Polyhedron International Journal in Mathematics Education
Publication details, including instructions for authors and subscription information:
https://nakiscience.com/index.php/pijme

PIJME
Polyhedron International Journal in Mathematics Education
Editor-in-Chief
Dr. Sudirman

Bridging abstract to concrete: The SPLDV board as an innovative tool for teaching systems of linear equations

Chatra Arlinta Maurilla[a], Puguh Darmawan[b]*
[a]Department of Mathematics Education, Universitas Negeri Malang, Malang, Indonesia, chatra.arlinta.2203116@students.um.ac.id
[b*]Department of Mathematics, Universitas Negeri Malang, Malang, Indonesia, puguh.darmawan.fmipa@um.ac.id

To cite this article:
Maurilla, C.A & Darmawan, P. (2025). Bridging abstract to concrete: The SPLDV board as an innovative tool for teaching systems of linear equations. *Polyhedron International Journal in Mathematics Education*,*3*(2), 60-71
To link to this article:
https://nakiscience.com/index.php/pijme
Published by:
Nasir Al-Kutub Indonesia
Residential Street Kila Rengganis, Block I, Number 11, Labuapi, Indonesia, 83361

Polyhedron International Journal in Mathematics Education
Volume 3, Issue 2, pp. 60-71, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme

Original Article

Bridging abstract to concrete: The SPLDV board as an innovative tool for teaching systems of linear equations

Chatra Arlinta Maurilla[a], Puguh Darmawan[b*]
[a]Department of Mathematics Education, Universitas Negeri Malang, Malang, Indonesia, chatra.arlinta.2203116@students.um.ac.id
[b*]Department of Mathematics, Universitas Negeri Malang, Malang, Indonesia, puguh.darmawan.fmipa@um.ac.id

*Corresponding Author: puguh.darmawan.fmipa@um.ac.id

Abstract
This qualitative case study examines the effectiveness of the SPLDV Board, a color-coded manipulative tool, in teaching systems of linear equations with two variables to 37 mathematics education students. Through inquiry-based instruction and systematic questioning, the study analyzed students' conceptual understanding, procedural fluency, and engagement patterns. Results demonstrated that the SPLDV Board's visual scaffolding significantly improved students' ability to identify coefficients, execute cross-multiplication procedures, and understand underlying mathematical structures, with all participants achieving fluent responses to guiding questions. However, limitations emerged: the tool only works for systems with unique solutions and some students remained passive during instruction. Findings provide practical guidance for developing accessible manipulative materials that support both procedural and conceptual learning in algebra, with design principles transferable to other mathematical topics requiring multi-step problem-solving.

Article History
Received:
13 August 2025
Revised:
28 September 2025
Accepted:
29 October 2025
Published Online:
30 November 2025

Keywords:
Algebraic problem-solving; Linear equations; Manipulative tools; Mathematics pedagogy; Visual learning aids

1. Introduction

Mathematics education in the 21st century faces persistent challenges in ensuring students develop both procedural fluency and conceptual understanding across fundamental algebraic topics (Yumiai et al., 2024). Among these critical topics, systems of linear equations with two variables (SPLDV - Sistem Persamaan Linear Dua Variabel) constitutes essential foundational knowledge that students must master at the junior secondary level, as mandated by Indonesia's Merdeka Curriculum framework (Ministry of Education, Culture, Research, and Technology, 2022). SPLDV serves as a gateway concept connecting arithmetic reasoning to abstract algebraic thinking, requiring students to integrate multiple competencies including pattern recognition, symbolic manipulation, structural understanding of number systems, and mathematical modeling (Habibah et al., 2020; Monike e al., 2025; Nihayah, 2021; Nandang et al., 2021; Sudirman et al., 2023). However, empirical evidence consistently reveals that students encounter substantial difficulties in mastering SPLDV, with error patterns persisting across diverse educational contexts. These difficulties manifest across multiple dimensions: conceptual misunderstandings of the problem structure, inadequate planning of solution strategies, procedural errors during implementation, and failures in constructing appropriate mathematical models or verifying solutions (Ferdianto & Yesino, 2019). The complexity is further compounded by the availability of multiple solution methods—graphical, substitution, elimination, and combined approaches—which, while offering flexibility, paradoxically creates confusion and increases the likelihood of computational errors (Riyadi, 2006). Given SPLDV's foundational role in developing algebraic reasoning and its prerequisite status for advanced mathematics topics, addressing these learning difficulties represents a critical priority for mathematics education research and practice.

