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Enhancing Mathematical Communication Skills in Linear Algebra Through the Talking Stick Learning Model

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ABSTRACT

Background. Mathematical communication competence is essential for Information Technology Education students, particularly in articulating linear algebra concepts underlying core IT domains such as data structures, algorithms, and programming.

Purpose. This study examines changes in students' mathematical communication skills and learning outcomes following implementation of the Talking Stick method, integrated with Flippity a digital random name picker in a Linear Algebra and Matrix course focusing on solving Linear Systems of Equations using Elementary Row Operations.

Method. This study employed a pre-experimental one-group pretest–posttest design supported by classroom observation, measuring learning outcomes via pretest and posttest instruments. Data were analyzed using a paired-samples t-test and normalized gain (N-gain) analysis, with observational data analyzed descriptively. The study involved 18 undergraduate students in the Linear Algebra and Matrix course, selected through total sampling.

Results. Observations indicate that the Talking Stick model fosters an active classroom atmosphere, peer interaction, and engagement. Statistical testing revealed a significant difference between pretest and posttest scores in mathematical communication ability ($t(17) = -4.826$, $p < .001$), with the mean increasing from 2.5139 to 3.1028 and a large effect size (Cohen's $d = 1.14$), alongside a high N-gain of 0.898 in solving Linear Equation Systems through Elementary Row Operations.

Conclusion. This research concludes that communication-based teaching-learning strengthens mathematical understanding and communication competencies among pre-service IT teachers through active explanation and classroom interaction.

KEYWORDS
Information Technology Education, Instructional Model, Linear Algebra and Matrices, Mathematical Communication, Talking Stick

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INTRODUCTION

Mathematical communication ability is a critical yet frequently underdeveloped competency among undergraduate students in technology-based education programs worldwide. The demand for graduates to articulate mathematical reasoning has intensified in the era of Industry 4.0, where computational thinking and clear communication of algorithmic processes are indispensable professional skills (World Economic Forum, 2023). Studies indicate that approximately 60% of undergraduate students in STEM fields struggle to explain mathematical procedures verbally, even when they can execute them computationally, revealing a significant gap between procedural fluency and communicative competence (OECD, 2023; Tall, 2021). In the Indonesian higher education context, the National Accreditation Board for Higher Education (BAN-PT) has explicitly emphasized communication competency as one of the graduate learning outcomes in information technology education programs, reflecting its strategic importance in preparing future educators (BAN-PT, 2022). This phenomenon underscores the urgent need for innovative pedagogical strategies that simultaneously develop both mathematical understanding and communicative proficiency among pre-service IT teachers.

Linear Algebra serves as a foundational pillar in Information Technology Education programs, yet it remains one of the most conceptually challenging courses for undergraduate students to communicate effectively. Linear Algebra underpins critical IT concepts, including data structures, algorithms, machine learning, computer graphics, and data processing, making mastery of it both an academic requirement and a functional necessity for future IT professionals (Supriyadi et al., 2024; Zaki & Pratama, 2026). So far, existing studies demonstrate that students frequently experience difficulties not merely in solving Linear Equation Systems procedurally, but more critically in articulating the reasoning behind each operational step, particularly when connecting procedural mathematics with geometric interpretation and real-world IT applications (Oktaç, 2018; Woods, 2022). Research further confirms that many students mistakenly equate memorizing definitions and formulas with genuine mathematical understanding, leading to superficial learning that impedes the communicative expression of mathematical thinking (Biber, 2023; Hamid, 2025). These converging findings establish that the absence of deliberate communication-focused pedagogy in Linear Algebra and Matrix courses creates a persistent barrier to the holistic mathematical development of IT education students.

Furthermore, growing recognition of mathematical communication as a core competency, and empirical research specifically targeting communicative skill development in Linear Algebra and Matrix within Information Technology Education programs remains remarkably scarce. Existing studies on mathematical communication predominantly focus on secondary school contexts or general mathematics courses, leaving a substantial research gap at the tertiary level within technology-oriented programs (Planas & Pimm, 2024; Sfard, 2021; Juhansar et al., 2025). Collaborative and participatory learning models, such as the Talking Stick Model, have been shown to enhance verbal participation, mathematical discourse, and self-regulated learning across various educational settings (Istiqomah, 2023; Nanda, 2022; Aswadi et al., 2025). Moreover, peer-based assessment mechanisms embedded within the Talking Stick approach have been shown to promote metacognitive awareness, enabling students to reflect on and monitor their own learning processes through structured peer evaluation (Firdian & Rahmelina, 2025; Bormayanti & Rafianti, 2024; Halimatussa'diyah et al., 2018). Nevertheless, the application of the Talking Stick Model specifically within Linear Algebra instruction for pre-service IT teachers has not been systematically explored, representing a significant gap that this study aims to address.

