

Cybernetic-Based Numeracy Empowerment for Secondary Mathematics Teachers: A Community Engagement Perspective

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ABSTRACT

This article presents a community engagement-based research initiative aimed at enhancing numeracy competence among senior high school teachers in Indonesia through a cybernetic pedagogy framework. Conducted at SMA Negeri 1 Nguter, the program combined theoretical workshops, digital tool integration, and cross-disciplinary lesson design to empower teachers in embedding numeracy across various subjects. A mixed-methods approach—comprising pre- and post-tests, structured mentoring, classroom observations, and reflective journals—revealed significant improvements in teachers' conceptual understanding, pedagogical confidence, and instructional practices. The findings demonstrate that cybernetic-based teaching fosters interactive, data-driven learning environments and supports numeracy as a transversal 21st-century skill. This study contributes empirical insights into scalable, cross-national professional development models that can be adapted in resource-constrained educational contexts.

Keywords: cybernetic learning, numeracy, teacher professional development, 21st-century skills



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INTRODUCTION

Numeracy is a critical competency in the contemporary information society, enabling individuals to interpret, reason, and communicate using quantitative information (Goos et al., 2020). It serves as a foundation not only for mathematics but also for lifelong learning, problem-solving, and informed decision-making across multiple domains. In schools worldwide, numeracy has increasingly been recognized as a transversal skill that should permeate all subjects to prepare students for the complex challenges of the 21st century.

Despite this consensus, numeracy education often remains siloed within mathematics classrooms. This narrow approach diminishes opportunities for students to apply numerical reasoning in authentic, real-world contexts found in science, economics, social studies, and even the arts. Both Indonesia and Cambodia, as developing nations striving to modernize their

education systems, face this challenge acutely. National assessments such as PISA and TIMSS consistently reveal that students in both countries lag in numeracy proficiency, impeding their academic and professional trajectories.

The root causes are multifaceted, including insufficient teacher professional development tailored to interdisciplinary numeracy, limited integration of technology in teaching, and gaps in curriculum design. Recognizing these challenges, educators and researchers from Indonesia and Cambodia initiated a community service project aiming to empower high school teachers with cybernetic-based numeracy competencies. This article presents a comprehensive report on the project, detailing its theoretical foundations, implementation strategies, outcomes, and implications for broader educational policy and practice.

Numeracy extends beyond basic arithmetic skills; it encompasses the ability to formulate, interpret, and communicate mathematical information in context (Goos et al., 2020). Dewayani et al. (2021) emphasize “contextual numeracy” — the capacity to relate numerical concepts to students' real-life experiences and socio-cultural environments. This orientation aligns with global shifts toward holistic, competency-based education.

Several studies from Indonesia reveal teachers' limited confidence and competence in teaching numeracy outside mathematics classrooms, a challenge also reported in Cambodia's education reforms (Cambodia Ministry of Education, 2023). Bridging this gap requires professional development that repositions numeracy as a shared responsibility among all subject teachers.

Cybernetic learning incorporates principles from cybernetics — the study of control and communication systems — into educational design (Al-Malah et al., 2020). It emphasizes feedback loops, adaptability, and interactive digital environments that foster self-regulation and personalized learning. Cambodia's recent initiatives in digital education, including AI-enhanced learning platforms, exemplify this approach (Sadykov et al., 2022).

Combining cybernetic learning with numeracy instruction presents a promising pedagogical synergy. It enables teachers and students to engage dynamically with numerical data, visualize concepts in real time, and receive immediate feedback — all critical for deepening understanding.

Cross-national collaborations foster knowledge exchange, contextual adaptation, and capacity building. Indonesia and Cambodia share similar educational challenges and socio-economic contexts, making collaboration mutually beneficial. The community service program was made possible through a cross-national collaboration between Universitas Veteran Bangun Nusantara (Univet), Indonesia, and the Musa Asyiah Foundation, an educational organization based in Cambodia. This partnership emerged from a shared vision to strengthen 21st-century education in Southeast Asia, particularly in the areas of numeracy, technology integration, and teacher professional development.