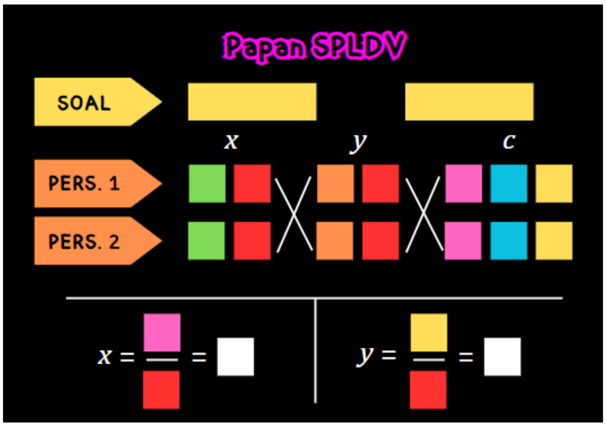
The pedagogical challenges surrounding SPLDV instruction are exacerbated by traditional teacher-centered approaches that emphasize algorithmic procedures over conceptual understanding, resulting in mechanical learning without meaningful comprehension. Research indicates that conventional lecture-based instruction, which remains prevalent in many Indonesian classrooms, frequently fails to support students in developing robust mental models of linear systems or understanding the structural relationships between algebraic and graphical representations (Agustini & Pujiastuti, 2020; Sudirman et al., 2021). Students taught through traditional methods often demonstrate specific weaknesses in algebraic operations required for elimination and substitution methods, struggle with fundamental addition and subtraction operations within algebraic contexts, and lack strategic flexibility in selecting and applying appropriate solution methods for different problem types (Pradini et al., 2020). Furthermore, the abstract nature of algebraic symbolism, combined with limited opportunities for concrete manipulation and visualization, creates cognitive barriers that particularly affect students with less developed spatial reasoning or symbolic manipulation skills (Rismawati et al., 2017). These instructional limitations highlight the urgent need for innovative pedagogical approaches that provide concrete, manipulative experiences to bridge the gap between arithmetic intuition and formal algebraic reasoning, while simultaneously addressing the multiple dimensions of difficulty students encounter in SPLDV learning.

Recognizing these challenges, educational researchers and practitioners have explored various instructional interventions designed to enhance SPLDV learning outcomes. Several studies have investigated technology-enhanced learning environments, including dynamic geometry software and computer algebra systems, demonstrating moderate success in improving students' graphical understanding of linear systems (Simanullang & Exaudi, 2020). Other research has examined cooperative learning strategies, finding that structured peer collaboration can support students in articulating their reasoning and identifying conceptual errors through social negotiation of mathematical meaning (Johnson & Johnson, 2019). Additionally, contextualized problem-based learning approaches have shown promise in helping students develop more robust connections between abstract symbolic representations and real-world applications (Lesh & Doerr, 2003). However, a critical analysis of existing research reveals that most interventions focus primarily on improving procedural proficiency or problem-solving accuracy, with limited attention to developing students' conceptual understanding of why particular methods work or how different solution approaches relate to each other structurally. Moreover, existing studies predominantly employ digital technologies that may not be accessible in resource-constrained settings or fail to provide the tactile, concrete experiences that support concept formation for students with diverse learning preferences (Moyer-Packenham & Bolyard, 2016). These limitations suggest the need for low-cost, concrete manipulative tools that can provide structured scaffolding for both procedural execution and conceptual understanding while remaining accessible across diverse educational contexts.

Despite considerable research attention to SPLDV instruction, significant gaps remain in understanding how concrete manipulative materials can be designed and implemented to address the specific cognitive challenges students face in mastering linear systems. While manipulatives have demonstrated effectiveness in supporting learning across various mathematical domains—particularly in early arithmetic and geometric reasoning—their application to algebraic topics like SPLDV remains underdeveloped (Carbonneau et al., 2013). The limited existing research on algebraic manipulatives tends to focus on elementary topics such as integer operations or simple equation solving, with minimal investigation of how physical tools might scaffold the more complex reasoning required for systems of equations (Vlassis, 2008). Furthermore, most studies examining manipulative use in algebra adopt quantitative experimental designs that measure learning outcomes but provide insufficient detail about implementation processes, student interactions with materials, or the specific ways manipulatives support conceptual development. This methodological limitation restricts teachers' ability to implement research findings effectively in their own classrooms. Additionally, existing research has not adequately examined how color-coding and spatial organization in manipulative design might leverage cognitive principles of working memory, attention, and visual processing to reduce cognitive load and minimize procedural errors during multi-step solution processes. The absence of detailed qualitative investigations into students' experiences using algebraic manipulatives, including their reasoning patterns, common misconceptions that emerge, and strategies for overcoming difficulties, represents a critical knowledge gap that this study aims to address.