This study examines the use of the Talking Stick learning model to enhance mathematical communication skills and learning-teaching outcomes among Information Technology Education students in the Linear Algebra and Matrix course, particularly on the topic of Linear Equation Systems through Elementary Row Operations (EROs). The Talking Stick Model is hypothesized to create active classroom dynamics that encourage voluntary verbal participation, promote student interaction, and cultivate positive emotional engagement with mathematical content. The study employs a one-group pretest–posttest design, with data collected through observational instruments, mathematical communication self-assessment sheets, and learning-teaching achievement tests, and analyzed using paired-samples t-tests and normalized gain analysis. These methodological choices enable a rigorous examination of both the magnitude and quality of learning-teaching improvements attributable to the intervention. Thus, this research seeks to provide empirical evidence that communication-based learning-teaching supports mathematical comprehension and strengthens the pedagogical communication competencies essential for future IT educators in the digital age. Indeed, most recent research on the Talking Stick model has focused on school students and outcomes such as mathematical communication and academic achievement. There has been little exploration of how this model works with university students in Information Technology Education, especially in Linear Algebra and Matrix learning. The idea of using a digital random name picker to help with turn-taking in the Talking Stick model has also not been widely studied. In this study, we used Flippity with the Talking Stick model to give Information Technology Education students random chances to explain mathematical procedures and share their mathematical thinking. By combining an active-learning approach with a simple digital tool, this study supports mathematics learning among pre-service IT teachers.

In this study, the Talking Stick learning-teaching model is positioned as a transformative pedagogical intervention that bridges the gap between mathematical procedural competence and communicative expression among pre-service IT teachers. Pre-service IT teachers who are trained to articulate mathematical ideas verbally and symbolically are better equipped to foster conceptual understanding in their future students, aligning with the communicative demands of 21st-century education (NCTM, 2015; Planas & Pimm, 2024). The structured turn-taking mechanism of the Talking Stick model compels students to maintain continuous readiness, actively process course material, and formulate coherent verbal explanations under authentic classroom conditions (Istiqomah, 2023; Firdian & Rahmelina, 2025). Evidence from adjacent fields suggests that participatory verbal learning models significantly reduce mathematics anxiety, increase self-efficacy in mathematical communication, and improve overall academic achievement in abstract mathematics courses (Aswadi et al., 2025; Biber, 2023). Therefore, this study argues that integrating the Talking Stick model into Linear Algebra instruction for Information Technology Education students constitutes a contextually relevant, empirically grounded, and pedagogically sound approach to cultivating the communicative mathematical competencies demanded by contemporary digital education environments.

RESEARCH METHODOLOGY

This study employs a pre-experimental one-group pretest–posttest research design using a quantitative approach, supported by classroom observation. Quantitative data were collected through pretest and posttest instruments to measure students' learning outcomes. Classroom observations were conducted during the implementation of the instructional intervention to document the learning process and provide supporting evidence. Quantitative data were analyzed using a paired-samples t-test and normalized gain (N-gain) analysis to examine differences and improvements between pretest and posttest scores, while observational data were analyzed descriptively. The participants were 18 Information Technology Education students enrolled in the Linear Algebra and Matrix course during the 2025/2026 academic year. All students in the class took part in the study, as only one class was available that year. The study aims to examine changes in their mathematical communication skills and learning outcomes related to Linear Equation Systems. Since there was no control group, it is not possible to say with certainty that the observed changes were solely due to the intervention, as other factors may have played a role. Figure 1 shows the research procedure, starting with preparation and ending with data analysis.

