The Sets of Light Diagram Model on Diverse Learners' Performance and Motivation in Teaching Mathematics in the Modern World

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ABSTRACT:
This study examined the effectiveness of the Sets of Light Diagram Model (SLDM) on the mathematics performance and motivation of diverse learners in teaching Mathematics in the Modern World. The study employed a mixed-methods explanatory sequential design integrating quantitative and qualitative approaches. Eighty first-year college students participated in the study and were divided into experimental and control groups. The experimental group was exposed to the Sets of Light Diagram Model, while the control group was taught using the lecture method. Quantitative data were gathered using a researcher-made Mathematics Performance Test, while qualitative data were collected through reflective journals. Findings revealed that learners exposed to the SLDM achieved significantly higher mathematics performance compared to those taught through the lecture method. Qualitative findings further showed that the instructional model enhanced learners' interest, engagement, confidence, perceived usefulness of mathematics, and collaborative participation. The study concludes that the Sets of Light Diagram Model is an effective instructional intervention that supports both the cognitive and affective learning needs of diverse learners through interactive, visual, and learner-centered mathematics instruction.

Keywords: Sets of Light Diagram Model, Diverse Learners, Mathematics Performance, Motivation, Mathematics Education

1. Introduction

Mathematics plays an important role in developing learners' analytical thinking, reasoning ability, and problem-solving skills, making it a fundamental discipline in modern education. In higher education, the course Mathematics in the Modern World emphasizes the practical application of mathematical concepts in real-life situations. However, many learners continue to experience difficulties in mathematics because of its abstract nature, symbolic representations, and procedural demands. As a result, students often develop low confidence, anxiety, and negative attitudes toward mathematics, which affect their academic performance and motivation to learn (Barton et al., 2018).

These challenges are more evident among diverse learners with varying learning styles, academic preparedness, and motivational levels. Barton et al. (2018) explained that poor mathematics performance is commonly associated with the abstractness of mathematical concepts and the higher-order thinking skills required in problem-solving tasks. Similarly, Amir et al. (2018) emphasized that inadequate instructional strategies and limited learning resources contribute to students' difficulties in understanding mathematical concepts. Despite continuous educational reforms, traditional lecture-based instruction remains widely used in many classrooms, often limiting learners' opportunities for active participation, visualization, and experiential learning.

Motivation is also considered a significant factor influencing students' engagement and achievement in mathematics. According to Muchacka and Dec (2023), learners with strong self-efficacy are more likely to persist in academic tasks and overcome learning difficulties. Likewise, Eustaquio et al. (2025) emphasized that intrinsically motivated learners demonstrate deeper engagement and more meaningful learning experiences. However, mathematics instruction often lacks interactive and learner-centered experiences that promote motivation, confidence, and participation among diverse learners.

Several studies have highlighted the effectiveness of visual and interactive instructional approaches in improving mathematical understanding and learner engagement. Bruner's Constructivist Learning Theory explains that learners develop deeper understanding through active participation and experiential learning (Bruner, 1996). Cruz and Gomez (2023) reported that model-based instructional strategies enhance students' conceptual understanding and classroom engagement, while Lee and Johnson (2023) found that visual and manipulative learning approaches improve learners' participation and motivation in mathematics.

Although previous studies have demonstrated the effectiveness of visualization and motivational strategies in mathematics education, limited studies have explored instructional models that simultaneously improve mathematics performance and learner motivation among diverse learners in Mathematics in the Modern World. Existing instructional tools often remain teacher-centered and observational, limiting opportunities for active manipulation and collaborative learning (Lee & Johnson, 2023). This gap highlights the need for innovative instructional interventions that support both the cognitive and affective learning needs of diverse learners.

To address this gap, the present study introduces the Sets of Light Diagram Model (SLDM) as an interactive and manipulative instructional intervention designed to improve learners' mathematics performance and motivation. The SLDM allows learners to visualize and manipulate mathematical set relationships through light-based representations and collaborative activities. Through active participation and immediate visual feedback, the model aims to strengthen conceptual understanding, increase learner confidence, and improve engagement in mathematics learning.