To address these research gaps, this study proposes and investigates the implementation of a novel concrete manipulative tool—the SPLDV Board—specifically designed to scaffold students' conceptual understanding and procedural execution in solving systems of linear equations with two variables. The SPLDV Board employs a color-coded matrix structure that provides designated spaces for coefficients, constants, cross-multiplication products, and solutions, systematically guiding students through the elimination-substitution solution process while maintaining explicit connections to the underlying mathematical structure. This design draws on established principles from cognitive load theory, which emphasizes the importance of external representations that reduce working memory demands during complex problem-solving (Runisah et al., 2021; Sweller et al., 2011), and from research on color psychology in educational materials, which demonstrates that strategic use of color can enhance attention, organization, and emotional engagement with learning tasks (Dzulkifli & Mustafar, 2013). Unlike digital interventions or purely symbolic approaches, the SPLDV Board provides a concrete, kinesthetic learning experience that allows students to physically manipulate numerical values while maintaining clear visual organization of the solution procedure. This approach aims to support students in developing both procedural fluency and conceptual understanding by making the structural relationships within linear systems more transparent and memorable. Moreover, the SPLDV Board's low-cost, low-technology design makes it potentially scalable across diverse educational settings, including resource-constrained environments where access to digital technologies remains limited (See Figure 1).

Figure 1
Illustration of the SPLDV Board

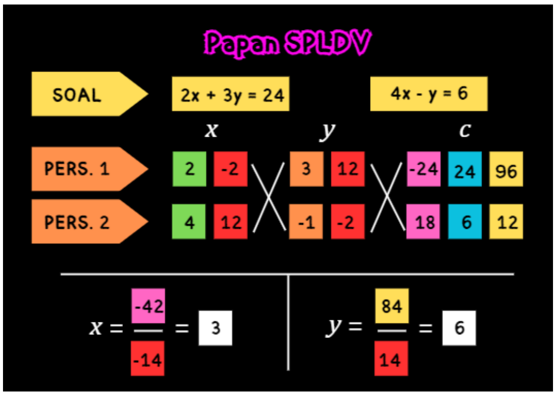


The primary purpose of this qualitative case study research is to examine the implementation of the SPLDV Board manipulative tool in actual instructional contexts and to analyze students' understanding levels, reasoning patterns, and learning processes when using this tool to solve systems of linear equations. Specifically, this study aims to: (1) document students' cognitive processes and reasoning strategies when using the SPLDV Board to solve SPLDV problems, (2) identify patterns of conceptual understanding and persistent misconceptions that emerge during SPLDV Board implementation, (3) analyze the effectiveness of the tool's color-coding and spatial organization in supporting accurate problem-solving and reducing common errors, (4) examine students' affective responses, including engagement, confidence, and attitudes toward SPLDV learning when using manipulative-based instruction, and (5) identify limitations of the SPLDV Board approach and conditions under which it may be more or less effective as an instructional tool. By employing a qualitative case study methodology with university students as participants, this research provides rich, detailed insights into the learning processes facilitated by the SPLDV Board that can inform both theoretical understanding of algebraic learning and practical implementation by mathematics teachers. The findings contribute to growing evidence regarding effective uses of manipulative materials in secondary mathematics education and offer concrete, actionable guidance for practitioners seeking to improve SPLDV instruction in their classrooms (See Figure 2).

Polyhedron International Journal in Mathematics Education
Volume 3, Issue 2, pp. 60-71, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme

Original Article

Figure 2
Illustration of the use of the SPLDV Board



2. Methods

2.1 Research Design and Approach

This study employed a qualitative research approach with a case study design. According to Kusumastuti and Khoiron (2019), qualitative approach is one of the approaches related to subjective values of attitudes, opinions, and behaviors. The purpose of this qualitative research is to gain understanding of reality through inductive thinking processes (Adlini et al., 2022). The researcher conducted observations of students' learning styles that influence difficulties in solving systems of linear equations with two variables. From this observation, the researcher could draw conclusions about the factors causing student difficulties and appropriate solutions to overcome these problems.

Case study is a research method where researchers explore a case within a specific time and activity, collecting detailed information through various data collection procedures during a certain period. The purpose of case study research is to reveal uniqueness or characteristics in the case being studied. Another purpose of case studies is to understand deeply about individual development in adjusting to their environment (Assyakurrohim et al., 2023). In this research, case study methodology was employed to obtain data information through direct observation and literature review from previous research journals discussing student difficulties during SPLDV learning processes.

2.2 Research Setting and Participants

Research participants in this study were 37 practitioner students from the Mathematics Education study program offering C, class of 2022. The research procedures conducted by the researcher included: (1) Research participants observed and understood the usage process of the SPLDV Board learning media, and (2) The researcher provided a case, then with the researcher's assistance, research participants were asked to solve the given case gradually. Through these two procedures, research participants showed attitude changes, namely new understanding regarding solving systems of linear equations with two variables. In addition, during practice observation activities, the enthusiasm of research participants toward the new solution model given could be observed. This could minimize errors that often occur in the process of solving systems of linear equations with two variables.