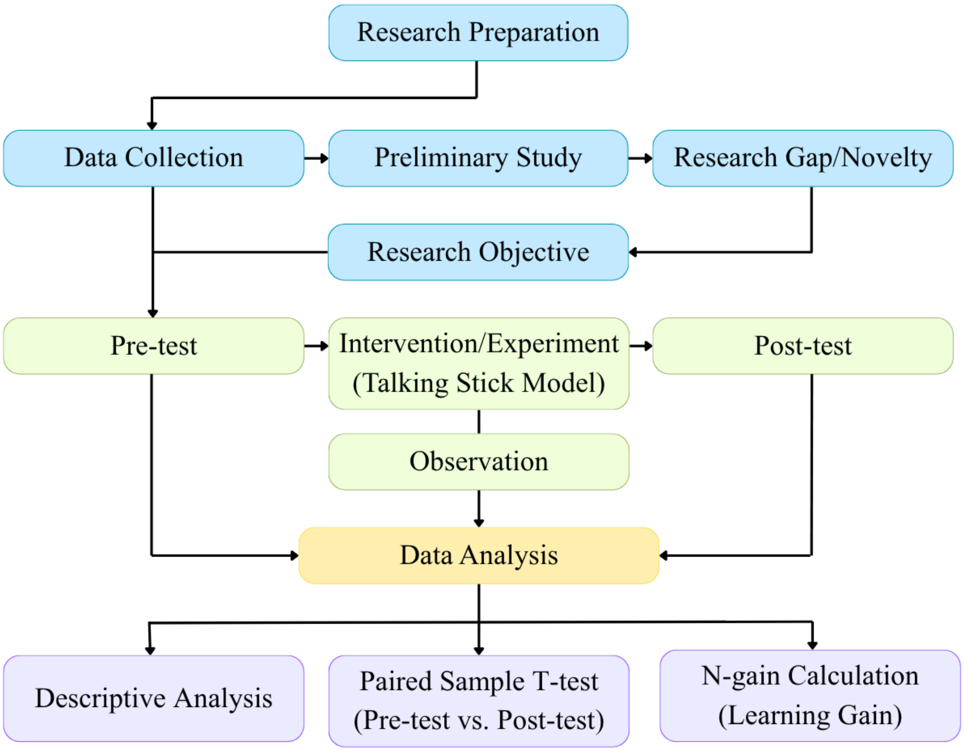

Figure 1. Research Procedures

Figure 1 shows the workflow used in this study. The process began with research preparation, proceeded through data collection and a preliminary study, and concluded with the identification of the research gap and novelty. These steps helped shape the research objective. In the preparation phase, the team created all needed instructional and assessment materials. These included content on Linear Equation Systems focused on the Elementary Row Operations (EROs) method, an observation sheet for monitoring Talking Stick implementation, a rubric for mathematical communication skills, and essay-based test instruments to measure learning and teaching outcomes (Inganah et al., 2023; Rohid et al., 2019; Lloyd & Murphy, 2023; Hendriana, 2020). The instruments matched the Course Learning Outcomes (CLOs) and were reviewed by experts for relevance and clarity. The team revised the materials based on expert feedback before starting the intervention. The reliability test showed strong internal consistency for the 12-item mathematical communication self-assessment, with Cronbach's alpha values of 0.885 for both the pretest and posttest.

Following the preparation phase, the experimental procedure was carried out in three sequential stages, viz. pretest, intervention, and posttest, as depicted in Figure 1. All 18 respondents completed a pretest designed to assess their baseline mathematical communication ability (NCTP, 2015) and initial understanding of Linear Equation Systems using Elementary Row Operations (EROs). Furthermore, the Talking Stick Model was implemented as the instructional intervention across several class meetings, in which students took turns holding the talking stick, selected using the Flippity Random Name Picker application, and were required to verbally explain each step of the LES solution process using EROs. Throughout the intervention, peer-to-peer interaction was actively facilitated to reinforce conceptual understanding, while the researcher systematically documented classroom dynamics, student participation, and interactional patterns using a structured observation sheet (Goos, 2002; Lestari et al., 2022; Firdian & Rahmelina, 2025).

The intervention comprised three instructional sessions, each lasting 100 minutes. Before the intervention, students participated in a 100-minute introductory session during which the lecturer explained the concepts of Linear Equation Systems and Elementary Row Operations, demonstrated calculation procedures, and provided conventional practice exercises. During each Talking Stick session, students solved new problems involving Linear Equation Systems and Elementary Row Operations. Flippity, a digital random-name picker, was used exclusively to determine the turn order. The selected student received the stick, solved the problem at the board, and explained the calculation steps orally. Depending on the number of reduction steps required, the student could continue explaining the solution or pass the turn to another student for the subsequent step. Peers were encouraged to respond, ask questions, and provide supportive feedback throughout the activity. Classroom observations were conducted during the Talking Stick sessions to document student participation, interaction, enthusiasm, and classroom dynamics. After the intervention sessions, all participants completed a posttest to assess their mathematical communication skills and learning outcomes.