This study employed a mixed-methods explanatory sequential design to examine the effectiveness of the Sets of Light Diagram Model in teaching Mathematics in the Modern World. Specifically, the study investigated learners' mathematics performance in terms of understanding, accuracy, and application of concepts, as well as their motivation in terms of interest, engagement, confidence, and perceived usefulness of mathematics learning. The findings of the study may contribute to the development of innovative and inclusive instructional strategies that support meaningful mathematics learning experiences for diverse learners.

2. Methodology

Research Design

This study employed a mixed-methods explanatory sequential design (QUAN→qual) to examine the effectiveness of the Sets of Light Diagram Model (SLDM) on the mathematics performance and motivation of diverse learners in Mathematics in the Modern World. Creswell

(2012) explained that explanatory sequential designs involve collecting quantitative data first, followed by qualitative data to explain and enrich the quantitative findings. The study also utilized a quasi-experimental pretest-posttest control group design to compare learners exposed to the Sets of Light Diagram Model and those taught using the lecture method. According to Fraenkel et al. (2012), quasi-experimental designs are appropriate in educational settings where intact groups are used to determine the effectiveness of instructional interventions.

Participants/Sample

The participants of the study consisted of 80 first-year college students enrolled in Mathematics in the Modern World during the second semester of Academic Year 2023–2024 at Iloilo State University of Fisheries Science and Technology (ISUFST) – Dingle Campus, Iloilo, Philippines. The participants represented diverse learners with varying academic preparedness, learning preferences, and motivational experiences in mathematics learning.

Two intact classes were selected for the study. One group consisting of 40 students served as the experimental group exposed to the Sets of Light Diagram Model, while another group consisting of 40 students served as the control group taught through the lecture method. The fishbowl sampling technique was employed to determine group assignment.

Instruments

Two research instruments were utilized in gathering the data needed for the study.

Mathematics Performance Test

The primary quantitative instrument was a 50-item researcher-made Mathematics Performance Test designed to measure students' understanding, accuracy, and application of mathematical concepts related to sets. The test was constructed based on the learning competencies prescribed in the Mathematics in the Modern World curriculum and aligned with the Table of Specifications to ensure balanced distribution of test items across cognitive domains.

To establish content validity, the instrument underwent face and content validation by three experts in mathematics education and instructional research. Their recommendations were incorporated in revising the instrument. Initially, 60 items were prepared; however, only 50 items were retained after expert evaluation and panel recommendations.

The reliability of the instrument was determined using the Kuder–Richardson Formula 20 (KR-20), which yielded a reliability coefficient of 0.81, indicating acceptable internal consistency and reliability for educational research purposes.

Reflective Journals

The qualitative data regarding students' motivation and learning experiences were gathered through reflective journals. The journals enabled students to express their experiences, perceptions, engagement, confidence, and motivational responses while using the Sets of Light Diagram Model during classroom activities.

The reflective journals specifically explored learners':

- interest in mathematics learning,
- engagement during instructional activities,
- confidence in understanding mathematical concepts, and
- perceived usefulness of mathematics in real-life situations.

The use of reflective journals allowed the researcher to gather rich and descriptive qualitative insights regarding the affective dimensions of students' learning experiences.

Procedure

Prior to data collection, permission to conduct the study was secured from the university administration. Both the experimental and control groups were first administered a pretest to determine their baseline mathematics performance.

During the four-week intervention period, the experimental group was taught using the Sets of Light Diagram Model, which utilized visual and manipulative activities to demonstrate mathematical set operations such as union, intersection, and complement. Meanwhile, the control group received instruction using the lecture method.

After the intervention, both groups were administered the posttest to measure changes in mathematics performance. Reflective journals were also collected from learners in the experimental group to determine their motivational experiences while using the instructional model.

Data Analysis

Quantitative data gathered from the Mathematics Performance Test were encoded and analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics such as mean and standard deviation were used to determine students' levels of mathematics performance before and after the intervention.