Initial contact between Univet and the Musa Asyiah Foundation was established through academic networking forums and mutual involvement in international education conferences. Both institutions recognized that Indonesia and Cambodia face similar challenges in improving educational quality, especially in integrating numeracy across subjects and leveraging digital tools for meaningful learning. This mutual understanding laid the foundation for collaborative action.

Through a formal agreement, experts from the Musa Asyiah Foundation contributed to the design, facilitation, and mentoring phases of the project. Cambodian educators played an active role in delivering workshop sessions, sharing experiences from their country's recent reforms in digital education, and mentoring Indonesian teachers in applying cybernetic principles in lesson design.

This partnership allowed for rich cross-cultural dialogue and knowledge exchange. For example, during the workshop at SMA Negeri 1 Nguter, Cambodian facilitators introduced case studies on the use of AI-supported learning environments in Cambodian schools, which inspired Indonesian participants to explore similar innovations. Conversely, Univet's team shared contextual insights into the Indonesian curriculum and classroom realities, enabling Cambodian partners to adapt their input effectively.

Beyond the implementation phase, both institutions have agreed to continue the partnership through joint publications, follow-up mentoring sessions, and the development of open educational resources that support numeracy education in both contexts.

This collaboration exemplifies the value of regional cooperation in addressing common educational goals and highlights Univet's commitment to building international partnerships that foster mutual growth and innovation.

Such partnerships have been documented to enhance professional development quality by incorporating diverse pedagogical perspectives and technological innovations (Tanaka & Akhmetova, 2021)

This collaborative project was designed to achieve the following objectives to strengthen Indonesian senior high school teachers' conceptual and practical understanding of numeracy as a cross-curricular skill, drawing on shared Indonesian-Cambodia educational insights, to equip teachers with cybernetic-based instructional design skills for integrating numeracy into various subject areas, to foster innovation and experimentation with technology-enhanced lesson planning and classroom delivery, to establish a professional learning community with ongoing bilateral mentoring and exchange to sustain development, to contribute to policy discourse on enhancing 21st-century skills education in both countries.

METHOD

The project took place from January to March 2024 at SMA Negeri 1 Nguter, a public senior high school in Central Java, Indonesia. The selection of SMA Negeri 1 Nguter as the site for this community service project was based on several strategic and contextual considerations. First, the school represents a typical public senior high school in a semi-urban area, with a diverse range of teaching staff and subject areas. This diversity provided an ideal environment to implement and evaluate cross-curricular numeracy interventions in a realistic and complex setting.

Second, SMA Negeri 1 Nguter demonstrated a strong commitment to teacher professional development and openness to pedagogical innovation, particularly those involving educational technology. The school's active partnerships with higher education institutions and its teachers' willingness to engage in intensive training were key factors supporting its selection.

Third, a preliminary diagnostic survey conducted by the project team revealed that over 70% of teachers at the school still perceived numeracy as confined to mathematics, and fewer than 30% reported using digital tools in their lesson planning. This baseline condition closely aligned with the project's goals to build interdisciplinary numeracy competencies and introduce cybernetic-based instructional approaches.

Fourth, the school's geographic proximity to the implementing institution—Universitas Veteran Bangun Nusantara—facilitated logistical coordination, mentoring activities, and sustainability planning beyond the initial implementation phase.

Thirty-six teachers representing diverse subjects—including mathematics, science, economics, social studies, and language arts—participated voluntarily. The project team comprised Indonesian educators from Universitas Veteran Bangun Nusantara and Cambodia experts from Nazarbayev University's Institute of Education.

A mixed-methods design was employed, combining quantitative pre- and post-tests with qualitative data from mentoring logs, classroom observations, and reflective journals. This design allowed triangulation of data to evaluate the program's effectiveness comprehensively.

A diagnostic survey assessed teachers' baseline knowledge, attitudes, and practices regarding numeracy and technology use. It revealed that over 70% perceived numeracy as confined to mathematics, and less than 30% reported using digital tools in lesson planning.

