UJMER Volume 2 No 5 2025

Unnes Journal of Mathematics Education Research

http://journal.unnes.ac.id/sju/index.php/ujmer

Implementation of a STEAM-Ethnomathematics Learning Management System with Problem-Based Learning to Enhance Students' Mathematical Representation Ability in Linear Equation Systems

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Article Info

Article History:
Received 22 August 2025
Accepted 26 November 2025
Published 29 December 2025

Keywords:
Ethnomathematics, Learning Management System, Mathematical Representation Ability, Problem-Based Learning, STEAM.

Abstract

Mathematical representation ability is one of the essential competencies that students need to develop in mathematics learning because it enables them to express mathematical ideas through visual, symbolic, and verbal forms. However, many junior high school students still experience difficulties in representing mathematical concepts, particularly in solving problems related to Systems of Linear Equations in Two Variables (SLETV). This study aimed to develop and implement a Learning Management System (LMS) integrated with the STEAM approach, ethnomathematics, and the Problem-Based Learning (PBL) model to improve students' mathematical representation ability. The research adopted the ADDIE development model consisting of analysis, design, development, implementation, and evaluation stages. The developed LMS was implemented using a one-group pretest-posttest design involving 32 eighth-grade students at SMP Negeri 2 Ungaran in the 2025/2026 academic year. Data was collected through expert validation sheets, mathematical representation tests, observations, and documentation. The findings indicated that the developed LMS achieved a very high level of validity based on expert evaluations. Furthermore, students' mathematical representation ability improved significantly after the implementation of the LMS. The Wilcoxon Signed-Rank Test revealed a significant difference between pretest and posttest scores ($p < 0.05$), while the average normalized gain score reached 0.75, indicating a high improvement category. These findings demonstrate that integrating STEAM, ethnomathematics, and Problem-Based Learning into an LMS provides an effective learning environment for enhancing students' mathematical representation ability in learning Systems of Linear Equations in Two Variables.

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p-ISSN 2252-6455
e-ISSN 2502-4507

INTRODUCTION

Mathematics is a fundamental discipline that plays a significant role in developing logical reasoning, problem-solving skills, and critical thinking. In contemporary education, mathematics learning is expected not only to improve students' computational skills but also to cultivate higher-order thinking skills that enable students to understand, analyze, and solve real-life problems. Consequently, mathematics instruction should provide meaningful learning experiences that encourage students to construct mathematical concepts actively rather than merely memorizing formulas.

One of the fundamental competencies emphasized in mathematics education is mathematical representation ability. According to the National Council of Teachers of Mathematics (NCTM), mathematical representation enables learners to organize, communicate, and interpret mathematical ideas through various forms, including visual representations, mathematical symbols, diagrams, graphs, tables, and verbal explanations. Students who possess strong representation skills are generally more capable of translating contextual situations into mathematical models and explaining their reasoning systematically. Therefore, representation serves as an essential bridge between conceptual understanding and mathematical problem solving.

Despite its importance, numerous studies have reported that junior high school students continue to demonstrate relatively low mathematical representation ability. Many students experience difficulties in converting contextual problems into mathematical equations, interpreting graphical information, and communicating mathematical reasoning using appropriate mathematical language. These limitations become particularly evident when students learn Systems of Linear Equations in Two Variables (SLETV), a topic requiring the integration of symbolic manipulation, graphical interpretation, and verbal reasoning. Consequently, students frequently rely on memorized procedures without fully understanding the underlying concepts, resulting in poor learning outcomes and limited conceptual understanding.

To address these challenges, integrating digital learning technologies into mathematics instruction has become increasingly important. One promising innovation is the utilization of a Learning Management System (LMS), which provides flexible access to learning materials, facilitates communication between teachers and students, and supports interactive learning activities regardless of time and location. Learning Management Systems also promote independent learning by allowing students to revisit instructional materials and complete learning activities at their own pace. Recent studies have demonstrated that LMS-based learning can improve students' engagement, motivation, and academic achievement when appropriately designed.

However, technology alone is insufficient to enhance students' mathematical understanding. Effective digital learning environments should be supported by appropriate pedagogical approaches that actively engage learners in meaningful problem-solving activities. One instructional model widely recognized for promoting critical thinking and conceptual understanding is Problem-Based Learning (PBL). Through authentic and contextual problems, PBL encourages students to investigate, collaborate, formulate hypotheses, evaluate alternative solutions, and construct mathematical knowledge independently. This learner-centered approach has consistently been shown to improve mathematical reasoning, communication, and representation abilities.

Furthermore, mathematics learning can become more meaningful when it incorporates students' cultural backgrounds. Ethnomathematics offers an educational perspective that connects mathematical concepts with local cultural practices, allowing students to recognize mathematics as an integral part of everyday life. Integrating ethnomathematics into classroom instruction not only increases students' motivation but also promotes appreciation of local wisdom while facilitating conceptual understanding through familiar contexts. In this study, the traditional culinary product Serabi Solo was employed as a contextual medium for

introducing Systems of Linear Equations in Two Variables. The production and sales scenarios associated with Serabi Solo provide authentic mathematical situations that enable students to formulate, represent, and solve linear equation problems meaningfully.