To determine significant differences between and within groups, inferential statistical analyses were employed. The paired sample t-test was used to determine significant differences between pretest and posttest scores within each group, while the independent sample t-test was utilized to determine significant differences between the experimental and control groups after the intervention. The level of significance was set at 0.05.

Qualitative data gathered from the reflective journals were analyzed using Reflexive Thematic Analysis following Braun and Clarke's (2006, 2019, 2021) six-phase framework:

1. familiarization with the data,
2. generation of initial codes,
3. searching for themes,
4. reviewing themes,
5. defining and naming themes, and
6. producing the final report.

The researcher repeatedly reviewed and analyzed the journal entries to identify meaningful patterns and themes related to students' motivational experiences, engagement, confidence, and perceived usefulness of the Sets of Light Diagram Model.

Data saturation was considered achieved when no new themes or significant patterns emerged from the participants' responses. Responses unrelated to motivation, learning experiences, and engagement were excluded from the thematic coding process to maintain analytic focus and consistency.

The integration of quantitative and qualitative findings enabled the researcher to explain how students' motivational experiences contributed to improvements in mathematics performance, thereby strengthening the interpretation of the study's results.

3. Results

Mathematics Performance of Diverse Learners Before and After Exposure to the Sets of Light Diagram Model

Table 1 presents the pretest and posttest results of the diverse learners exposed to the Sets of Light Diagram Model (SLDM) and the lecture method in teaching *Mathematics in the Modern World*.

Table 1. Level of Mathematics Performance of Diverse Learners Before and After Exposure to the Sets of Light Diagram Model and Lecture Method

Group	N	Mean (Pretest)	SD	Description	Mean (Posttest)	SD	Description
Experimental Group (SLDM)	40	15.43	3.05	Developing	30.83	2.88	Proficient
Control Group (Lecture Method)	40	14.95	3.13	Developing	27.45	3.05	Approaching Proficiency

The findings revealed that both groups initially demonstrated comparable levels of mathematics performance before the intervention. The experimental group obtained a pretest mean score of 15.43 (SD = 3.05), while the control group obtained a mean score of 14.95 (SD = 3.13), both interpreted as "Developing."

After exposure to the instructional intervention, the experimental group achieved a posttest mean score of 30.83 (SD = 2.88), interpreted as "Proficient." Meanwhile, the control group obtained a posttest mean score of 27.45 (SD = 3.05), interpreted as "Approaching Proficiency."

The results indicate that learners exposed to the Sets of Light Diagram Model demonstrated higher improvements in mathematics performance compared to learners taught using the lecture method.

Motivational Experiences of Diverse Learners Using the Sets of Light Diagram Model

The qualitative analysis of learners' reflective journals generated several themes describing the motivational experiences of diverse learners exposed to the Sets of Light Diagram Model. The emerging themes included: (1) enhanced interest and enjoyment in learning, (2) increased confidence and independence, (3) improved understanding and perceived usefulness, and (4) collaboration and active engagement through peer interaction.

Theme 1: Enhanced Interest and Enjoyment in Learning

Learners described the Sets of Light Diagram Model as engaging, enjoyable, and visually stimulating. The instructional activities captured students' attention and encouraged active participation during mathematics lessons.

> *"It helps us focus more because the lights and activities make the lesson easier and more interesting to understand."*
> *"The model made mathematics more enjoyable because we were not just listening to discussions but actually participating in the activity."*

The responses indicate that learners experienced increased interest and enjoyment while using the Sets of Light Diagram Model during classroom instruction.

Theme 2: Increased Confidence and Independence

The findings also revealed that learners developed greater confidence in understanding and solving mathematical problems after exposure to the Sets of Light Diagram Model.

> *"Using the model gave me confidence because I could actually see and understand how the sets worked."*
> *"I became less afraid of answering because I understood the lesson better through the activities."*

The responses suggest that the instructional model contributed to learners' confidence and independence in mathematics learning.

