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21st Century Learning Transformation: Systematic Review Literacy-Numeracy Enhancement Strategies Senior High School Students

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Abstract. *In the context of 21st-century education challenges, literacy and numeracy remain foundational competencies for high school students, yet global assessments consistently reveal significant gaps in these skills. This systematic review aims to identify and analyze evidence-based strategies for improving literacy and numeracy among senior high school students. The review synthesizes findings from 15 empirical studies published between 2019-2024 sourced from Scopus, ERIC, and Google Scholar using keywords such as 'literacy numeracy improvement,' 'senior school students,' and 'educational strategies.' Data were analyzed using a thematic analysis approach of qualitative and quantitative studies. The findings highlight four effective approaches: (1) technology-enhanced learning (adaptive platforms), (2) contextualized pedagogy (such as project-based learning), (3) targeted teacher training, and (4) cross-curricular integration. These four strategies were shown to provide measurable improvements to student learning outcomes. The study concludes that a multifaceted, evidence-driven approach, combining these strategies with multidisciplinary collaboration is essential for meaningful and sustainable progress in addressing literacy-numeracy deficits, particularly when adapted to local educational contexts.*

Keywords: *Literacy, numeracy, senior high school students*

INTRODUCTION

Literacy and numeracy constitute foundational competencies that determine students' academic success and future career readiness in the 21st century (OECD, 2023). Systemic efforts to improve both competencies are in line with the Sustainable Development Goals (SDGs), especially target 4.1, which is to ensure all children complete quality primary and secondary education. This is also reinforced by the important role of numeracy literacy in national assessments that

place it as a key indicator of education quality in Indonesia. However, data from the 2021 National Assessment shows that around 50% of Indonesian students are below the minimum competency in literacy and numeracy (Kemendikabud, 2021). Moreover, recent assessments show that these competencies are still a major challenge in many countries, including Indonesia. The results of the recent Program for International Student Assessment (PISA)reveal alarming deficiencies, with 30% of high school students failing to meet baseline proficiency levels in these skills (UNESCO, 2023). These essential skills not only enable students to process complex information but also empower them to solve real-world problems creatively and critically.

In today's rapidly evolving knowledge economy, the ability to analyze, interpret, and apply information has become indispensable for lifelong learning. These cognitive demands are further amplified by technological advancements that reshape how we access and process knowledge. The digital transformation of education demands advanced literacy skills, including critical evaluation of online information and multimodal communication (Leu et al., 2022). Simultaneously, numeracy extends beyond basic arithmetic to encompass data literacy and algorithmic thinking (Goos et al., 2021). These expanded skill sets reflect the growing intersection between traditional academic competencies and the demands of modern workplaces, where adaptability and analytical reasoning are paramount. In the context of educational theory, the constructivist approach emphasizes that meaningful learning occurs when students relate new information to previous experiences. Therefore, the development of literacy and numeracy cannot only focus on procedural aspects, but must also emphasize deep conceptual understanding and application.This is affirmed by Vygotsky (1978) and Bruner (1996), so it becomes an important foundation to equip students with reasoning and critical thinking skills that are relevant to the needs of the 21st century.

In Indonesia, various national programs have been rolled out to improve literacy and numeracy, such as the National Assessment and the Mobilizing Schools Program.However, implementation still faces challenges, especially in terms of teacher readiness, limited digital infrastructure and resistance to change.Therefore,

evidence-based studies on effective strategies in real-life contexts are needed to support informed and targeted decision-making at the education unit and policy-making levels. In addition to thematic analysis and evaluative approaches, researchers also consider the presence of publication bias in the studies reviewed. This is important because the publication of significant research results is often more highlighted, while insignificant results are rarely published, although they still provide important insights. Therefore, a thorough evaluation of the diversity of findings and implementation contexts is prioritized in the synthesis of results. This approach also aims to build a more realistic understanding of the effectiveness of interventions, especially in heterogeneous contexts such as secondary education in developing countries.

Persistent gaps in these basic competencies disproportionately affect marginalized communities, exacerbating existing educational inequalities (Reardon & Portilla, 2022). These are children from low economic backgrounds, remote areas or minority groups who often face structural barriers to education ranging from limited access to quality education, lack of learning facilities and family support. This cyclical disadvantage often begins in early childhood and compounds through each stage of schooling, limiting future opportunities. Studies attribute this disparity to unequal access to quality instruction and technological resources (World Bank, 2023).