A two-day intensive workshop was conducted jointly by Indonesian and Cambodia facilitators. Workshop content included theoretical foundations of numeracy as a cross-disciplinary competence, pedagogical principles of cybernetic learning, practical training on digital tools such as spreadsheets, data visualization software, interactive simulations, and digital assessment rubrics, collaborative lesson design sessions integrating numeracy with

participants' subject specialties.

A post-test identical in structure to the pre-test measured knowledge gains. The average increase of 43% indicated substantial improvement. Subsequently, teachers received one month of online mentoring involving lesson plan submissions, pilot teaching sessions, and feedback cycles. Mentoring was conducted collaboratively by educators from both countries, using video conferencing and shared digital workspaces.

Classroom observations were conducted to assess actual implementation. Teachers maintained reflective journals documenting challenges, innovations, and perceived impacts. A final feedback session facilitated peer sharing and program evaluation.

RESULTS AND DISCUSSION

The training was designed in response to specific challenges identified among teachers at SMA Negeri 1 Nguter. The community service activity was implemented from January to March 2024 at SMA Negeri 1 Nguter, Central Java, Indonesia. The program was designed to strengthen high school teachers' understanding of numeracy as a cross-disciplinary skill and to introduce cybernetic-based approaches using digital tools in classroom instruction. A total of 36 teachers from various subject areas—including mathematics, science, economics, social studies, and language—participated in the program.

The activity began with a two-day intensive workshop facilitated jointly by education experts from Universitas Veteran Bangun Nusantara (Univet) and the Musa Asyiah Foundation, Cambodia. On the first day, teachers were introduced to the concept of numeracy beyond mathematics and explored how numerical reasoning could be embedded into their own disciplines. The atmosphere was highly interactive with teachers engaged in discussions, group tasks, and hands-on exercises that challenged their assumptions and expanded their pedagogical perspectives.

On the second day, the focus shifted to cybernetic learning, a concept emphasizing feedback, adaptability, and the use of technology for personalized instruction. Teachers were trained to use tools such as spreadsheets, data visualization software, digital assessment rubrics, and interactive simulations. Working in interdisciplinary teams, they designed lesson plans that incorporated numeracy using these tools and shared their ideas with peers for feedback.

Following the workshop, the program entered a one-month mentoring phase, where teachers were supported in implementing their new lesson plans in the classroom. Through online platforms, Indonesian and Cambodian mentors provided feedback, answered questions, and guided reflection. Teachers conducted pilot lessons, many of which integrated student-centered activities using digital tools, for example, analyzing local economic data, interpreting scientific trends, or exploring patterns in literature using graphs.

Throughout the program, teachers were encouraged to document their experiences in reflective journals, which served as a valuable tool for both personal growth and program evaluation. Classroom observations were also conducted to assess the real-time impact of the training on instructional practices.

The program concluded with a final reflection and sharing session, where teachers presented their work, discussed the challenges they encountered, and celebrated their learning journey. The session highlighted not only increased knowledge and confidence but also a growing sense of collaboration and innovation among the teachers.

This community service activity succeeded in creating a professional learning

environment that bridged theory and practice, strengthened international collaboration, and contributed meaningfully to educational development at the local level.

Based on preliminary observations and a diagnostic survey conducted prior to the program, it was evident that most teachers still perceived numeracy as a domain exclusive to mathematics. Many lacked the confidence and practical skills to integrate numerical reasoning into their own subject areas—such as social studies, language, or science, especially in ways that were relevant to students' real-life contexts. Moreover, the use of digital tools in lesson planning and delivery was minimal, limiting opportunities for innovation and dynamic engagement in the classroom.

Recognizing these gaps, the community service team formulated a solution grounded in two core strategies: first, promoting numeracy as a cross-curricular competency that can enrich all subjects; and second, equipping teachers with skills to implement cybernetic learning principles through digital tools. The training aimed to reposition numeracy as a shared pedagogical responsibility while encouraging more reflective, technology-enhanced instruction.

