed to phase out manual scratchwork and build rapid mental automaticity.

The evaluation protocol engaged three primary participant groups: expert validators (comprising Mathematics Content Experts and Educational/Information Technology Specialists), Grade 8 Mathematics teachers, and Grade 8 student-users. Software content validity, instructional quality, technical quality, and technical error mitigation were appraised using the DepEd Learning Resource Management and Development System (LRMDS) Non-Print Evaluation Framework. System usability across System Usefulness, Information Quality, Interface Quality, and Overall Satisfaction was measured using an adapted Computer System Usability Questionnaire (CSUQ).

Based on the data collected and analyzed through the ADDIE development life cycle, expert validation, and user acceptability assessments, the main findings of the study are as follows:

1. Pre-assessments revealed that Grade 8 learners possessed a solid foundational understanding of basic arithmetic operations but were constrained by a distinct accuracy ceiling and significant response latency. These operational bottlenecks were primarily driven by carry-over slips, column misalignment, working memory fatigue, and a heavy reliance on traditional paper-and-pencil scratchwork during multi-step longhand calculations.
2. The developed digital learning tool for Vedic Math was successfully engineered as a native Android application using Kotlin and custom XML layouts, operating 100% offline client-side under 30 MB for budget smartphones. The software digitized four Vedic Sutras, establishing *Urdhva-Tiryagbhyam* as the primary general method corresponding to algebraic binomial expansion $(ax + b)(cx + d)$, alongside three specialized sutras (*Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam*) as mental arithmetic prerequisites.
3. An offline native Android application was engineered in strict alignment with Department of Education (DepEd) LRMDS quality pillars. The software digitized core Vedic Mathematics sutras to condense complex multi-step multiplication into single-line operations directly mapped to Grade 8 algebra competencies. The platform operationalized a three-tiered trajectory: interactive visual tutorials for concept acquisition, scaffolded practice fields featuring real-time carry-over error feedback, and a latency-timed challenge module designed to phase out manual scratchwork and build rapid mental automaticity.
4. Evaluation by expert validators, mathematics teachers, and student users confirmed high standards in mathematical accuracy, pedagogical scaffolding, technical stability, and mobile interface design. Both teachers and students expressed very high usability and overall satisfaction, validating that the digital tool's real-time error prompts and timed pacing successfully eliminated intermediate calculation slips and noticeably accelerated student computational speed.
5. Although *VedaMatrix2* earned strong expert validation and high usability scores from both students and teachers, baseline testing identified key areas for software optimization. To overcome the observed accuracy ceiling caused by carry-over slips and the speed bottleneck stemming from a heavy reliance on paper scratchwork, the application will integrate an adaptive diagnostic error-remediation engine in the *Learn* and *Practice* screens to offer step-by-step visual guidance, alongside dynamic timed speed-runs embedded with instant audio feedback for every correct answer to strengthen positive reinforcement and promote rapid mental arithmetic. Additionally, the user interface was updated with enlarged touch targets, high-contrast visual modes, and dynamic text scaling to improve ergonomics, clarity, and readability on budget smartphones.

Conclusions

Based on the findings of the study, the following conclusions are drawn:

1. Traditional paper-and-pencil multiplication algorithms create an operational bottleneck for Grade 8

learners. Although students possess foundational arithmetic knowledge, reliance on multi-step longhand scratchwork induces cognitive fatigue, column misalignments, and frequent carry-over slips. This demonstrates that traditional algorithms alone are insufficient for fostering high-speed, high-precision computational fluency, underscoring the vital need for scaffolded mental arithmetic interventions.