In addition to cultural integration, this study adopts the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach to enrich students' learning experiences. STEAM promotes interdisciplinary learning by encouraging students to integrate scientific inquiry, technological literacy, engineering design, artistic creativity, and mathematical reasoning in solving real-world problems. Combining STEAM with ethnomathematics and Problem-Based Learning within an LMS environment is expected to create an innovative instructional model that supports both conceptual understanding and the development of twenty-first-century competencies.

Based on these considerations, this study developed and implemented a STEAM-Ethnomathematics Learning Management System integrated with Problem-Based Learning for learning Systems of Linear Equations in Two Variables. Specifically, the study aimed to: (1) develop a valid LMS integrating STEAM, ethnomathematics, and Problem-Based Learning; (2) investigate the effectiveness of the developed LMS in improving students' mathematical representation ability; and (3) examine students' learning improvement following the implementation of the developed learning environment.

METHOD

This study employed a Research and Development (R&D) approach using the ADDIE instructional design model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because of its systematic structure, making it suitable for developing and evaluating the effectiveness of digital learning media, particularly a Learning Management System (LMS) integrated with the STEAM approach, Ethnomathematics (Serabi Solo), and the model of learning process is Problem-Based Learning (PBL).

Before the learning process began, a pretest was administered to a single experimental group to determine students' initial learning outcomes. After the instructional intervention, a posttest was conducted to measure students' learning achievement following the implementation of the Problem-Based Learning (PBL) model through a Google Classroom-based LMS.

The population refers to the entire group of individuals or objects possessing specific characteristics relevant to a study (Nur Fadilah & Sabaruddin Garancang, 2023). The population in this research consisted of all eighth-grade students at SMP Negeri 2 Ungaran.

The sample comprised 32 students from Class VIII-I, who participated as the experimental group in the implementation of the Google Classroom-based LMS integrated with the Problem-Based Learning model for learning the topic of Systems of Linear Equations in Two Variables (SLETV).

Data Collection and Analysis

Validation Analysis

The feasibility of the developed Google Classroom-based LMS learning module was evaluated through expert validation. The validation process involved media experts, subject matter experts, and learning practitioners, who assessed the product using a validation questionnaire.

$$percentage = \frac{Score\ obtained}{maximum\ score} \times 100$$

The validation scores were interpreted according to the validation criteria presented in Table 1.

Table 1 The validation criteria

Percentage	Category
$81\% - 100\%$	Very Valid
$61\% - 80\%$	Valid
$41\% - 60\%$	Moderately Valid
$21\% - 40\%$	Invalid
$0\% - 20\%$	Very Invalid

Competency Assessment Analysis

Individual Mastery

Individual mastery was used to determine whether each student achieved the expected learning outcomes based on the Learning Objective Achievement Criteria, which was set at 70. Students obtaining a score of 70 or higher were considered to have achieved mastery.

Classical Mastery

Classical mastery was used to evaluate the overall learning achievement of the class. Learning was considered successful if at least 75% of the students achieved individual mastery.

Normality Test

A normality test was conducted to determine whether the research data followed a normal distribution, which is a prerequisite for subsequent parametric statistical analyses. Since the sample size was fewer than 50 participants, the Shapiro–Wilk test was employed (Marwinda & Danardono, 2024).

The decision criteria were: If Sig. > 0.05, the data were considered normally distributed. If Sig. ≤ 0.05, the data were considered not normally distributed.

Mean Difference Test

Following the normality test, hypothesis testing was conducted according to the distribution of the data. If the data were normally distributed, a Paired Sample t-test was performed. Otherwise, the Wilcoxon Signed-Rank Test was used (Kurniawan & Purnamawati, 2022). The research hypotheses were formulated as follows:

H_0: There is no significant difference between students' pretest and posttest scores.

H_1: There is a significant difference between students' pretest and posttest scores.

The decision criteria were: If Sig. > $0.05, H_0$ is accepted and H_1 is rejected. If Sig. ≤ $0.05, H_0$ is rejected and H_1 is accepted.

N-Gain Test

The Normalized Gain (N-Gain) test was conducted to determine the extent of students' learning improvement after participating in the instructional intervention.

The interpretation of N-Gain values is presented in Table 2.

Table 2 The interpretation of N-Gain values

Interval N-Gain	Category
$g < 0.3$	Low
$0.3 \leq g \leq 0.7$	Medium
$g \geq 0.7$	High

RESULTS AND DISCUSSIONS

The Learning Management System (LMS) was developed using the ADDIE model consisting of Analysis, Design, Development, Implementation, and Evaluation. During the analysis stage, preliminary observations indicated that students experienced difficulties in translating contextual problems into mathematical representations, particularly in the topic of Systems of Linear Equations in Two Variables (SLETV). Therefore, an LMS based on Google Classroom integrating STEAM, ethnomathematics, and Problem-Based Learning (PBL) was designed to facilitate contextual and interactive learning.