Theme 3: Improved Understanding and Perceived Usefulness

Learners reported that the Sets of Light Diagram Model improved their understanding of mathematical concepts and enabled them to recognize the usefulness of mathematics in real-life situations.

> *"The model helped me understand sets better because I could actually see how the relationships worked."*
> *"I realized that mathematics can be useful in organizing information and solving real-life problems."*

The findings indicate that learners developed clearer conceptual understanding and stronger appreciation of the practical applications of mathematics.

Theme 4: Collaboration and Active Engagement Through Peer Interaction

Another theme that emerged from the reflective journals was collaboration and active engagement through peer interaction. Learners appreciated the opportunity to work collaboratively with classmates during instructional activities.

> *"Working with my classmates made the activities more enjoyable and helped me understand the lesson better."*
> *"The teamwork during the activities helped us learn from one another and become more active in class."*

The responses demonstrate that collaborative learning experiences contributed to learners' engagement and participation during mathematics instruction.

4.3 Difference in Mathematics Performance of Diverse Learners Before and After Exposure to the Sets of Light Diagram Model

To determine whether significant differences existed between the mathematics performance of learners exposed to the Sets of Light Diagram Model and those taught through the lecture method, paired and independent sample t-tests were conducted.

Table 2. Difference in Mathematics Performance of Diverse Learners Before and After Exposure to the Sets of Light Diagram Model and Lecture Method

Variable	Group Comparison	N	t	Sig. (2-tailed)	Effect Size (Cohen's d)	Interpretation
Performance – Pretest	SLDM vs. Lecture	40	0.688	0.494	—	Not Significant
Performance – Posttest	SLDM vs. Lecture	40	-5.091	0.000*	1.14 (Large)	Significant

*p < 0.05

The pretest findings revealed no significant difference between the mathematics performance of the experimental and control groups ($t = 0.688$, $p > 0.05$), indicating that both groups possessed comparable levels of mathematical competence before the intervention.

In contrast, the posttest findings revealed a statistically significant difference between the two groups ($t = -5.091$, $p < 0.05$). The learners exposed to the Sets of Light Diagram Model achieved significantly higher mathematics performance compared to those taught using the lecture method.

Furthermore, the computed effect size (Cohen's $d = 1.14$) indicated a large practical effect of the instructional intervention on learners' mathematics performance.

4. Discussion

The findings of the study revealed that the Sets of Light Diagram Model (SLDM) significantly improved the mathematics performance of diverse learners in Mathematics in the Modern World. Learners exposed to the instructional intervention achieved higher posttest scores compared to those taught using the lecture method. The findings suggest that interactive and manipulative instructional approaches contribute positively to learners' conceptual understanding, accuracy, and application of mathematical concepts. These results support the study of Cruz and Gomez (2023), who emphasized that model-based instructional strategies enhance students' mathematical understanding and classroom engagement. Similarly, Lee and Johnson (2023) found that visual and manipulative learning approaches improve learners' comprehension and participation in mathematics instruction.

The improvement in mathematics performance may be attributed to the interactive and experiential characteristics of the Sets of Light Diagram Model, which enabled learners to actively manipulate and visualize abstract mathematical relationships such as union, intersection, and complement. Through immediate visual feedback and collaborative exploration, learners were able to connect abstract concepts with concrete experiences. These findings align with Bruner's Constructivist Learning Theory, which explains that learners develop deeper understanding when actively involved in discovery-based and experiential learning activities (Bruner, 1996). The results therefore indicate that learner-centered instructional approaches grounded in constructivist principles can effectively support diverse learners in mathematics education.

The findings also revealed that the Sets of Light Diagram Model positively influenced learners' motivation in terms of interest, engagement, confidence, and perceived usefulness of mathematics. Learners described the instructional activities as interactive, enjoyable, and meaningful, indicating that the model promoted a more positive learning experience. These findings support Wang and Liu (2021), who emphasized that meaningful and visually stimulating instructional materials enhance learners' attention, engagement, and participation. Likewise, Eustaquio et al. (2025) explained that intrinsically motivated learners tend to demonstrate stronger persistence and deeper engagement in academic tasks.