2. Digitizing Vedic Mathematics sutras into an offline, lightweight mobile application offers a technically viable and curriculum-aligned instructional solution for resource-constrained basic education environments. Establishing *Urdhva-Tiryagbhyam* as a general calculation method mapped directly to algebraic binomial expansion complemented by *Ekadhikena Purvena*, *Antyayordasake'pi*, and *Nikhilam* confirms that Vedic mental operations serve as a digital scaffold for junior high school algebra.
3. The integration of interactive conceptual tutorials, real-time error-feedback practice fields, and latency-timed challenge modules provides an effective framework for skill acquisition. Immediate carry-over feedback prevents error habituation, while structured pacing systematically phases out learner reliance on physical scratchwork, transitioning students from slow manual calculations to rapid mental automaticity.
4. The high evaluation marks and very high usability ratings from expert validators, mathematics teachers, and student users affirm that the Vedic Mathematics Digital Learning Tool meets DepEd LRMDs standards for content accuracy, instructional quality, and mobile interface design. The application serves as an expert-approved, highly acceptable, and effective supplementary tool that successfully eliminates intermediate calculation slips and accelerates student computational speed.
5. The findings confirm that traditional longhand algorithms impose a heavy cognitive load on Grade 8 learners, establishing a clear need for scaffolded mental math tools like *VedaMatrix2*. The software fully satisfies Department of Education (DepEd) LRMDs standards and achieves Very High Usability among both students and teachers by successfully bridging arithmetic speed with Grade 8 algebraic competencies. Its lightweight, offline-first design ensures equitable classroom accessibility, while integrated enhancements such as adaptive error remediation, immediate audio feedback for correct responses, and ergonomic UI adjustments provide a validated, data-driven framework to transform learner procedural competence into rapid, high-precision mental computational fluency.

Recommendations

Based on the findings, expert validation, and usability evaluations of the study, the following actionable recommendations are presented for key stakeholders and target benefactors:

The learners are encouraged to engage in regular, self-paced mental math practice using the application during daily warm-ups or independent study. Learners should utilize the timed Challenge Screen and Drill Review features to phase out written scratchwork, reduce calculation anxiety, and build computational speed and accuracy.

The mathematics teachers may integrate the digital tool into regular classroom instruction as a 5-to-10-minute mental warm-up, remedial intervention, or supplementary activity for multiplying binomials. Teachers may leverage the built-in diagnostic reviews to identify student calculation error patterns and tailor instructional scaffolding accordingly.

School Administrators may institutionalize the adoption of low-footprint, offline digital learning tools across Grade 8 level. Administrators may organize school-based

Learning Action Cell (LAC) sessions and capacity-building workshops to train mathematics faculty on integrating mobile-assisted mental math strategies.

CID personnel may Benchmark and may incorporate alternative mental arithmetic heuristics (such as Vedic Mathematics sutras) into local secondary mathematics contextualization plans. CID supervisors may use the empirical of this study to guide policy formulation and instructional supervision in STEM learning.

The Learning Resources Management and Development System Chief Personnel may catalog, archive, or may publish the expert-validated Digital Learning Tool in teaching Vedic mathematics non-print learning resource on the division LRMDs portal. This might ensure wide accessibility and systematic distribution across public secondary schools within the division.

Parents may encourage children to use the offline mobile resource at home as a productive, safe, and screen-positive study routine. Parents may support their children's mathematical confidence without incurring recurring cellular data charges or internet subscription costs.

The researcher continues refining technical competencies in instructional software design, mobile app development, and educational research. The researcher should actively disseminate these findings through academic conferences and publication outlets to advocate for practical mobile learning tools in basic education.

The Future researchers may conduct quasi-experimental studies to evaluate longterm academic gains, latency reduction, and skill retention. Additionally, scholars may expand the application engine to higher-order operations (multi-digit multiplication and division) and adapt it for cross-platform iOS and web environments.