2.3 Instructional Procedures

Data collection was conducted through direct practice activities with practitioner students who were part of the researcher's data sources, involving practitioner students in the practice process to determine their level of understanding in using the SPLDV Board media. The practice procedure stages began with an opening delivered by the researcher. Core activities were conducted by briefly reviewing material about algebra and single-variable linear equations, followed by discussing SPLDV material. Next, the researcher explained the SPLDV Board, starting from the uses of boxes with different color combinations and the function of each box. The following step, the researcher demonstrated the use of the SPLDV Board by presenting a real-life problem. Then, the researcher conducted question-and-answer discussions with practitioner students by giving new problems. From here, the researcher measured the understanding level of practitioner students by identifying fluency in answering given statements.

2.4 Data Sources and Collection

Data sources are subjects from which data are obtained. Generally, data sources are divided into two: primary data sources and secondary data sources. Primary data sources are data taken by researchers directly without intermediaries, while secondary data sources are data taken through intermediaries or parties who have previously collected the data (Khasanah, 2022). In this research, the researcher used primary data sources in the form of practitioner students and course instructors. In addition, the researcher also used secondary data sources in the form of previous journals and articles on the same topic. Based on the selected data sources, the researcher obtained research data in the form of video recordings of teaching practice using SPLDV Board media and notes from the course instructor. Both data were obtained after the researcher conducted practice using SPLDV Board media with practitioner students. In addition, data were also obtained from literature review of previous journals and articles, where the researcher obtained data regarding student difficulties in solving systems of linear equations with two variables and appropriate solutions to overcome these problems.

2.5 Data Analysis

Qualitative data analysis techniques are qualitative research methodologies useful for processing data into information that can be understood by readers. In this research, the data analysis technique used was interactive data analysis technique. This is because this research consists of four components of the analysis process: data collection, data reduction, data presentation, and conclusion drawing (Darmawan & Yusuf, 2022). In the data collection process, the researcher conducted observations by performing practices and directly observing the understanding level of practitioner students regarding SPLDV solutions using the new model. The results of data collection in this research were in the form of video recordings of teaching practice using SPLDV Board media. After data were collected, the researcher performed data reduction by summarizing data and tracking important points so that final conclusions could be drawn. After data reduction was completed, the data were then presented in narrative form and table presentation. Conclusion drawing was conducted at the final stage of the analysis process. When data had been presented with focus on the problems, research conclusions could be obtained from the results of data analysis that had been conducted previously (Salma, 2023).

3. Results and Discussion

3.1 Results

The research findings revealed active participation of practitioner students in responding to researcher questions related to the media used. During the practice process, the researcher's role was limited to directing the solution process while practitioner students responded according to the given directions. The direction process for problem-solving was delivered in the form of questions directed to practitioner students, following an inquiry-based instructional approach that promotes active construction of knowledge rather than passive reception of information. Before explanation of the media usage concept, practitioner students appeared less active and demonstrated limited mastery of contextual problems related to SPLDV. This initial passive behavior aligns with typical patterns observed in traditional mathematics instruction where students have become accustomed to receiving algorithmic procedures without engaging in conceptual reasoning. However, following the SPLDV Board introduction and demonstration, the fluency of practitioner students in responding to usage directions from the researcher showed significant improvement in material understanding level, suggesting that the concrete manipulative tool successfully scaffolded their algebraic reasoning processes (See Figure 3).

Polyhedron International Journal in Mathematics Education
Volume 3, Issue 2, pp. 60-71, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme

Figure 3
Process of practice, giving directions, and feedback

The guiding questions delivered by the researcher encompassed general questions related to SPLDV Board media and appropriate placement of numbers in the provided boxes. This systematic questioning strategy served multiple pedagogical purposes: assessing student understanding, making mathematical structure explicit, and engaging students in metacognitive reflection about problem-solving procedures. The various guiding questions and responses that occurred during practice activities demonstrated a consistent pattern of accurate understanding across different aspects of the SPLDV Board usage. Specifically, ten types of guiding questions were posed sequentially, each targeting specific conceptual or procedural knowledge components necessary for successful SPLDV solution using the manipulative tool (See Figure 4).

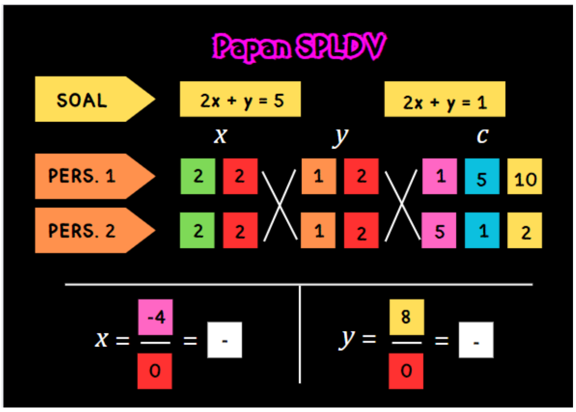
Figure 4
Example of SPLDV

$2x + y = 5 \dots (1)$ $2x + y = 1 \dots (2)$	The equation given
$y = -2x + 5$	Convert equation (1) into form $y = \frac{ax-c}{b}$
$= 2x + y = 1$ $2x + (-2x + 5 = 1$ $5 = 1$	Substitute into equation (2)

