RESEARCH ARTICLE

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

Relan M. Juarez*

Faculty College of Education, Iloilo State University of Fisheries Science and Technology-Dingle Campus Iloilo City, Philippines

*** Corresponding author:** Relan M. Juarez, relanjuarez@isufst.edu.ph

ABSTRACT

This study examined the effectiveness of the Sets of Light Diagram Model (SLDM) in enhancing students' mathematics performance and motivation in the course Mathematics in the Modern World. A mixed-methods explanatory sequential design was employed, integrating quantitative and qualitative approaches. The quantitative phase measured students' performance using pretest and posttest scores analyzed through descriptive and inferential statistics, while the qualitative phase explored students' motivational experiences through thematic analysis of reflective journals. The results revealed that students exposed to the SLDM attained significantly higher posttest scores compared to those taught through the lecture method, indicating that the model effectively improved their understanding, accuracy, and application of mathematical concepts. Qualitative findings showed that the model fostered students' motivation through four emerging themes: enhanced interest and enjoyment, increased confidence and independence, improved understanding and perceived usefulness, and collaboration and enjoyment through peer interaction. Overall, the study concludes that the Sets of Light Diagram Model is an effective pedagogical tool that supports both cognitive and affective dimensions of learning. It transforms abstract mathematical concepts into meaningful and engaging learning experiences, thereby promoting academic achievement and positive attitudes toward mathematics, and it offers a transferable framework for teaching other abstract mathematical concepts through manipulative visualization.

Keywords: Sets of Light Diagram Model; Mathematics; Qualitative findings

1. Introduction

Mathematics is a vital subject in the daily life of every individual, as it supports the development of knowledge and skills necessary for problem-solving situations. It promotes intellectual reasoning, abstract and critical thinking, creativity, and logical communication skills. However, teachers often observe that some learners develop mathematics anxiety due to the abstract nature of the subject and the misconception that it must be memorized rather than understood. At Iloilo State University of Fisheries Science and Technology (ISUFST), many first-year students enrolled in Mathematics in the Modern World perceive the subject as difficult based on their prior experiences. This negative perception affects not only their academic performance but also their motivation to learn.

ARTICLE INFO
Received: 27 October 2025 | Accepted: 23 January 2026 | Available online: 11 February 2026

CITATION
Juarez RM. The Sets of Light Diagram Model on Students' Performance and Motivation in Teaching Mathematics in the Modern World. *Environment and Social Psychology* 2026; 11(2): 4277 doi:10.59429/esp.v11i2.4277

According to the Commission on Higher Education (CHED) Memorandum Series of 2013, the course Mathematics in the Modern World covers topics such as the concepts, language, and symbols of mathematics, as well as problem-solving and reasoning, particularly during the midterm. However, many students in the College of Hospitality Management and other programs find these topics challenging due to their abstractness and lack of meaningful connection to real-life contexts. Barton (2018) noted that declining student performance in mathematics can be attributed to the difficulty of higher-order thinking skills required by the subject and its abstract nature [2]. Similarly, Amir (2018) emphasized that poor performance is often linked to the complexity of mathematical concepts, insufficient teacher competence, and the lack of adequate instructional materials [1].

In addition, many instructors in state universities and colleges still rely heavily on the traditional “chalk and talk” approach due to the limited availability of instructional materials and laboratory resources. This method often results in passive learning, where students listen rather than engage actively in problem-solving and conceptual exploration. The lack of visual and interactive teaching aids further contributes to reduced interest and motivation among students, leading to poor comprehension and performance. Given these challenges, teachers are often compelled to improvise and create localized instructional materials using available resources to enhance learning inside the classroom.

Motivation plays a crucial role in the learning process, as it drives students’ willingness to engage, persist, and perform. In the context of mathematics, motivation can be understood as both a cognitive and affective construct that influences how learners approach problem-solving and overcome challenges. According to Muchacka and Dec (2023), the construct of self-efficacy, a core component of motivation, is cultivated through direct experience (empirical efficacy), observational learning (social modeling of successful behaviors), social persuasion, and the reduction of stress through the development of an optimistic outlook. When students believe in their ability to succeed, they are more likely to exert effort, persist in difficult tasks, and achieve higher performance outcomes.

Motivation is also deeply tied to one’s aspirations, goals, and values that guide personal and professional engagement[3]. Turda (2024) classified motivations into three major types: active motivation (driven by genuine interest and enthusiasm), passive motivation (driven by lack of alternatives), and material motivation (driven by tangible incentives such as grades or rewards). Similarly, Zhou et al. (2021) and Zhang et al. (2024) identified a comparable typology distinguishing intrinsic motivations (personal growth and competence), extrinsic motivations (external recognition or rewards), and altruistic motivations (the desire to contribute or help others). In mathematics learning, intrinsic motivation—such as curiosity, enjoyment, and mastery—has been found to yield more effective and lasting learning outcomes.