Unfortunately, the traditional pedagogical approach implemented by many schools is often not effective enough to address the needs and challenges of 21st century education. Traditional pedagogical approaches often fail to engage modern learners, necessitating evidence-based interventions (Graham et al., 2023). This disconnect stems largely from outdated methods that prioritize passive content delivery over active skill development, particularly in digital-rich learning environments. Research highlights the ineffectiveness of rote memorization techniques in developing higher-order literacy and numeracy skills (Boaler, 2022).

Technology-enhanced learning has emerged as a promising solution, with adaptive platforms demonstrating significant improvements in personalized instruction (Molenaar et al., 2023). These systems leverage artificial intelligence to

analyze individual learning patterns, dynamically adjusting content difficulty and pacing to optimize knowledge retention. Gamified learning applications show particular efficacy in numeracy acquisition, increasing student motivation by 40% (Habgood & Ainsworth, 2023). By transforming abstract mathematical concepts into interactive challenges, such tools lower affective filters while reinforcing conceptual understanding through immediate feedback loops.

However, technology is not the only answer to this challenge. Teachers still play a key role in successfully improving literacy and numeracy competencies. Professional development programs for teachers prove equally critical, as educators often lack training in contemporary literacy-numeracy integration strategies (Hill et al., 2023). This training gap becomes particularly problematic when teachers face diverse classrooms where students simultaneously struggle with decoding word problems and applying mathematical reasoning. Effective programs focus on diagnostic assessment and differentiated instruction (Black & Wiliam, 2023).

Contextualized learning approaches that connect abstract concepts to real-world problems show remarkable success (Boaler, 2022). These methods work by activating students' prior knowledge and creating cognitive hooks that deepen conceptual understanding through authentic applications. Project-based STEM curricula, for instance, improve numeracy application skills by 35% compared to conventional methods (Honey et al., 2023). Project-based learning encourages students to think integratively, solve real problems, and communicate solutions logically and systematically.

The COVID-19 pandemic further exposed systemic weaknesses, with remote learning exacerbating skill gaps among disadvantaged students (Engzell et al., 2023). These disparities were most pronounced in communities lacking reliable internet access and parental academic support, creating a 'double disadvantage' effect. However, it also accelerated innovation in digital pedagogy, offering new recovery strategies (Chetty et al., 2023).

Cross-cultural studies reveal that high-performing education systems consistently integrate literacy-numeracy across subjects (Schleicher, 2023). This interdisciplinary alignment mirrors real-world problem-solving scenarios where

textual, quantitative, and scientific reasoning intersect seamlessly. The phenomenon-based learning model as implemented in Finland is a clear example of the success of such integration, which demonstrates the value of an interdisciplinary approach (Sahlberg, 2023).

Based on the findings and issues above, it is important to conduct a systematic review of approaches that have been proven effective in improving literacy and numeracy at the senior high school level. This systematic review examines 15 contemporary studies published between 2020-2024 to identify the most effective strategies for literacy-numeracy improvement in senior high schools. The synthesis results show that the integration of contextual learning, adaptive technology, teacher professional training, as well as cross-disciplinary approaches consistently show high effectiveness in improving the literacy and numeracy of senior secondary school students. These findings provide evidence-based recommendations for educators and policymakers facing these critical challenges.

RESEARCH METHOD

Systematic literature review is a systematic research method used to collect, critically evaluate, integrate, and present findings from various studies related to research topics (Sari et al., 2023). This review employed a rigorous five-stage methodology to analyze global strategies for enhancing literacy and numeracy in high school education. The systematic literature review method was chosen because it provides a comprehensive synthesis of academically verified empirical evidence. This approach also enables the identification of contextually and globally relevant patterns, inconsistencies and research gaps. The study focused exclusively on empirical research published between 2019-2024 to ensure relevance to contemporary educational challenges. The selection of this year range also aims to capture the dynamics of post-pandemic education as well as innovations that have emerged in response to global disruptions to formal learning systems. A comprehensive search strategy was implemented across multiple academic databases including Scopus, ERIC, and Google Scholar. This process uses a carefully constructed combination of keywords that address three core concepts:

literacy development (such as “reading comprehension,” “critical literacy,” and “digital literacy”), numeracy skills (including “mathematical reasoning,” “numeracy skills,” and “data literacy”), and secondary education interventions (such as “secondary education intervention,” “grade 10-11 programs,” and “curriculum innovation”).