Data analysis employed three complementary analytical procedures, as illustrated in the final tier of Figure 1. *First*, descriptive statistics summarized students' pretest and posttest scores using the mean and standard deviation, offering an overview of performance before and after the intervention. *Second*, a paired sample t-test was conducted in SPSS at a significance level of $\alpha = 0.05$ to assess whether a statistically significant difference existed between pretest and posttest scores. A Sig. (2-tailed) value below 0.05 was interpreted as evidence that the Talking Stick model significantly influenced students' mathematical communication ability (Muzawi et al., 2024; Setyaedhi et al., 2025). *Third*, N-gain was calculated for each participant as (posttest score-pretest score) / (maximum score-pretest score), and the mean N-gain was computed across all respondents to quantify learning gains. Scores below 0.3 indicate low gain, scores between 0.3 and 0.7 indicate moderate gain, and scores above 0.7 indicate high gain (Hajar et al., 2026; Juhansar et al., 2023). Cohen's d was also calculated to determine the effect size of the observed change. Collectively, these analytical approaches provided a comprehensive assessment of the Talking Stick model's utilization in enhancing mathematical communication competency among Information Technology Education students.

RESULTS AND DISCUSSION

Classroom Dynamics in Talking Stick-Based EROs Learning-Teaching

The application of the Talking Stick model in a Linear Equations System course delivered through Elementary Row Operations (EROs) generated a classroom atmosphere that was markedly dynamic and enthusiastic. Observational records indicate that the stick-passing rotation unfolded in a structured and rule-consistent manner, with students awaiting their turns with visible eagerness. Each transfer of the stick was met with audible encouragement from the rest of the class, and it was not uncommon to see students displaying a blend of nervous anticipation and genuine excitement as they recognized their turn approaching. Far from disrupting the instructional flow, this rotation mechanism cultivated a productively competitive climate in which students were individually motivated to perform their best when demonstrating EROs procedures at the board. These observations are consistent with Santoso's (2023) finding that the degree of student involvement directly shapes the quality of the educational experience.

Most students who participated in the Talking Stick activity demonstrated a solid ability to articulate the computational process orally. They explained each row operation performed, although some exhibited brief hesitation or required guidance from the instructor and reassurance from peers. This pattern indicates that the Talking Stick activity serves a dual instructional role: it reinforces mathematical conceptual understanding. It fosters academic communication skills and self-confidence, both of which are essential for prospective teachers in the Information Technology

Education program. This outcome is consistent with the social constructivist framework proposed by Azis et al. (2025), which asserts that learning is more effective when situated within meaningful social interactions with peers or instructors, rather than in isolation. Supporting this theoretical perspective, Hartina (2020) and Riskawati (2025) found that the Talking Stick model produces measurable improvements in students' oral communication skills. By providing each student with a structured opportunity to speak, the activity encourages active participation in class discussions. It facilitates purposeful, substantive communication among participants, thereby fostering the development of verbal academic skills.

Peer-to-peer interaction emerged as another distinctly prominent feature of the classroom dynamic observed during the Talking Stick sessions. Rather than assuming the role of passive listeners, students actively responded to one another's explanations, offered additions or corrections, and occasionally introduced light humor to ease the tension, a quality of spontaneous exchange that is rarely fostered by conventional instructional formats. When a classmate made a minor computational error, peers were quick to step in with constructive feedback or to redirect the solution process in a notably supportive, rather than critical, manner, reflecting a classroom culture in which mistakes were treated as shared learning opportunities rather than individual shortcomings. This pattern of communication is indicative of a well-functioning learning community, one in which students collaborate to build understanding of EROs' concepts without the inhibition of fear of being wrong. These findings are consistent with Rienovita et al. (2018), who found that interactive peer learning actively encourages students to teach concepts to classmates who need assistance, a reciprocal process that, in turn, strengthens individual motivation, self-esteem, and academic self-efficacy across the group. The mutual teaching dynamic documented here not only deepened each student's grasp of the material but also sustained a level of active, meaningful interaction that contributed to the formation of an inclusive and psychologically safe learning environment, one in which all students, regardless of their initial proficiency, felt both supported and genuinely engaged in the learning process.