The training program began with a two-day intensive workshop held at SMA Negeri 1 Nguter. On the first morning, the atmosphere was filled with anticipation and curiosity. Teachers from various subject backgrounds: mathematics, science, economics, language, and social studies, gathered in the school hall, which had been transformed into an interactive learning space with projectors, internet access, and digital learning stations.

The facilitators opened the session by inviting teachers to reflect on their own understanding of numeracy and share experiences. This created a warm and open environment that allowed for honest discussions about challenges and misconceptions. Laughter and thoughtful expressions filled the room as teachers engaged in activities that challenged their assumptions, for example, exploring how data analysis applies to historical events or how proportional reasoning is relevant in language teaching.

During the second day, participants received hands-on training with digital tools such as spreadsheets, data visualization software, and online simulations. They worked collaboratively in subject-based groups to design lesson plans that integrated numeracy using a cybernetic approach. The facilitators from Indonesia and Cambodia provided real-time feedback and support, ensuring that each group could turn theory into practice.

Following the workshop, the program continued with one month of online mentoring. Teachers submitted their revised lesson plans and received personalized guidance. Some conducted pilot lessons in their classrooms, which were observed by the mentoring team. These sessions were rich with interaction—students using tablets to analyze survey data, visualized historical trends, or interpreted scientific models using graphs and simulations.

Teachers also maintained reflective journals throughout the implementation, documenting their learning process, classroom experiences, and student reactions. These narratives revealed a growing sense of agency and innovation among the participants.

By the end of the program, a final sharing session was held where teachers presented their best practices and discussed challenges they had overcome (Figure 1). The collaborative spirit, growth in pedagogical awareness, and concrete outputs of the program demonstrated the real impact of the community service effort—rooted not only in knowledge transfer, but in sustained professional transformation.



Figure 1. Follow up about the material

Quantitative data from pre- and post-program assessments indicate a significant improvement in teachers' understanding and application of cross-disciplinary numeracy concepts. Participants' average test scores increased by 43%, with a statistically significant p-value of < 0.01 . This growth reflects not only conceptual mastery but also shifts in pedagogical awareness.

Breaking down the data by subject domain:

- STEM teachers (science, technology, engineering, mathematics) saw an average gain of 47%, suggesting that even with prior exposure to numerical reasoning, the cybernetic approach expanded their instructional strategies.
- Social science teachers achieved an average increase of 39%, highlighting the accessibility of data-driven approaches in civic and historical contexts.
- Language and humanities teachers showed a 36% increase, underscoring the breakthrough in realizing that numeracy can serve analytical and interpretive functions even in literature and language education.

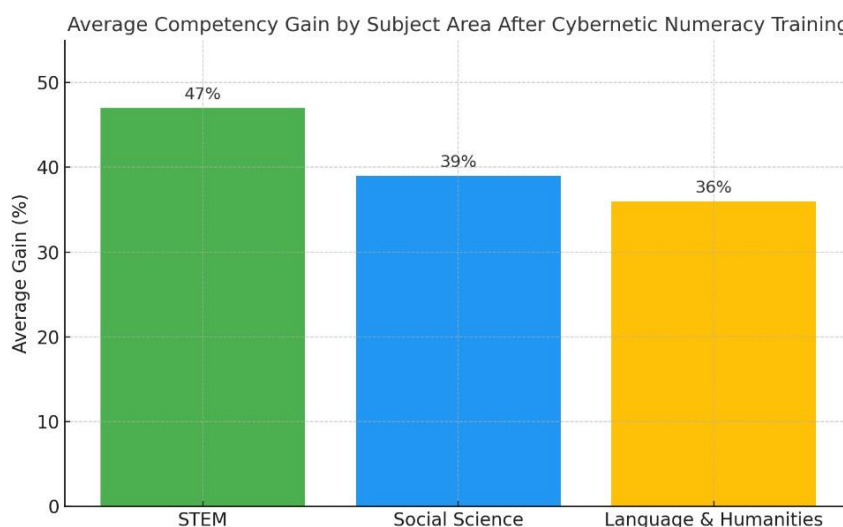


Fig 1. Average Competency Gain

These quantitative outcomes indicate that teachers began to reconceptualize numeracy not merely as computational skill, but as a critical thinking lens applicable across disciplines. Many participants reported that the training reshaped their pedagogical priorities and opened their perspective to integrative lesson design.