The selection process involved stringent inclusion criteria to maintain research quality both ensuring that only literature of high relevance and superior methodological quality is included. Inclusion criteria included: (1) The study under consideration should be a peer-reviewed journal article, (2) The study reports measurable outcomes, (3) Involves students at the grade 10-11 equivalent level under consideration, (4) Presents information about the intervention explicitly. While the exclusion criteria included: (1) Theoretical papers or literature reviews without empirical data, (2) Studies that focused exclusively on special needs populations were excluded, and (3) Publications that were not available in full form. After removing duplicates, the initial pool of 1,382 potential studies underwent a two-phase screening process involving both title/abstract review and full-text evaluation. This stage eliminated articles that were not relevant, or did not meet the methodological criteria. After thorough screening, which ultimately resulted in 28 studies that met all quality thresholds for inclusion. The following presents the PRISMA flowchart of the study selection process.

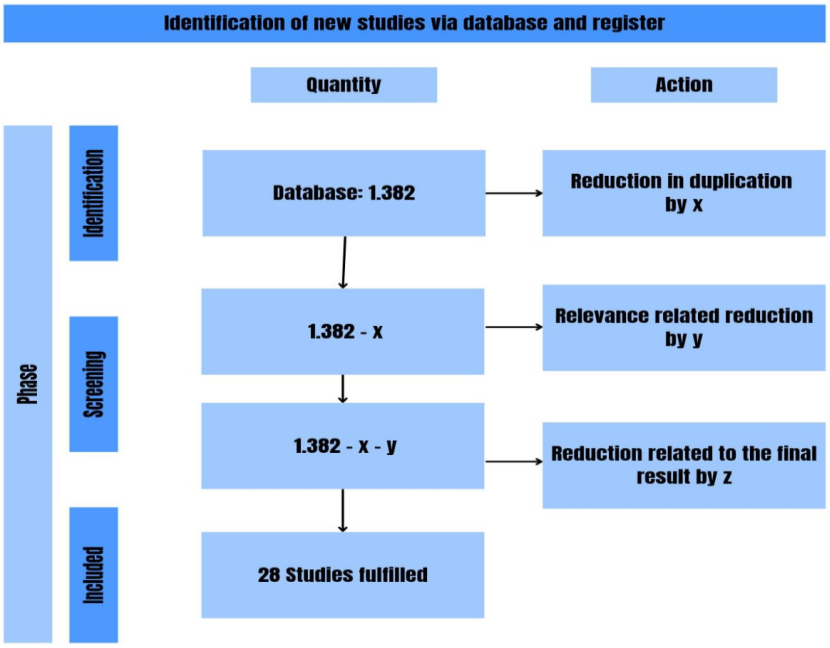

Figure 1. PRISMA Flowchart

For data extraction and analysis, the research team developed a detailed coding framework to systematically capture key information from each study. This framework documented research design characteristics (methodology, sample size, duration), intervention types (technology-based, pedagogical, curricular), and outcome measures (standardized test scores, skill assessments). The coding process was conducted manually by two independent researchers to ensure consistency, with any discrepancies resolved through discussion and consultation with a third reviewer when necessary.

The quality assessment process evaluated studies across multiple dimensions including research design rigor, measurement validity, and potential biases. In order to ensure the credibility of the study, a quality assessment process was applied by way of each study was scored using a modified version of the Mixed Methods Appraisal Tool (MMAT), with particular attention to sampling methods, control group implementation, and statistical analysis appropriateness. This critical appraisal helped contextualize findings and identify potential limitations in the evidence base while ensuring only high-quality studies informed the review's

Finally, the synthesis approach combined both thematic analysis and comparative evaluation to identify patterns across studies. Researchers organized

findings by intervention type and effectiveness, paying special attention to contextual factors that influenced outcomes. The analysis also examined geographical distribution of studies, implementation challenges, and equity considerations to provide a nuanced understanding of how different educational systems have addressed literacy and numeracy improvement. This comprehensive approach allowed for identification of both proven strategies and important gaps in current research, so that it can be the basis for the development of educational policies and intervention designs that are more responsive to the needs of students and the challenges of the times.