The first question, "From the given problem, what information is known?" received responses identifying coefficients of variable x, coefficients of variable y, and constants. This question targeted students' ability to parse word problems and extract relevant mathematical information—a critical initial step in mathematical modeling that students often struggle with. The second through fourth questions addressed placement of these identified values: "Where should the coefficient of variable x be placed?" (response: green box), "Where should the coefficient of variable y be placed?" (response: orange box), and "Where should the constant be placed?" (response: blue box). These questions assessed students' understanding of the SPLDV Board's organizational structure and their ability to map symbolic representations onto the physical manipulative spaces.

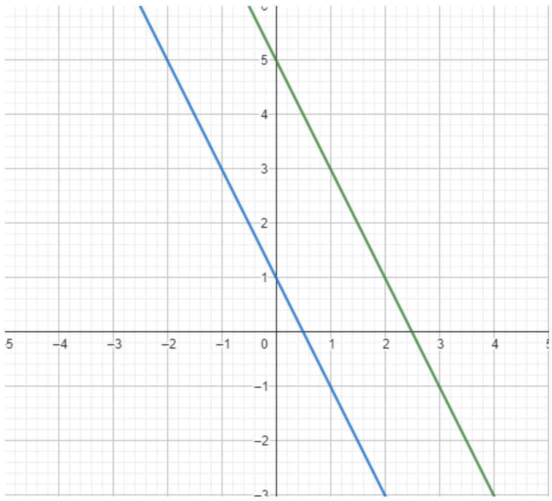
Questions five through seven targeted cross-multiplication procedures and their representation on the board: "Where should the cross-multiplication result of x and y coefficients be placed?" (response: red box), "Where should the cross-multiplication result of constants and variable y be placed?" (response: pink box), and "Where should the cross-multiplication result of constants and variable x be placed?" (response: yellow box). These questions engaged students with the procedural core of the elimination-substitution method while maintaining explicit connections between calculations and physical locations on the board. Question eight, "Where should the results for variables x and y be placed?" (response: white box) addressed the final solution representation, ensuring students understood the endpoint of the solution procedure (See Figure 5).

Figure 5
Application on Media



The final two questions targeted deeper procedural understanding: "How to obtain the denominator?" (response: subtract the cross-multiplication results of x and y coefficients) and "How to obtain the numerator?" (response: subtract the cross-multiplication results of constants with variables x and y). These questions required students to articulate the mathematical operations underlying the elimination-substitution algorithm, promoting explicit awareness of why the procedure produces valid solutions rather than merely how to execute mechanical steps (See Figure 6).

Figure 6
Graph Form



The systematic responses to these questions, documented in Table 1, demonstrated consistent fluency across all question types, suggesting that the SPLDV Board's color-coding and spatial organization successfully supported students' development of both procedural proficiency and conceptual understanding. The fluency category "Lancar" (fluent) was assigned when students responded correctly with minimal hesitation and without requiring additional prompting or clarification—an operational definition indicating automaticity and confidence in understanding.

Table 1
Guiding Questions and Practitioner Student Responses

Guiding Question	Response Form	Fluency Level
From the given problem, what information is known?	Coefficient of variable x, coefficient of variable y, and constant	Fluent
Where should the coefficient of variable x be placed?	Green box	Fluent

Guiding Question	Response Form	Fluency Level
Where should the coefficient of variable y be placed?	Orange box	Fluent
Where should the constant be placed?	Blue box	Fluent
Where should the cross-multiplication result of x and y coefficients be placed?	Red box	Fluent
Where should the cross-multiplication result of constant and variable y be placed?	Pink box	Fluent
Where should the cross-multiplication result of constant and variable x be placed?	Yellow box	Fluent
Where should the results for variables x and y be placed?	White box	Fluent
How to obtain the denominator?	Subtract the cross-multiplication results of x and y coefficients	Fluent
How to obtain the numerator?	Subtract the cross-multiplication results of constants with variables x and y	Fluent

In addition to responses from practitioner students, the researcher received special notes from the instructor indicating that the learning media used was not effective for all types of equations. The media can only be used for systems of linear equations with specific criteria, namely that the system of linear equations must intersect each other. This limitation arises because if the possessed equation system does not intersect, then that equation system has no solution. Therefore, in its application, it must first be tested whether the equation system intersects or not. This critical limitation highlights an important consideration for instructional media design: tools optimized for specific mathematical cases may inadvertently create misconceptions if applied uncritically to cases outside their valid domain. The instructor's observation underscores the necessity for explicit discussion of tool limitations alongside demonstrations of tool affordances, ensuring that students develop conditional knowledge about when particular solution methods are appropriate.