In terms of participation and enthusiasm, nearly all students displayed consistently positive affect throughout the sessions. They approached the activity with visible energy, and while some laughed quietly when nerves surfaced, each made a genuine effort to perform at their best in front of the class. This behavioural pattern speaks to both personal investment and a sense of shared responsibility toward the group. The activity demonstrably fostered self-confidence, a willingness to speak in public settings, and a deeper intrinsic motivation to engage with the course material, driven in part by students' awareness that they would be called upon to participate actively in subsequent sessions (Nurlaela et al., 2024; Waqia et al., 2023; Saputro et al., 2022). The overall classroom atmosphere was simultaneously active, enjoyable, and intellectually conducive, qualities that rarely coexist in undergraduate mathematics instruction without deliberate pedagogical design. The Talking Stick activity generated a positive collective energy in the room, as students visibly encouraged one another and seemed to find genuine satisfaction in the learning process itself rather than merely in its outcomes. Ultimately, the integration of physical movement, verbal communication, and cooperative problem-solving into a single structured activity transformed linear algebra, a subject that students often approach with apprehension, into an experience that felt both intellectually alive and personally meaningful.

The Effect of the Talking Stick Model on Students' Mathematical Communication Skills

A paired sample t-test was conducted to determine whether a statistically meaningful difference existed in students' mathematical communication ability before and after the instructional intervention. SPSS output indicates that the pretest mean was 2.5139, with a standard deviation of 0.46328. In contrast, the posttest mean rose to 3.1028 with a standard deviation of 0.32790, reflecting not only an upward movement in average performance but also a narrowing of score dispersion, suggesting that students became more consistently capable following the treatment. These descriptive statistics indicate that students' mathematical communication scores increased following the Talking Stick intervention.

Table 1. Descriptive Statistics of Students' Mathematical Communication Scores

		Mean	Std. Deviation
Pair 1	Pre	2.5139	0.46328
	Post	3.1028	0.32790

The paired-samples correlation analysis yields a correlation coefficient of 0.178 between pretest and posttest scores, with an associated significance value of 0.480, indicating a weak, statistically nonsignificant relationship between the two measurement points. This finding, however, should not be interpreted as evidence against the intervention's utilization, as the magnitude of the correlation reflects the degree of linear correspondence between paired scores rather than the presence or direction of mean-level change. Accordingly, the inferential focus of the analysis appropriately shifts to the paired-samples t-test results, which provide the proper statistical basis for determining whether a significant difference between pretest and posttest means was observed.

Table 2. Correlation between pretest and posttest Mathematical Communication Scores

		Correlation	**Sig**
Pair 1	Pre & Post	0.178	0. 480

The paired-samples t-test table shows a mean difference of −0.58889 between pretest and posttest scores, with a standard deviation of 0.51772, indicating a consistent, directionally uniform shift in performance across respondents. The computed t-value of −4.826 with 17 degrees of freedom yields a two-tailed significance value of 0.001, which falls well below the predetermined alpha threshold of 0.05. Based on these results, the null hypothesis of no difference between pretest and posttest means is rejected, and it is concluded that the instructional intervention produced a statistically significant improvement in students' mathematical communication ability.

Table 3. Paired-Samples t-Test Results for Mathematical Communication Scores

		Paired Differences				
		Mean	Std. Deviation	t	df	Sig. (2-tailed)
Pair 1	Pre & Post	-0.58889	0.51772	-4.826	17	0.000

The paired-sample t-test results confirm a statistically significant difference in students' mathematical communication ability between the pretest and posttest, providing quantitative support for the use of the Talking Stick model as an instructional intervention. The upward shift in mean scores from pretest to posttest suggests that a learning environment structured around active communication, one in which students are consistently required to verbalize their reasoning, explain procedural steps, and engage in purposeful academic dialogue, meaningfully strengthens their capacity to express mathematical ideas both verbally and symbolically. This finding reinforces the well-established position that mathematical communication does not develop optimally through passive instructional arrangements; rather, it requires learning conditions that deliberately place students in situations where speaking, explaining, and direct interaction are not peripheral activities but central to the learning process itself.