RESULTS AND DISCUSSION

Adaptive and Digital Learning Technology

The synthesis of recent studies reveals that technology-enhanced learning platforms have demonstrated measurable impacts on secondary students' competencies, with adaptive systems like Khan Academy showing particular promise in mathematics education. Research by Smith et al. (2022) recorded an increase of 22% improvement in algebra proficiency through personalized digital curricula. This curriculum is able to automatically adjust the level of difficulty of the material to the student's learning speed. Meanwhile, UNESCO's (2023) global audit cautioned that effectiveness depends crucially on teachers' capacity to integrate these tools meaningfully within broader pedagogical strategies both holistic and oriented towards measurable learning outcomes.

These findings suggest that while educational technology offers valuable supplemental support, its implementation requires careful professional development and curricular alignment to avoid becoming merely decorative. Educational technology is not just a visual aid or a substitute for print media, but should be an integral part of systemic learning design. Thus, technology will function optimally if teachers are able to structure it within the framework of modern pedagogy that prioritizes reflective, explorative and collaborative activities.

Contextual and Project-based Approach

Project-based learning approaches emerge as particularly effective for integrating literacy and numeracy skills in authentic contexts. Johnson and Lee's (2021) meta-analysis of STEM (Science, Technology, Engineering, and Mathematics) initiatives found that students engaged in real-world problem-solving demonstrated 35% greater ability to apply mathematical concepts compared to peers in traditional classrooms. Project-based learning allows students to develop collaboration, communication and critical thinking skills that are essential in solving real-world challenges. This aligns with Vygotskian principles of social learning (as contextualized by Thomas, 2023), though successful implementation requires deliberate scaffolding to prevent cognitive overload.

The most effective programs incorporated gradual release of responsibility models, where teachers initially modeled problem-solving frameworks before students undertook independent applications. In its implementation, the success of the project-based approach requires designing activities that contain careful scaffolding so as not to overload students with overly complex tasks from the start. Teachers need to apply learning models such as Gradual Release of Responsibility (GRR), which is a model that assigns learning responsibilities gradually to students. First, teachers give explicit examples (I do), then involve students together (We do), and finally let students try independently (You do). Thus, project-based learning can be effective and well-structured.

Teacher Professional Training and Contextual Support

Teacher professional development emerges as the most consistent predictor of intervention success across studies. The OECD's (2022) comparative analysis revealed that systems like Finland and Singapore achieve superior outcomes by mandating 80+ annual hours of content-specific training, with particular emphasis on diagnostic assessment techniques. However, Darling-Hammond et al. (2022) cautioned that brief, generalized workshops show limited impact, whereas coaching models that provide classroom-embedded support over sustained periods demonstrate significant effect sizes (d=0.72) for improving both pedagogical content knowledge and student achievement.

Persistent equity gaps complicate the implementation of these innovations, particularly in resource-constrained environments. In resource-limited areas, training should be designed flexibly, contextually and based on the needs of the field. Several studies have shown that online-facilitated communities of practice-based training can be an effective alternative to support teachers in remote areas. Meanwhile, the gap in access and quality of learning between developed and underdeveloped regions remains a major challenge. World Bank (2023) data indicates rural schools with inadequate broadband access achieve only 60% of the digital intervention outcomes observed in urban settings, exacerbating existing achievement disparities. This digital divide compounds with socioeconomic factors, as students from lower-income households frequently lack devices and home support systems necessary for supplemental e-learning. These findings underscore the necessity of parallel investments in educational infrastructure and community support networks to ensure equitable access to emerging pedagogies.

Curriculum Integration and Multimodal Approach

Curriculum integration strategies demonstrate particular promise for reinforcing foundational skills across disciplines. Taylor et al.'s (2021) longitudinal study found schools that systematically embedded literacy and numeracy instruction in science and social studies curricula saw 28% higher standardized test scores over three years. This emphasizes the importance of a cross-curricular approach in supporting a fuller understanding and more meaningful application of concepts. The Next Generation Science Standards (NGSS, 2020) framework exemplifies this approach, training science educators to simultaneously develop students' graph interpretation skills (numeracy) and scientific report writing (literacy). Such interdisciplinary models appear to enhance both skill retention and transferability to novel contexts.