3.2 Discussion

The SPLDV Board learning media practice demonstrated both notable strengths and important limitations that merit careful consideration for future implementation and refinement. Among the evident strengths observed during the practice process, practitioner students demonstrated enthusiasm for learning Systems of Linear Equations with Two Variables material using media-based instruction. This affective engagement represents a crucial factor in mathematics learning, as student motivation and positive attitudes toward mathematics strongly predict persistence and achievement. The presence of the SPLDV Board media facilitated the solution process for Systems of Linear Equations with Two Variables by providing concrete, visual scaffolding that reduced cognitive load and made abstract symbolic operations more transparent and memorable. The color-coding system appeared particularly effective in helping students organize multiple numerical values and track complex multi-step procedures without losing track of intermediate results—a common source of errors in algebraic problem-solving.

However, the practice process also revealed important limitations that require attention. Some practitioner students remained relatively inactive during instruction, creating challenges for the researcher in identifying whether these students had genuinely understood the material. The presence of inactive practitioner students raises concerns about possible lack of understanding of the presented material (Oktifa, 2022). This pattern of passive participation may reflect various underlying factors including: mathematical anxiety that inhibits voluntary response, prior negative experiences with mathematics that have conditioned students to avoid engagement, insufficient wait time between questions that disadvantages students requiring more processing time, or social dynamics where more confident students dominate interaction opportunities. Addressing this participation gap requires deliberate instructional strategies such as structured turn-taking protocols, think-pair-share activities that provide processing time before public response, or written response systems that enable all students to demonstrate thinking simultaneously.

Beyond facilitating Systems of Linear Equations with Two Variables solutions, the SPLDV Board media possesses a fundamental limitation: not all systems of linear equations with two variables can be solved using this media. Systems of linear equations with two variables that can be solved using this media are equation systems that have intersection points, because the intersection point produced represents the solution of the given SPLDV (Simanullang & Exaudi, 2020). This constraint emerges from the mathematical structure of linear systems: when two lines are parallel (having identical slopes but different y-intercepts), they never intersect and thus the system has no solution; when two equations represent the same line (identical slopes and y-intercepts), infinitely many solutions exist. The SPLDV Board, designed to find unique intersection points through elimination-substitution procedures, cannot meaningfully represent these alternative solution scenarios.

If the possessed equation system produces two parallel lines, then that SPLDV has no solution (Pradini et al., 2020). Therefore, to determine whether an equation has a solution or not, the initial step taken is transforming one equation from the form ax + by = c...(1) to the form y = (ax - c)/b...(2). Subsequently, the transformed equation is substituted into the other equation, thereby obtaining its solution (Rismawati et al., 2017). This preliminary testing procedure, while mathematically sound, adds complexity to instructional implementation and requires students to possess prerequisite knowledge of slope-intercept form and solution set types—knowledge that may not be fully developed among the target student population.

The figures above illustrate a specific case where the SPLDV Board's limitations become apparent. The system 2x + y = 5 and 2x + y = 1 consists of two parallel lines (both having slope -2), resulting in no intersection point and thus no solution. When students attempt to apply the SPLDV Board procedure to such systems, they encounter the contradiction 5 = 1, which emerges from the algebraic manipulation but may not be immediately recognized as indicating “no solution” without explicit instruction connecting this symbolic result to its graphical meaning. This disconnect between symbolic manipulation and geometric interpretation represents a common challenge in algebra instruction and highlights the importance of multiple representations and explicit connections among them.

The existence of this research provides impacts for researchers, students, and educators, contributing to the knowledge base and practical repertoire across multiple stakeholder groups. For researchers, conducting this investigation enabled direct experience with conditions that will be encountered when teaching, providing authentic situated knowledge that cannot be gained through purely theoretical study. Researchers also identified common difficulties generally experienced by students, thereby enabling development of strategies to solve these problems effectively. This practitioner knowledge—understanding of typical student difficulties, effective questioning sequences, productive uses of manipulative materials, and classroom management strategies—represents a crucial complement to formal pedagogical theory.

For students, the presence of this learning media can address problems related to SPLDV, such as difficulties in performing algebraic operations with elimination and substitution methods, and difficulties in conceptualizing solution processes for addition and subtraction operations (Agustini & Pujiastuti, 2020). The concrete, color-coded structure of the SPLDV Board provides external support that compensates for students' limited working memory capacity and underdeveloped metacognitive monitoring skills, enabling them to execute complex multi-step procedures successfully even before fully internalizing the underlying conceptual structures. Over time and with appropriate instructional fading, students may develop sufficient internalized schemas to solve SPLDV problems without physical manipulative support.

The implementation of Merdeka Curriculum requires educators to be creative and innovative in designing learning activities (Zulaiha et al., 2022). Consequently, through the existence of this research, educators can discover new ideas about appropriate learning media for teaching SPLDV material. The SPLDV Board represents one example of how teachers can design low-cost, accessible manipulative materials that address specific learning challenges identified through classroom experience and reflection. The design principles underlying the SPLDV Board—systematic color-coding, designated spaces for specific values, visual organization of procedural steps—can be adapted and applied to other mathematical topics where students struggle with symbolic complexity and multi-step procedures, such as factoring polynomials, solving quadratic equations, or performing matrix operations.