1. Integration of Cybernetic Numeracy in Classroom Practices

A total of 36 teachers successfully developed and implemented cybernetic numeracy-integrated lesson plans. Observation checklists and rubrics revealed:

- 78% of teachers implemented their lesson plans within two weeks of post-training.
- 66% incorporated digital tools such as spreadsheets, simulations, and adaptive rubrics.
- 87% transitioned from lecture-based methods to interactive, data-centric approaches.

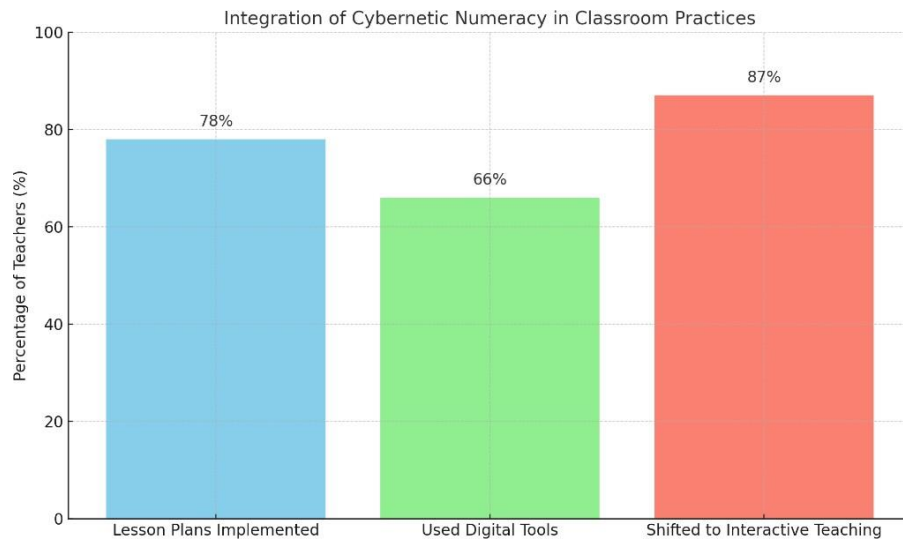


Fig 2. Integration of Cybernetic Numeracy

Concrete examples demonstrate diverse applications:

- In Economics, teachers used dynamic market simulations to explain demand-supply principles.
- In Geography, real census data was employed for population density mapping.
- In Indonesian literature classes, teachers introduced quantitative text analysis—students calculated diction frequency and syllable counts to explore poetic structures.

These changes signaled a broader redefinition of numeracy, extending beyond math into contextualized reasoning, modeling, and evidence-based interpretation. A chart (Figure 2) of tool usage frequency across subjects revealed that STEM subjects led in digital integration, while humanities showed growing engagement through creative adaptation.

2. Teacher Reflections: Cognitive and Affective Shifts in Teaching

Qualitative data from teacher reflection journals and mentoring logs revealed profound cognitive and affective transformations:

- Teachers reported increased self-efficacy in integrating numeracy across subject areas.
- Many noted stronger student engagement, particularly when using real-time visualizations.
- Teachers redefined numeracy as a way of thinking and interpreting the world, not merely calculating.

One language teacher reflected:

“I never imagined that poetry could be analyzed numerically. When students counted syllables, rhythm patterns, and metaphor frequencies, the poem became alive in a completely new way.”