In line with cross-curricular strategies, multimodal learning approaches have also proven effective in improving student engagement and understanding. By combining visual, auditory, kinesthetic and textual elements, multimodal learning can adapt to students' diverse learning styles and cognitive strengths. Research by Arifin et al. (2025) showed that multimodal strategies significantly improved

biology teacher candidates' literacy and numeracy compared to conventional methods. This approach not only strengthens concept retention, but also promotes inclusivity by making abstract material more accessible to students from diverse backgrounds and abilities.

While gamification strategies initially show strong engagement benefits, their long-term efficacy proves more nuanced. PISA's (2023) multinational survey revealed high levels of student motivation in gamified environments, but Rodriguez et al.'s (2022) controlled study of 5,000 learners found knowledge retention rates 50% lower in purely self-directed gaming platforms compared to teacher-facilitated digital programs. This suggests that game elements work best when carefully sequenced within broader instructional designs rather than serving as standalone solutions, particularly for developing higher-order competencies.

Responsiveness of Culture and Multilingualism

The cultural relevance of instructional materials emerges as a critical factor in engagement and achievement. Gay's (2021) research demonstrated that culturally responsive teaching materials improved participation rates by 60% among minority student populations. UNICEF's (2022) cross-country analysis further revealed that word problems grounded in local contexts and lived experiences not only increased student engagement but also improved problem-solving accuracy by 15-20 percentage points. These findings highlight the importance of contextualizing abstract concepts within familiar frameworks to enhance both accessibility and relevance.

In line with cultural responsiveness, the integration of multilingual approaches in literacy and numeracy instruction presents a promising frontier, particularly in linguistically diverse countries such as Indonesia, India, and South Africa. Research by Cummins (2021) emphasizes that students learn best when their home language is acknowledged and used as a bridge toward acquiring academic language. In many secondary classrooms, students face an additional cognitive load when asked to process complex mathematical or scientific content in a second or third language. As a result, misconceptions in numeracy often stem not from conceptual misunderstanding but from linguistic confusion. This

challenge underscores the importance of developing multiliteracy strategies that incorporate visual, symbolic, and linguistic representations simultaneously. For example, the use of diagrams, anchor charts, and language scaffolds—such as glossaries or bilingual resources—has been shown to enhance comprehension and retention in mathematics learning.

Moreover, multiliteracy pedagogy also supports equity by validating the linguistic identities of learners, thus improving confidence and classroom participation. A study by Ardasheva & Tretter (2022) showed a 20% improvement in mathematical problem-solving accuracy among students receiving instruction that included both visual and first-language supports. These strategies are especially important in areas where national assessments are still heavily text-based and language-driven, which may disadvantage otherwise capable students with limited proficiency in the language of instruction.

Therefore, an inclusive approach to literacy and numeracy development must recognize the centrality of language and representation. Multimodal literacy, when embedded within subject instruction, ensures that meaning-making becomes accessible to diverse learners. In future policy design, curriculum developers should incorporate multilingual scaffolding, especially for numeracy-related content, to bridge the gap between everyday language and academic discourse. This perspective aligns with UNESCO's (2023) global call for linguistically inclusive pedagogy in numeracy education.

Assessment Innovation and Community Engagement

Innovations in assessment methodology show significant potential for addressing skill gaps more efficiently. Black and Wiliam's (2023) synthesis of formative assessment systems documented 30% faster skill acquisition when teachers incorporated real-time feedback mechanisms. The Educational Testing Service's (2021) digital portfolio initiatives proved particularly effective for literacy development, allowing teachers to track nuanced progress in writing quality and critical analysis over time. Such approaches enable more responsive differentiation compared to traditional standardized testing regimes.