4. Conclussion

This research demonstrates that the SPLDV Board learning media effectively enhances active participation and student understanding of Systems of Linear Equations with Two Variables (SPLDV) material. The use of media with a color-coding system and spatial organization proved helpful for students in identifying variable coefficients, constants, and executing cross-multiplication procedures fluently. All practitioner students were able to respond to ten guiding questions with high fluency levels, indicating mastery of both procedural and conceptual aspects.

However, the research also revealed important limitations of this media. The SPLDV Board can only be used for equation systems that have intersection points (unique solutions), making it ineffective for systems that produce parallel lines (no solution) or coincident lines (infinite solutions). Additionally, some students remained passive during instruction, indicating possible lack of understanding or other participation barriers.

This research provides practical contributions for educators in developing innovative learning media aligned with Merdeka Curriculum requirements. The design principles of the SPLDV Board—color-coding, designated spaces for specific values, and visualization of procedural steps—can be adapted for other mathematical topics involving complex multi-step procedures. Moving forward, additional instructional strategies are needed to address student passive participation, and explicit instruction regarding media limitations is necessary to ensure students understand when particular solution methods are appropriate.

Acknowledgments
The authors would like to express sincere gratitude to all parties who contributed to the completion of this research. Special thanks are extended to the practitioner students who actively participated in this study and provided valuable insights through their engagement with the SPLDV Board learning media. We are deeply grateful to the instructors who offered constructive feedback and observations regarding the media's effectiveness and limitations, which significantly enriched our understanding of its practical implementation. Our appreciation also goes to the school administration for facilitating this research and providing the necessary support and resources. Finally, we acknowledge the valuable contributions of colleagues and peers who provided suggestions and encouragement throughout the research process.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this research. This study was conducted independently without any financial support or sponsorship from parties that could influence the research outcomes. The authors have no personal, financial, or professional relationships that could potentially bias the research findings or their interpretation. All data presented in this study were collected and analyzed objectively, and the findings reflect the actual observations and results obtained during the research process.

5. References

Adlini, M. N., Dinda, A. H., Yulinda, S., Chotimah, O., & Merliyana, S. J. (2022). Metode penelitian kualitatif studi pustaka. *Edumaspul: Jurnal Pendidikan*, *6*(1), 974-980. https://doi.org/10.33487/edumaspul.v6i1.3395

Agustini, D., & Pujiastuti, H. (2020). Analisis kesulitan siswa berdasarkan kemampuan pemahaman matematis dalam menyelesaikan soal cerita pada materi SPLDV. *Media Pendidikan Matematika*, *8*(1), 18-27. https://doi.org/10.33394/mpm.v8i1.2568

Assyakurrohim, D., Ikhram, D., Sirodj, R. A., & Afgani, M. W. (2023). Metode studi kasus dalam penelitian kualitatif. *Jurnal Pendidikan Sains dan Komputer*, *3*(1), 1-9. https://doi.org/10.47709/jpsk.v3i01.2209

Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology*, *105*(2), 380-400. https://doi.org/10.1037/a0031084

Darmawan, P., & Yusuf, F. I. (2022). *Teori kognitivisme dan penerapannya dalam penelitian pendidikan matematika*. Insan Cendekia Nusantara.

Dzulkifli, M. A., & Mustafar, M. F. (2013). The influence of colour on memory performance: A review. *The Malaysian Journal of Medical Sciences*, *20*(2), 3-9.

Ferdianto, F., & Yesino, L. (2019). Analisis kesalahan siswa dalam menyelesaikan soal pada materi SPLDV ditinjau dari indikator kemampuan matematis. *SJME (Supremum Journal of Mathematics Education)*, *3*(1), 28-38. https://doi.org/10.35706/sjme.v3i1.1784

Habibah, A., Nandang, N., & Sudirman, S. (2020). Identifikasi kesalahan-kesalahan siswa dalam menyelesaikan soal cerita pada materi sistem persamaan linear dua variabel berdasarkan prosedur newman. *Range: jurnal pendidikan matematika*, *1*(2), 122-129.

Johnson, D. W., & Johnson, R. T. (2019). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher*, *38*(5), 365-379. https://doi.org/10.3102/0013189X09339057

Khasanah, L. U. (2022, March 4). Empat sumber data sekunder dan primer. *DQLab*. https://dqlab.id/empat-sumber-data-sekunder-dan-primer

Kusumastuti, A., & Khoiron, A. M. (2019). *Metode penelitian kualitatif*. Lembaga Pendidikan Sukarno Pressindo.