REFERENCES

1. Albento, R. (2023). Procedural bottlenecks and computational fluency among Filipino learners in secondary mathematics. *Journal of Educational Realities*, 11(2), 45–58.
2. Awasthi, P., Sharma, R., & Kumar, A. (2023). Cognitive load in traditional arithmetic algorithms: Implications for working memory and execution speed. *International Journal of Educational Psychology*, 12(3), 112–129.
3. Baksh, A., Bhagarathi, L. K., & Ally-Charles, B. R. (2025). The challenges and opportunities of teaching mathematics online at the higher levels in Region 6, Guyana: A pilot study. *World Journal of Advanced Research and Reviews*, 25(3), 495–509.
4. Bandala, M. (2024). Enhancing secondary algebra performance through mental computation heuristics. *Philippine Journal of Mathematics Education*, 8(1), 34–49.
5. Bhattacharyya, P., & Gogoi, M. (2020). Development and standardization of a criterion-referenced achievement test for Class-VIII learners. *International Journal of Educational Research and Development*, 9(2), 45–58.
6. Cassibba, R., Ferrarello, D., Mammana, M. F., Musso, P., Pennisi, M., & Taranto, E. (2021). Teaching mathematics at distance: A challenge for universities. *Education Sciences*, 11(1), Article 1.
7. Chakravarthi, M. K. (2014). LabVIEW: An interactive teaching tool for few concepts of Vedic mathematics. *International Journal of Engineering Research & Technology*, 3(9).
8. Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* (4th ed.). John Wiley & Sons.
9. Congressional Policy and Budget Research Department. (2024). Philippines' performance in the 2018 and 2022 PISA (No. 11). House of Representatives.
10. Daliva, J., & Deita, K. (2025). Vedic mental multiplication techniques and student numeracy in Philippine public high schools. *Asia-Pacific Education Researcher*, 34(2), 201–215.
11. Department of Education. (n.d.). Learning Resource Management and Development System (LRMDS) non-print evaluation guidelines (Template 6.6). Bureau of Learning Resources.
12. Department of Education. (2010). Guidelines on the implementation of the DepEd Computerization Program (DCP) (DepEd Order No. 78, s. 2010). Republic of the Philippines.
13. Department of Education. (2015). Policy guidelines on classroom assessment for the K to 12 Basic Education Program (DepEd Order No. 8, s. 2015).
14. Department of Education. (2019). Policy guidelines on the implementation of the DepEd Child Protection Policy (DepEd Order No. 35, s. 2019). Republic of the Philippines.
15. Department of Education. (2020). Interim guidelines for assessment and grading in light of the Basic Education Learning Continuity Plan (DepEd Order No. 031, s. 2020).
16. Department of Education. (2024). Charting a course for improvement: Strategic directions in Philippine

- basic education. Department of Education Policy Brief Series.
17. Department of Education. (2026). Revised guidelines on classroom assessment, grading system, and performance level descriptors for basic education (DepEd Order No. 015, s. 2026).
18. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification". In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (pp. 9–15). Association for Computing Machinery.
19. Chaudhary, S., & Gupta, M. (2025). Indian Knowledge Systems in modern pedagogy: Cognitive and executive functioning gains through Vedic mathematics. *Journal of Cognitive Enhancement*, 9(1), 15–29.
20. Glewwe, P., Park, A., & Zhao, M. (2025). Mobile-assisted learning technology in developing nations: Empirical evidence from secondary school mathematics. *Educational Technology Research and Development*, 73(1), 89–110.
21. Gogoi, M. (2025). NEP 2020 and ICT in education: A brief analysis. *Discourse Z*, 2.
22. Insorio, A. O., & Macagga, A. R. (2022). Effectiveness of mobile gamified applications in junior high school mathematics: An experimental study. *Journal of Digital Learning in Teacher Education*, 38(4), 210–225.
23. Insorio, A. O., & Macagga, A. R. (2023). Interactive digital learning tools and self-paced math practice in secondary education. *International Journal of Mobile and Blended Learning*, 15(2), 33–50.
24. International Organization for Standardization / International Electrotechnical Commission. (2011). *Systems and software engineering Systems and software Quality Requirements and Evaluation (SQuaRE) System and software quality models (ISO/IEC Standard No. 25010:2011)*.
25. Johnston, D. (2023). Curriculum congestion and algorithmic instruction in Southeast Asian mathematics education. *Comparative Education Review*, 67(3), 312–330.
26. Keleszade, G., Guneyli, A., & Ozkul, A. E. (2018). Effectiveness of history teaching based on social constructivist learning and development of historical thinking skills. *Education and Science*, 43(195), 167–191.
27. Kilag, O. K., & Ledesma, J. (2024). Addressing systemic mechanical calculation habits in Philippine basic education. *Journal of Pedagogy and Educational Development*, 5(1), 77–91.
28. Koehler, M. J., Shin, T. S., & Mishra, P. (2012). How do we measure TPACK? Let me count the ways. In *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 16–31). IGI Global.
29. Lagria, T., & Pañares, L. (2023). Diagnostic assessment of arithmetic errors and cognitive fatigue among Filipino elementary and secondary learners. *Mindanao Journal of Educational Research*, 19(1), 62–78.
30. Lee, J. S., & Ginsburg, H. P. (2009). What is appropriate mathematics education for young children? Perspectives from constructivist and conventional educators. *Journal of Early Childhood Teacher Education*, 30(1), 3–26.
31. Mahajan, A. (2023). Speed and accuracy trade-offs in mental calculation: A meta-analysis of Vedic mental shortcuts. *British Journal of Educational Psychology*, 93(2), 411–428.
32. Mathews, N. S., Venigalla, A. S. M., & Chimalakonda, S. (2022). VedicViz: Towards visualizing Vedic principles in mental arithmetic. *arXiv*. <https://doi.org/10.48550/arXiv.2205.08845>
33. Mayer, R. E. (2001). *Multimedia learning*. Cambridge University Press.
34. Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.
35. Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, 38(1), 43–52.
36. Mehera, C. (2012). Computing technique in ancient India. In D.-S. Huang et al. (Eds.), *ICIC 2011*, LNBI 6840 (pp. 282–289). Springer.
37. Mercado, J. P. (2021). Navigating the digital divide in Philippine public education: Challenges and opportunities for technology integration. *Asia-Pacific Social Science Review*, 21(3), 115–128.
38. Miller, M. D., Linn, R. L., & Gronlund, N. E. (2021). *Measurement and assessment in teaching* (13th ed.). Pearson.
39. Ministry of Education. (2020). *National Education Policy 2020*. Government of India.
40. Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for