The developed LMS contains digital learning materials, instructional videos, interactive worksheets (LKPD), discussion forums, contextual problem-solving activities, and Wayground-based assessments. Ethnomathematics was incorporated through contextual problems involving Serabi Solo production and distribution, enabling students to connect mathematical concepts with local cultural practices.

The developed LMS was evaluated by media experts, subject matter experts, and learning practitioners before classroom implementation. Overall, the validation results indicated that the LMS achieved a very valid category, suggesting that the instructional content, interface design, language, and learning activities were appropriate for classroom use.

The high validation results demonstrate that integrating STEAM, ethnomathematics, and

Problem-Based Learning into a digital learning environment produces an instructional product suitable for mathematics learning. These findings are consistent with previous studies reporting that LMS-based learning environments facilitate more flexible and interactive learning experiences.

Students learning outcomes improved after participating in learning activities through the developed LMS. Before instruction, none of the students achieved the minimum mastery criterion. After implementation, 25 out of 32 students (78.12%) successfully achieved mastery learning.

The increase in learning achievement indicates that integrating contextual ethnomathematics, STEAM activities, and Problem-Based Learning within the LMS successfully engaged students in constructing mathematical concepts through authentic learning experiences.

Statistical Analysis

Normality Test

The Shapiro–Wilk test revealed that both the pretest and posttest scores were not normally distributed (pretest: $p = 0{,}000$; posttest: $p = 0{,}002$). Therefore, non-parametric analysis using the Wilcoxon Signed-Rank Test was employed.

Wilcoxon Signed-Rank Test

The Wilcoxon Signed-Rank Test showed a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between students' pretest and posttest scores. Furthermore, all 32 students obtained higher posttest scores than pretest scores, as indicated by 32 positive ranks and no negative ranks.

These findings suggest that the developed LMS effectively improved students' mathematical learning outcomes after the instructional intervention.

N-Gain Analysis

The average normalized gain (N-Gain) score was 0,75, which falls into the high improvement category. This result indicates that students experienced substantial learning improvement following the implementation of the LMS.

The findings demonstrate that implementing a Google Classroom-based Learning Management System integrating STEAM, ethnomathematics, and Problem-Based Learning effectively improves students' mathematical learning outcomes on the topic of Systems of Linear Equations in Two Variables.

Several factors contributed to this improvement. First, the LMS provided flexible access to instructional materials, allowing students to review videos, worksheets, and learning resources independently. Second, Problem-Based Learning encouraged students to analyze contextual problems, collaborate with peers, and formulate mathematical models actively rather than relying solely on procedural memorization.

Moreover, incorporating ethnomathematics through Serabi Solo contextual problems made abstract mathematical concepts more meaningful because students could relate learning activities to familiar cultural experiences. This contextual learning aligns with constructivist perspectives, emphasizing that knowledge is more effectively acquired when learners actively construct meaning from authentic situations.

The integration of the STEAM approach further enriched learning by combining mathematical reasoning with technology, creativity, and real-life applications. Interactive assessment using Wayground also increased students' engagement and motivation during classroom activities.

These findings support previous studies indicating that Learning Management Systems improve students' engagement and learning achievement (Haeruman et al., 2021), while Problem-Based Learning enhances mathematical representation ability (Firdaus et al., 2021). Likewise, ethnomathematics contributes to contextual understanding by connecting mathematics with local culture (Nursanti et al., 2024). Therefore, integrating these three components within one digital learning environment provides a comprehensive

instructional strategy for improving mathematics learning.

CONCLUSION

This study developed and implemented a Learning Management System (LMS) integrating the STEAM approach, ethnomathematics, and the Problem-Based Learning (PBL) model to improve eighth-grade students' mathematical representation ability in learning Systems of Linear Equations in Two Variables (SLETV). The instructional product was developed using the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation.

The expert validation results indicated that the developed LMS achieved a very high level of validity, demonstrating that its instructional content, language, presentation, and graphical design were appropriate for classroom implementation. Following implementation, students' mathematical representation ability improved considerably. Statistical analysis revealed a significant difference between pretest and posttest scores based on the Wilcoxon Signed-Rank Test ($p < 0.05$), while the average Normalized Gain (N-Gain) score of 0.75 indicated a high level of learning improvement.

These findings suggest that integrating digital learning technology, Problem-Based Learning, STEAM education, and ethnomathematics creates an engaging and meaningful learning environment that effectively supports students in constructing mathematical concepts through visual, symbolic, and verbal representations. The developed LMS not only facilitates students' conceptual understanding but also encourages active participation, collaborative learning, independent learning, and contextual problem solving.

This study contributes to mathematics education by providing an innovative instructional framework that combines technology-enhanced learning with culturally responsive pedagogy. Future studies are recommended to implement the developed LMS using experimental research designs involving larger and more diverse samples to further examine its effectiveness across different mathematical topics and educational contexts.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the principal, mathematics teachers, and eighth-grade students of SMP Negeri 2 Ungaran for their cooperation and participation throughout this study. The authors also extend their appreciation to the expert validators for their valuable suggestions and constructive feedback during the development of the Learning Management System. Their contributions have greatly improved the quality of this research.

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