Theoretically, these findings are consistent with studies indicating that mathematical communication is an indispensable component of useful mathematics instruction, one that cannot be meaningfully separated from classroom interaction and disciplinary discourse (Astuti & Leonard, 2012; Khadka, 2024; Vale & Barbosa, 2023). Student success in mathematics is not determined solely by the depth of intellectual engagement with content; it is equally shaped by the opportunities students have to externalize their thinking, respond critically to others' ideas, and participate as active contributors to the mathematical conversations that unfold among instructor and peers. In the context of the present study, the turn-taking mechanism inherent in the Talking Stick model provided precisely this kind of structured opportunity, establishing a clear and predictable format in which every student was afforded an equitable opportunity to articulate mathematical reasoning. This arrangement promoted broader and more evenly distributed verbal participation across the classroom than is typically observed in conventional instructional settings.

The observed improvement in mathematical communication ability can also be explained through the lens of social constructivism, a theoretical framework that situates the development of conceptual understanding within social interaction and meaningful dialogue rather than in individual cognitive effort alone. The present findings lend tangible support to this perspective, where students do not rely exclusively on instructor explanations as their primary source of learning but derive considerable understanding from peers' articulations, collaborative error correction, and spontaneous discussions that arose organically during the Talking Stick activity. This dynamic reinforces the argument that peer-to-peer interaction plays a constitutive, rather than merely supplementary, role in the construction of deep mathematical understanding, a position that has been consistently advanced across a growing body of research situated at the intersection of constructivist theory and mathematical communication (Gultom, 2024; Hayati & Husnidar, 2022; Tanjung et al., 2023).

These findings corroborate prior research demonstrating that communication-based instructional models produce measurable gains in mathematical communication ability (Ramadhani et al., 2021; Siregar et al., 2020). The rise in posttest scores indicates that students became increasingly comfortable explaining computational steps, articulating mathematical reasoning, and responding to peers' questions. These capacities were evidently limited at the outset but strengthened over the course of the intervention. The Talking Stick model thus functioned as an effective transitional mechanism, shifting students from tentative, procedurally constrained communication toward a more structured and confident mode of mathematical expression. Overall, this study provides empirical support for the Talking Stick model as a viable instructional strategy for enhancing mathematical communication in undergraduate Linear Algebra, while also extending the conversation beyond school-age learners to underscore its relevance for pre-service teachers who must ultimately communicate mathematical concepts with clarity and precision in their own future classrooms.

The Utilization of the Talking Stick Model on Communication and Learning Outcomes

To examine the instructional method's effect on students' ability to solve Linear Equation Systems using Elementary Row Operations (EROs), pretest and posttest assessments are administered to 18 respondents. The scores from both assessments were then used to calculate the normalized gain (N-gain) for each respondent, and the mean N-gain across all participants is as follows:

$$\text{Mean N-gain} = \frac{\sum N\text{-gain}}{n} = \frac{16.17}{18} \approx 0.898$$

The N-gain analysis shows a great mean improvement in students' ability to solve Linear Equation Systems using EROs, with a value of 0.898. It indicates that most of the gap between students' initial ability and the targeted learning outcomes was closed after the Talking Stick model was implemented, showing both statistical significance and educational meaningfulness. At the individual level, most respondents obtained N-gain scores close to 1.00, suggesting that nearly all targeted competencies were achieved by the end of the intervention.

To further examine the magnitude of the observed change, Cohen's d was calculated using the mean difference and standard deviation of the differences obtained from the paired-samples test:

$$\text{Cohen's d} = \frac{Mean\ Difference}{SD\ Difference} = \frac{-0.58889}{0.51772} \approx -1.137$$

The large effect size (Cohen's d = 1.14) suggests that the observed improvement was not only statistically significant but also substantial. This finding indicates that the learning activities provided students with meaningful opportunities to practice explaining mathematical procedures and communicating their reasoning. The result is consistent with the characteristics of the Talking Stick model, which requires students to participate actively and respond when selected. This pattern also suggests that the Talking Stick method accommodated differences in students' initial proficiency, as its structured turn-taking gave each participant an equal opportunity to engage with the material, ask questions, and explain their reasoning throughout the learning process.