- integrating technology in teacher knowledge. *Teachers College Record*, 108(6), 1017–1054. 100
41. National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*.
42. Naval, A., & Langam, R. (2026). A criterion-referenced equal-interval grading model as an alternative to the linear transformation scale in basic and higher education. *International Journal of Sociologies and Anthropologies Science Reviews*, 6(3), 119–140. <https://doi.org/10.60027/ijssar.2026.11463>
43. Nawale, S., Sakalkale, M., & Erande, V. (2026). The role of Vedic mathematics in enhancing computational speed and accuracy. *International Journal of Engineering Research & Technology*, 15(3).
44. Pallathadka, H., & Roy, P. D. (2025). Vedic mathematics: A comprehensive review of ancient wisdom and modern applications. *International Journal of Science, Engineering and Technology*, 13(3).
45. Piaget, J. (1954). *The construction of reality in the child*. Basic Books.
46. Pimpalkar, N. T. (2025). Theoretical foundations of Vedic mathematics and its educational implications. *Journal of Emerging Technologies and Innovative Research*, 12(3).
47. Sharma, D., Gahtyari, M., & Sharma, H. (2025). Innovative math teaching practices for building foundational skills: A step towards sustainable educational growth. *Global Journal of Research in Education & Literature*, 5(2), 42–45.
48. Sharma, V., & Bakshi, S. (2025). Visual pattern recognition versus vertical multiplication algorithms: A working memory evaluation. *Cognitive Research: Principles and Implications*, 10(1), Article 8.
49. Singh, A., & Malik, N. (2022). A review of TPACK framework in blended era. *Chetana International Journal of Education*, 7(2), 74–87.
50. Singh, S. K., Shah, S., Ranjan, T., Shreyansh, S., & Babu, R. K. N. (2023). Implementation of Vedic mathematic (Nikhilam Navatacharamam Dasatah) to perform mathematical operations quickly and accurately. *International Research Journal of Modernization in Engineering Technology and Science*, 5(6).
51. Srivastava, M., Deshpande, S., & Williams, K. (2023). Computational efficiency of Vedic mathematical methods: A comprehensive meta-analysis. *Journal of Educational Psychology*, 115(4), 723–742.
52. Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(2), 257–285.
53. Taracina, E. (2023). Integrating alternative mental math heuristics into Grade 8 algebra instruction. *Philippine Social Science and Education Journal*, 6(2), 104–119.
54. Tirthaji, B. K. (1965). *Vedic mathematics*. Motilal Banarsidass.
55. UNESCO. (2018). *A global framework to measure digital literacy skills*. UNESCO Institute for Statistics. University of Hartford. (n.d.). 12 principles of multimedia learning. <https://www.hartford.edu>
56. Vrasidas, C. (2000). Constructivism versus objectivism: Implications for interaction, course design, and evaluation in distance education. *International Journal of Educational Telecommunications*, 6(4), 339–362.
57. Williams, K., & Gaskell, M. (2022). Computation speed and accuracy advantages of Vedic mathematical methods: A five-year longitudinal study. *British Journal of Educational Psychology*, 92(3), 1132–1154.
58. Williams, M. K., & Bair, R. (2020). Aligning digital learning tools with grade-level learning standards: Strategies for educational software development. *Journal of Educational Technology Systems*, 49(2), 185–202.