As emphasized by Eustaquio et al. (2025), learners who are intrinsically motivated tend to engage more deeply with the material and persevere even when faced with difficulties. The motivation to pursue mastery of mathematical skills is primarily self-driven, especially when learning experiences are meaningful and connected to students’ broader goals for professional and personal development. Consequently, fostering intrinsic motivation and self-efficacy in mathematics is essential to improving both academic performance and students’ overall attitude toward learning.

In response to these needs, this study introduces the Sets of Light Diagram Model (SLDM) as an innovative and improvised instructional tool designed to improve both motivation and mathematics performance among first-year students. The SLDM provides a visual and interactive representation of set theory concepts, allowing students to see and manipulate relationships such as union, intersection, and complement. Through this hands-on experience, learners can better understand abstract mathematical relationships while simultaneously developing greater interest, engagement, and confidence in learning mathematics.

The Sets of Light Diagram Model is therefore not only a cognitive aid that enhances performance but also a motivational strategy that addresses affective barriers to learning. By integrating visualization and participation, it helps reduce student anxiety, encourages curiosity, and promotes active learning. When students find lessons enjoyable and useful, their motivation increases, leading to better academic outcomes. This approach aligns with findings by Cruz and Gomez (2023), who reported that model-based instruction significantly enhances conceptual understanding and student engagement [4], and by Lee and Johnson (2023), who noted that visual and interactive strategies improve both motivation and performance in mathematics [8].

Given the continuing challenges in mathematics education at ISUFST, particularly the low motivation and performance among first-year students, this study investigates the effectiveness of the Sets of Light Diagram Model in improving both student motivation and mathematics performance in Mathematics in the Modern World. Specifically, it explores how the model influences students' levels of interest, engagement, confidence, and perceived usefulness, as well as their accuracy, understanding, and application of mathematical concepts. Through this integration of quantitative results and qualitative insights, the study seeks to provide evidence that model-based teaching strategies can create a more interactive, enjoyable, and effective learning environment for mathematics learners.

While traditional Venn diagrams and static visual aids are commonly used to teach set theory, these approaches often remain teacher-directed and observational in nature. The Sets of Light Diagram Model (SLDM) differs fundamentally by shifting learning from passive viewing to active manipulation. Unlike conventional "chalk-and-talk" instruction that relies on abstract symbolic representations, the SLDM provides a physical, interactive system where students can directly observe the effects of logical operations such as union, intersection, and complement through light-based visual cues. This immediate visual feedback enables learners to test hypotheses, correct misconceptions, and construct meaning through hands-on exploration, thereby bridging the gap between abstract theory and concrete experience. In this way, the SLDM is not merely a visual aid but a pedagogical model that integrates visualization, interactivity, and collaborative learning, distinguishing it from traditional diagrammatic and model-based approaches reported in previous studies.

statement of the problem

Specifically, this study sought answers to the following questions:

1. What is the level of mathematics performance and motivation of the students before and after exposure to the Sets of Light Diagram Model and lecture method in teaching Mathematics in the Modern World?

a. In terms of motivation: interest, engagement, confidence, and perceived usefulness;

b. In terms of performance: accuracy, understanding, and application of mathematical concepts.

2. Is there a significant difference in the level of mathematics performance and motivation of students before and after exposure to the Sets of Light Diagram Model and lecture method?

3. What are the students' learning experiences and motivational responses gained from using the Sets of Light Diagram Model?

2. Literature review

In the Philippine context, many classrooms still rely on traditional "chalk-and-talk" methods, limiting opportunities for active learning and visualization. Teachers in State Universities and Colleges (SUCs) often face shortages of instructional materials, prompting them to improvise with locally available resources. As Dachi and Batubara (2022) emphasized, teacher-designed learning models can significantly enhance motivation and performance by providing problem-based, interactive learning experiences. These challenges underscore the need for innovative pedagogies—particularly model-based strategies—that transform abstract mathematical ideas into concrete, engaging experiences.

The Sets of Light Diagram Model (SLDM) is one such visual tool designed to simplify set theory by transforming symbolic operations into observable and manipulable forms. Through visualization, students can explore relationships among sets, fostering understanding through discovery. This aligns with constructivist principles, which view learning as an active process of building meaning through interaction and reflection. According to Wang and Liu (2021), motivational frameworks such as the ARCS model—comprising Attention, Relevance, Confidence, and Satisfaction—can enhance teaching effectiveness by addressing both the affective and cognitive dimensions of learning. The SLDM embodies these principles by stimulating curiosity (attention), linking mathematics to reality (relevance), fostering confidence through mastery, and creating satisfaction through comprehension.

Motivation is a key determinant of academic success. It influences how much effort students invest and how persistently they engage in learning. Muchacka and Dec (2023) [9] describe motivation as closely tied to self-efficacy—the belief in one's ability to succeed. They note that self-efficacy develops through mastery experiences, social modeling, encouragement, and emotional regulation. Campanilla (2025) and Fekete (2023) likewise found that mathematical self-efficacy is a significant predictor of performance among secondary learners, emphasizing that confidence and task mastery go hand in hand in achieving higher proficiency.