The high N-gain value is attributable to the defining characteristics of the Talking Stick method, which demands active student involvement at every stage of the learning process rather than passive reception of instructor-delivered content. Students are not simply asked to solve SLE problems procedurally; they are also required to verbally explain each ERO's step in front of their peers, a demand that compelled them to revisit, reorganise, and consolidate the concepts under study internally, thereby reinforcing both conceptual understanding and procedural fluency in tandem. This dual reinforcement mechanism aligns with a broader body of active learning research affirming that direct engagement in explaining and discussing mathematical solutions consistently yields higher learning outcomes than conventional instructional approaches (Kimbrough et al., 2022). Indeed, the improvement in students' mathematical communication can be attributed to the active verbal participation required during Talking Stick activities. In contrast to conventional problem-solving tasks, where students often complete mathematical procedures without articulating their reasoning, the Talking Stick model required selected students to explain the steps of Elementary Row Operations orally. This approach prompted students to organize their mathematical thinking before expression, justify each operation, and address questions or feedback from peers.

In short, the Talking Stick sessions reveal that students' understanding comes as much from instructor explanations as from peer articulations and collaborative error correction. This form of interaction creates conditions for concept clarification, mistake remediation, and comprehension reinforcement through language that is closer to students' own ways of thinking, a quality of exchange that formal instruction alone rarely replicates. These findings align with prior research affirming that communication-centered mathematics instruction enhances learning utilization, particularly in abstract, procedurally demanding content areas, such as Elementary Row Operations (Wardi et al., 2023; Yuwono & Rita, 2025). This study, therefore, provides empirical evidence that the Talking Stick method strengthens mathematical communication ability and yields substantive gains in students' capacity to solve Linear Equation Systems through EROs, a finding that enriches the existing active learning literature by demonstrating that deliberate communicative reinforcement has direct implications for improved mathematical learning outcomes.

The findings indicate that the Talking Stick model offers pre-service IT teachers valuable opportunities to practice explaining mathematical procedures, responding to peers, and communicating ideas to a class. The integration of Flippity demonstrates that a simple digital tool can facilitate active participation and structured turn-taking during learning activities. These experiences are particularly relevant for pre-service IT teachers, who require not only technical and mathematical expertise but also strong communication and instructional skills for their future professional roles. However, this study has several limitations. The sample consisted of only 18 students from a single Information Technology Education class, which limits the generalizability of the results to broader student populations and higher-education contexts. Furthermore, the one-group pretest–posttest design lacked a control group, making it difficult to attribute observed changes exclusively to the Talking Stick intervention. Additional factors may have influenced students' performance. Future research should include larger, more diverse samples and incorporate a comparison or control group to strengthen the evidence base.

CONCLUSION

This study concludes that the Talking Stick instructional method improved Information Technology Education students' ability to solve Linear Equation Systems using Elementary Row Operations, thereby directly fulfilling the study's objective of evaluating an instructional approach grounded in active participation and peer mathematical interaction. The integration of Flippity, a digital random name picker, provided a simple technology-enhanced mechanism for randomized turn-taking during the Talking Stick activities. Students in this program have historically encountered considerable difficulty with linear algebra. This subject serves as the conceptual foundation for critical IT domains, including optimization, computer graphics, data processing, machine learning, and database management. The findings demonstrate that the Talking Stick method provided opportunities to develop both students' understanding of the material and their mathematical communication competence. The paired sample t-test confirmed a statistically significant difference between pretest and posttest scores. The N-gain analysis indeed indicates a high degree of overall learning-teaching improvement. The effect size was large, with a Cohen's d value of 1.14, indicating a substantial difference between the pretest and posttest scores.

This study affirms that interactive instructional methods such as the Talking Stick model can provide opportunities for students to develop both a theoretical understanding of linear algebra and the mathematical communication skills necessary for future learning-teaching. These findings open productive avenues for further research, including comparative studies evaluating the Talking Stick method against alternative instructional strategies, as well as investigations into its broader impact on mathematical creativity, problem-solving ability, and the application of algebraic reasoning within information technology contexts. However, the findings should be interpreted with caution due to the small sample and one-group pretest–posttest design without a control group. Future studies should use larger, more diverse samples, control or quasi-experimental designs, and technology-enhanced mathematics learning environments. Collectively, this study contributes to the development of pedagogically sound, curriculum-relevant instructional strategies for the Information Technology Education program and supports the formation of mathematically competent and professionally prepared future educators.

DECLARATION OF AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors used Grammarly to ensure grammatical accuracy, enhance clarity, and strengthen the manuscript's overall professionalism, thereby increasing its likelihood of acceptance by peer reviewers and editors. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Methodology; Project administration; Formal analysis; Writing – original draft; Writing review and editing.

Author 2: Data curation; Investigation; Formal analysis.

Author 3: Data curation; Investigation; Resources.

Author 4: Validation; Supervision.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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