Such testimonies suggest that numeracy, as framed in cybernetic pedagogy, supports multimodal understanding. Interdisciplinary applications also emerged:

- In Civics, teachers used basic statistics to help students analyze voter behavior surveys.
- In English, sentence structure was examined through average sentence length and syntax distribution.
- In Biology, teachers introduced population growth models based on field data.

These transformations not only diversified classroom practices but fostered quantitative literacy across the curriculum, contributing to students’ readiness for data-intensive futures.

3. Barriers and Contextual Challenges: Lessons from the Field

Despite these gains, several challenges surfaced during implementation:

- **Disciplinary Resistance:** Humanities teachers initially struggled to identify authentic numerical contexts. This underscores the need for discipline-specific scaffolding.
- **Infrastructural Limitations:** Some classrooms lacked stable internet or projectors, hampering digital tool deployment.
- **Short Mentorship Period:** A one-month mentoring window was insufficient for iterative experimentation, particularly for digitally novice teachers.
- **Cultural-Linguistic Nuances:** Cross-national collaboration revealed differences in pedagogical assumptions, requiring careful facilitation and contextual adaptation.

Nonetheless, many teachers described these challenges as growth opportunities. Rather than viewing constraints as limitations, they fostered peer collaboration and localized innovation. Teachers formed informal working groups to adapt tools and examples to their specific school contexts. These insights stress the importance of long-term support and cultural alignment when replicating the model in different educational settings.

4. Theoretical Reflections: Rethinking Cybernetic Pedagogy

The project reinforces the relevance of cybernetic theory in education, particularly in advancing numeracy and responsive teaching. Key principles such as feedback loops, self-regulating systems, dynamic adaptation, were evident in both teacher behavior and instructional design.

For example, digital rubrics allow students to receive instant feedback and revise their work independently. Teachers adjusted lesson pacing based on live classroom data, aligning with the cybernetic notion of homeostasis—maintaining balance through ongoing feedback.

These practices suggest that cybernetic numeracy support not only academic outcomes but also 21st-century learning competencies: adaptability, self-regulation, and problem-solving.

At a systems level, the approach offers a model for curriculum reform that bridges disciplinary silos and prepares learners to function in data-rich environments. Teachers become designers of learning systems, not just content deliverers.

5. Professional Learning Communities and Future Implications

This international initiative catalyzed the emergence of cross-border Professional Learning Communities (PLCs). Digital tools such as shared drives, collaborative lesson planning platforms, and bilingual mentoring sessions facilitated sustained engagement beyond the program duration. Key strategies recommended by participants include:

- Establishing a shared digital repository of lesson plans, video demos, and teacher reflections.
- Training local mentors to scale the program in other schools.
- Integrating cybernetic numeracy into pre-service teacher education, ensuring future educators develop interdisciplinary and technological fluency from the outset.

These efforts point toward the potential of cybernetic pedagogy not only as a content innovation but as a systemic change mechanism—building institutional capacity, fostering teacher agency, and bridging local-global educational contexts.

A similar community service initiative was conducted in 2022 by a team from Universitas Negeri Malang, which focused on integrating numeracy into science teaching through inquiry-based learning. That program involved a smaller group of science teachers and emphasized numeracy within a specific subject rather than across disciplines. The intervention consisted mainly of lecture-based workshops and the development of simple teaching aids, with limited use of digital tools or follow-up mentoring.

While the Malang program successfully raised awareness of the importance of numeracy in science instruction, its impact was relatively contained due to the absence of interdisciplinary collaboration and sustained support after the workshop.

In contrast, the community service program conducted by Universitas Veteran Bangun Nusantara in partnership with the Musa Asyiah Foundation demonstrated broader and deeper benefits for the partner school. This project not only introduced numeracy as a cross-curricular competence but also integrated cybernetic learning principles and technology-enhanced instruction. The one-month mentoring phase following the workshop significantly reinforced the teachers' ability to apply what they learned and adapt it to their classroom contexts.

Quantitative data from pre- and post-program assessments showed a 43% average increase in teacher competence, and qualitative reflections revealed greater confidence in integrating numeracy into a wide range of subjects. Teachers also expressed increased enthusiasm for using digital tools and reported improvements in student engagement during pilot lessons.