The increased confidence demonstrated by learners after exposure to the Sets of Light Diagram Model also highlights the role of self-efficacy in mathematics learning. Learners reported feeling more confident in solving mathematical problems because the model enabled them to understand concepts through visualization and active participation. Muchacka and Dec (2023) explained that learners with stronger self-efficacy are more likely to persist despite academic difficulties and achieve better learning outcomes. Similarly, Campanilla (2025) identified mathematics self-efficacy as a significant predictor of learners' mathematics performance. Through active manipulation and collaborative learning activities, the SLDM helped reduce learners' anxiety and strengthened their confidence in mathematics.

The study further revealed that learners developed stronger appreciation of the relevance and usefulness of mathematics in real-life situations. Through hands-on activities and visual representations, learners recognized how mathematical concepts could be applied in organizing information and solving practical problems. These findings are consistent with Arili, Turmudi, and Dasari (2024), who emphasized that perceived usefulness and intrinsic motivation positively influence learners' engagement and problem-solving performance in mathematics. Amaral et al. (2024) likewise noted that learners become more motivated when instructional activities are meaningful and relevant to their experiences.

Another important finding of the study was the positive influence of collaboration and peer interaction on learners' engagement and participation. Learners appreciated the opportunity to work collaboratively during classroom activities, which contributed to active participation and shared understanding of mathematical concepts. These findings support Eustaquio et al. (2025), who emphasized that collaborative learning strengthens learners' intrinsic motivation and academic persistence. Similarly, Zakiya et al. (2024) noted that collaborative learning environments reduce mathematics anxiety and encourage learners' participation in problem-solving activities.

The statistically significant difference between the posttest scores of the experimental and control groups further confirms the effectiveness of the Sets of Light Diagram Model as an instructional intervention for diverse learners. The large effect size obtained in the study indicates that the instructional model produced meaningful educational impact on learners' mathematics achievement. These findings support Smith and Hill (2021), who explained that learner-centered instructional interventions contribute to significant academic gains in mathematics education. Likewise, Siadat (2023) emphasized that mastery-based and interactive instructional approaches strengthen learners' conceptual understanding and academic achievement.

The findings of the study suggest that the Sets of Light Diagram Model is an effective instructional innovation capable of addressing both the cognitive and affective dimensions of mathematics learning among diverse learners. By integrating visualization, interaction, collaboration, and experiential learning, the instructional model created a more inclusive and meaningful mathematics learning environment. The findings also imply that mathematics educators and educational institutions may benefit from integrating innovative and learner-centered instructional strategies that accommodate diverse learning needs and promote active learner participation.

Despite the positive findings of the study, several limitations should be acknowledged. The study was conducted within a single educational institution and involved a limited number of participants, which may affect the generalizability of the findings. The intervention was also limited to the topic of sets and was implemented over a four-week period only. Furthermore, motivation was explored qualitatively through reflective journals, which may be influenced by learners' personal perceptions and experiences. Future studies may investigate the effectiveness of the Sets of Light Diagram Model across different mathematical topics, educational levels, and learner populations using larger samples and longer intervention periods.

5. Conclusion

The study concluded that the Sets of Light Diagram Model (SLDM) is an effective instructional intervention for improving the mathematics performance and motivation of diverse learners in *Mathematics in the Modern World*. Learners exposed to the model achieved significantly higher mathematics performance compared to those taught using the lecture method. The findings also revealed that the SLDM enhanced learners' interest, engagement, confidence, perceived usefulness of mathematics, and collaborative participation during classroom activities.

The results suggest that interactive, visual, and manipulative instructional approaches can support both the cognitive and affective learning needs of diverse learners by making abstract mathematical concepts more meaningful and engaging.

Based on the findings, mathematics educators are encouraged to integrate innovative and learner-centered instructional strategies in mathematics instruction. Future studies may further examine the effectiveness of the Sets of Light Diagram Model across different mathematical topics, educational levels, and learner populations.

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