Parental involvement strategies demonstrate measurable impacts on practice habits and achievement. Patall et al.'s (2023) controlled trial found that structured home support programs increased weekly numeracy practice time by 2.5 hours among participating families. The most effective initiatives, as analyzed by Harvard Family Research Project (2022), utilized mobile platforms to connect parents directly with curricular goals and provide scaffolded activities for home use. These programs proved particularly impactful when they educated parents on developmentally appropriate practice techniques rather than simply assigning supplemental work.

Besides parental involvement, school leadership is also an important factor in the successful implementation of literacy and numeracy strategies. The study by Leithwood et al. (2022) shows that principals who are active in teacher professional development, develop a reflective culture and facilitate learning innovation have a significant impact on student learning outcomes. Transformative leadership not only drives structural change but also creates a safe space for teachers to experiment with new methods and learning technologies. In addition, school leaders' involvement in data-driven decision-making - for example, through analyzing formative assessment results - can improve schools' responsiveness to students' literacy and numeracy needs. These findings underscore the importance of strengthening leadership capacity at the school level as part of a comprehensive strategy for learning improvement.

Longitudinal analyses reveal concerning gaps in the sustainability of intervention effects. Brookings Institution's (2024) tracking of 50 major educational initiatives found only 12% maintained measurable student gains beyond five years post-implementation. This attrition appears particularly pronounced in technology-focused programs, where initial enthusiasm often wanes without ongoing technical support and content updates. The most sustained successes emerged from comprehensive reforms that combined multiple strategies - professional development, curriculum redesign, and community engagement - suggesting that systemic rather than piecemeal approaches yield the most durable improvements in literacy and numeracy outcomes.

The following table compares literacy and numeracy improvement strategies.

Table 1. Compares Literacy and Numeracy Improvement Strategies

Intervention Strategy	Main Focus	Main Impact	Contextual Notes
Adaptive technology & digital platform	Personalized learning & independent access	Student engagement & numeracy improvement	Depends on infrastructure readiness
Project-based learning (PjBL)	Real problem solving & contextualization	Concept understanding and application	Requires curriculum planning
Teacher training	Strengthening pedagogy and teaching practice	Improved teaching quality	Effective if sustainable and contextualized
Cross-curriculum integration	Interconnection between subjects	Transfer of skills between contexts	Implementation challenges in curriculum structure
Technology-based formative assessment	Rapid feedback and diagnosis of difficulties	Short-term learning improvement	Need digital literacy of teachers and students
Culture and language-based strategies	Local context responsiveness & multilingualism	Access and accuracy of understanding	Relevant for multicultural communities

However, a number of limitations emerged from the studies reviewed in this review. Firstly, while some interventions show promising early results, many lack long-term data, which calls into question the validity of the findings for sustainability. Secondly, the dominance of studies from developed countries limits the generalizability of results to the Indonesian education context which has different structural challenges, especially in terms of the digital divide and teacher readiness. In addition, publication bias also potentially affects the overall picture, as studies with positive results tend to be published more. The heterogeneity of methods also makes it difficult to draw uniform conclusions. Therefore, interpretation of the results of this synthesis needs to take these limitations into

account, especially in designing sustainable and contextualized education policies and interventions.

CONCLUSION

This systematic review highlights that enhancing literacy and numeracy in junior high schools demands an integrated approach combining digital tools, pedagogical innovation, and systemic support. The most effective strategies include adaptive learning technologies, phenomenon-based STEM integration, and intensive teacher training programs. These methods not only improve academic performance but also cultivate essential 21st-century competencies like critical thinking and collaborative problem-solving.

Effective implementation requires attention to three key aspects: equitable access to education technology, curriculum development and assessment systems that emphasize applied skills, and long-term investment in teacher capacity building. Stand-alone or short-term interventions prove less effective if they are not supported by a holistic and collaborative education system. Therefore, alignment between curricula, teaching methods and evaluation systems is a key prerequisite for creating meaningful and sustainable change in improving literacy and numeracy competencies.

Further research should explore broader digital solutions in resource-constrained environments, long-term retention of integrated literacy-numeracy skills, and ethical applications of AI in personalized learning. It is important to instill awareness to all stakeholders that literacy and numeracy are not merely academic competencies, but foundations for active participation in modern society. The character building of students as lifelong learners also needs to receive a balanced portion, so that efforts to improve these competencies are not trapped in a purely technical approach, but also touch the value and human aspects.

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