Based on this comparison, it is evident that this community service program provided meaningful and measurable benefits to the partner school. It not only addressed existing gaps in pedagogical practice but also fostered a culture of innovation, collaboration, and sustained professional growth among teachers.

A comparable community service initiative was documented in an article titled “*Enhancing Numeracy in Science Teaching through Inquiry-Based Approaches: A Teacher Training Program in East Java*” (Rahmawati et al., 2022). This program, conducted by a team from Universitas Negeri Malang, focused on integrating numeracy within science education by equipping teachers with inquiry-based lesson planning strategies. The program involved a short workshop and the distribution of printed teaching modules, primarily targeting science teachers.

While the initiative reported positive outcomes—such as increased awareness of the role of numeracy in science and improved lesson plan design, it was limited in scale and scope. The training did not include interdisciplinary collaboration, the integration of digital tools, or extended mentoring support. As a result, the long-term impact on classroom practice was not deeply examined in the article.

In comparison, the community service program implemented by Universitas Veteran Bangun Nusantara (Univet Bantara) in collaboration with the Musa Asyiah Foundation, Cambodia, demonstrated more comprehensive and sustainable results. This program emphasized numeracy as a cross-curricular skill and employed cybernetic learning approaches, including training in digital tools such as spreadsheets, data visualization software, and interactive simulations. Furthermore, the one-month online mentoring phase ensured that teachers received continuous guidance as they applied new strategies in real classroom settings.

Evidence of the program's effectiveness includes a 43% average increase in teachers' post-test scores, greater confidence in using numeracy across different subjects, and improved student engagement during lesson implementation. Teachers also reported a stronger sense of collaboration and innovation, which has continued beyond the project timeline.

Compared to the initiative reported in *Educate*, this program offered more robust support, a wider pedagogical scope, and clearer evidence of impact—demonstrating that the activity was not only beneficial but also transformative for the partner school.

CONCLUSION AND RECOMMENDATION

This Indonesia–Cambodia collaborative community engagement project successfully empowered high school teachers at SMA Negeri 1 Nguter to integrate numeracy across subjects using cybernetic-based pedagogical approaches. Supported by the Musa Asyiah Foundation, the

initiative shifted teachers' views of numeracy from math-specific to cross-curricular, enhancing their confidence and instructional skills through workshops, mentoring, and classroom implementation.

Post-program assessments showed a 43% improvement in teacher competence, with digital tools and feedback-driven learning fostering more interactive and student-centered classrooms. The bilateral mentoring model promoted a sustainable, cross-cultural professional learning community. Despite challenges such as infrastructure and subject-specific adaptation, the program demonstrated scalable impact and relevance for teacher development policy in both countries. This initiative offers a replicable model for transforming teaching practice through technology, collaboration, and localized innovations, especially in resource-limited contexts.

Based on the success and lessons from the Indonesia–Cambodia collaboration on cybernetic-based numeracy empowerment, the following practical recommendations are proposed included in teacher education programs in both countries should include training on how to teach numeracy across different subjects using digital tools. This will help new and current teachers gain the skills they need. Establish long-term mentoring between Indonesian and Cambodian teachers. Online groups or communities can be created so teachers can continue sharing ideas, lesson plans, and classroom experiences. Develop simple and useful teaching materials that show how numeracy can be used in subjects like language, history, or civics. These resources should be easy to access and tailored to local needs. Ensure schools have the basic technology needed to support cybernetic teaching, such as internet access, projectors, and computers. Without proper tools, digital teaching methods are difficult to apply. The program should be brought to more schools, especially in rural or underserved areas. Training should be adjusted based on each school's context and available resources. Support teachers in writing short reflections about their teaching. This helps them think critically about what works, what doesn't, and how to improve their lessons. Education policymakers should support the integration of numeracy across all subjects. National curricula and assessments should reflect the importance of numeracy and digital teaching methods

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