Lesh, R., & Doerr, H. M. (2003). *Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching*. Lawrence Erlbaum Associates. https://doi.org/10.4324/9781410607713

Ministry of Education, Culture, Research, and Technology. (2022). *Kurikulum Merdeka* [Merdeka curriculum]. Government of Indonesia.

Moyer-Packenham, P. S., & Bolyard, J. J. (2016). Revisiting the definition of a virtual manipulative. In P. S. Moyer-Packenham (Ed.), *International perspectives on teaching and learning mathematics with virtual manipulatives* (pp. 3-23). Springer. https://doi.org/10.1007/978-3-319-32718-1_1

Monike, R. S., Sudirman, S., Kandaga, T., & Rodríguez-Nieto, C. A. (2025). Effectiveness of ChatGPT-integrated discovery learning on mathematical literacy in three-variable linear equation systems: A quasi-experimental study. *International Journal of Didactic Mathematics in Distance Education*, *3*(1), 64–82. https://doi.org/10.33830/ijdmde.v3i1.13157

Nandang, N., Fitriyani, F., Gunadi, F., & Sudirman, S. (2022). Penggunaan algebraic experience materials terhadap hasil belajar siswa materi sistem persamaan linear dua variabel. *Gema Wiralodra*, *13*(1), 273–284. https://doi.org/10.31943/gemawiralodra.v13i1.230

Nihayah, E. F. (2021). Analisis penguasaan materi prasyarat aljabar dalam menyelesaikan soal sistem persamaan linear dua variabel. *Linear: Jurnal Ilmu Pendidikan*, *5*(1), 23-33. https://doi.org/10.53090/jlinear.v5i1.138

Oktifa, N. (2022). Kenali ciri-ciri siswa tidak paham pelajaran: Gejala-gejala anak yang berkesulitan belajar. *Aku Pintar*. https://akupintar.id/info-pintar/-/blogs/kenali-ciri-ciri-siswa-tidak-paham-pelajaran

Pradini, W., Muhsetyo, G., & Rahardjo, S. (2020). Kesulitan siswa SMP dalam menyelesaikan soal cerita sistem persamaan linear dua variabel. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *5*(1), 31-38. http://dx.doi.org/10.17977/jptpp.v5i1.13107

Rismawati, M., Irawan, E. B., & Susanto, H. (2017). Struktur koneksi matematis siswa kelas X pada materi sistem persamaan linear dua variabel. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *2*(4), 465-469. http://dx.doi.org/10.17977/jptpp.v2i4.8547

Riyadi, S. (2006). Sistem persamaan linear dua variabel (SPLDV). In *Be smart matematika* (p. 57). Grafindo Media Pratama.

Salma. (2023, September 15). Teknik analisis data: Pengertian, macam, dan langkah. *Deepublish*. https://penerbitdeepublish.com/teknik-analisis-data/

Simanullang, R., & Exaudi, M. (2020). Perbedaan pemahaman konsep matematis antara model pembelajaran kooperatif tipe TGT dengan model pembelajaran problem based learning pada materi sistem persamaan linear dua variabel kelas VIII SMP Swasta Bhakti Bangsa Sei Semayang [Unpublished thesis]. Universitas HKBP Nommensen.

Sudirman, S., Mellawaty, M., Yaniawati, P., & Indrawan, R. (2021). Augmented reality application: What are the constraints and perceptions of the students during the covid 19 pendemic's 3D geometry learning process?. In *Journal of Physics: Conference Series* (Vol. 1783, No. 1, p. 012007). IOP Publishing.

Sudirman, S., Andrés Rodríguez-Nieto, C., Bongani Dhlamini, Z., Singh Chauhan, A., Baltaeva, U., Abubakar, A., O. Dejarlo, J., & Andriani, M. (2023). Ways of thinking 3D geometry: exploratory case study in junior high school students. *Polyhedron International Journal in Mathematics Education*, *1*(1), 15–34. https://doi.org/10.59965/pijme.v1i1.5

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Springer. https://doi.org/10.1007/978-1-4419-8126-4

Vlassis, J. (2008). The role of mathematical symbols in the development of number conceptualization: The case of the minus sign. *Philosophical Psychology*, *21*(4), 555-570. https://doi.org/10.1080/09515080802285552

Yumiati, Y., Rodriguez-Nieto, C.A., Bonyah, E., Sudirman, S & Haji, S. (2024). Evaluating Bengkulu culture's role in mathematics learning outside classrooms for understanding measurement. *International Journal of Evaluation and Research in Education*, *13*(6), 4307-4320. http://doi.org/10.11591/ijere.v13i6.30163

Zulaiha, S., Meldina, T., & Meisin. (2022). Problematika guru dalam menerapkan kurikulum merdeka belajar. *TERAMPIL: Jurnal Pendidikan dan Pembelajaran Dasar*, *9*(2), 163-177. https://doi.org/10.24042/terampil.v9i2.13185