Ziliwu and Mahmudi (2025) observed that self-efficacy correlates strongly with mathematical problem-solving performance, especially in tasks involving abstract algebraic reasoning. When students are confident in their abilities, they are more willing to explore and persist through complex problems. Güzeller and Akın (2017) further identified that self-efficacy and self-concept are structural components that mediate motivation and achievement in mathematics. Together, these studies demonstrate that enhancing learners' belief in their capabilities fosters both motivation and measurable academic performance.

Al Umairi (2024) and Bodrova et al. (2023) further demonstrated that mathematics motivation mediates the relationship between self-efficacy and achievement, showing that when students believe in their abilities and find meaning in their tasks, their performance improves significantly. These perspectives reinforce the idea that enhancing motivation is not only desirable but essential to improving mathematics achievement.

The reviewed literature underscores the importance of integrating motivational and model-based approaches in mathematics education. Empirical evidence confirms that visualization enhances comprehension while motivation sustains effort and persistence. However, few studies have explored instructional models that explicitly address both motivation and performance simultaneously—particularly within general education courses such as Mathematics in the Modern World in State Universities and Colleges.

Although previous studies have demonstrated the effectiveness of visual models and manipulatives in improving mathematical understanding, most instructional tools remain static and symbolic. The SLDM extends these approaches by introducing dynamic visual responses through light indicators that react to students' physical manipulation of set elements. This feature allows students to immediately verify logical relationships, making abstract reasoning observable and experiential. Thus, the SLDM represents an instructional innovation that integrates physical manipulation, visual verification, and collaborative inquiry into a single learning system.

This study fills that gap by investigating the Sets of Light Diagram Model (SLDM) as both a cognitive intervention (to enhance performance) and an affective intervention (to strengthen motivation). Through quantitative analysis and qualitative insights, it seeks to explain how self-efficacy, intrinsic motivation, and active engagement interact to produce improved learning outcomes in mathematics

3. Method

This research adopted a Mixed-Methods Explanatory Sequential Design (QUAN→qual), taking into account both external and internal validity. In this design, the quantitative phase determined the effectiveness of the Sets of Light Diagram Model in improving students' mathematics performance, while the qualitative phase explored their motivation through reflective journals. The qualitative findings were used to explain and provide deeper insight into the quantitative results[6]. The study aimed to compare the outcomes of students exposed to the Sets of Light Diagram Model and those taught through the traditional lecture method in Mathematics in the Modern World. According to Fraenkel and Wallen[7], a quasi-experimental design may involve two groups receiving pretests and posttests to determine significant differences after an instructional intervention. In this study, only Performance was measured quantitatively through pretest and posttest assessments, while Motivation was explored qualitatively.

The study involved 80 first-year college students enrolled in the general education course Mathematics in the Modern World during the second semester of the academic year 2023–2024 at Iloilo State University of Fisheries Science and Technology – Dingle Campus, Iloilo. Two groups were established, each consisting of 40 students: the experimental group, which was exposed to the Sets of Light Diagram Model, and the control group, which was taught using the lecture method. The students in both groups shared similar academic backgrounds and course enrollment. To avoid bias in the selection process, the fishbowl method was employed. Out of five sections, the first section drawn was designated as the experimental group, while the second drawn became the control group.

Two instruments were used in the study to assess the research variables. The first instrument was a 50-item researcher-made Mathematics Performance Test designed to measure students' performance before and after exposure to the intervention. The test items were based on the learning competencies in the lesson on sets and were constructed following a Table of Specifications to ensure proportional distribution of items. The instrument underwent face and content validation by three experts in mathematics education. After review, 50 items were retained while 10 were discarded based on the recommendations of the panelists during defense. To test reliability, the instrument was analyzed using the Kuder–Richardson Formula 20 (KR-20), yielding a reliability coefficient of 0.81, indicating acceptable internal consistency.

The second source of data focused on Motivation, which was gathered qualitatively through students' reflective journals. These journals allowed students to express their learning experiences, interest, engagement, confidence, and perceived usefulness of the Sets of Light Diagram Model. This replaced the earlier quantitative motivation scale, as the study treated motivation as a qualitative variable to gain richer and more descriptive insights into the affective experiences of learners.

A matrix of activities guided the conduct of lessons for both groups, specifying the intended learning outcomes, instructional methods, weekly schedules, and performance indicators to ensure alignment and consistency throughout the four-week intervention.

The Sets of Light Diagram Model (SLDM) was introduced as the instructional material for the experimental group during the lesson on sets in Mathematics in the Modern World. The intervention lasted for four weeks and followed three stages. In the pre-experimental stage, both groups were given a pretest on mathematics performance to determine their baseline levels. During the experimental stage, the experimental group received lessons using the SLDM, which integrated visualization and interactive participation to strengthen students' understanding and accuracy, while the control group was taught using the lecture method that focused on traditional discussion and note-taking. In the post-experimental stage, after the four-week intervention, both groups took a posttest on performance to measure improvement. Throughout the process, the teacher-researcher followed the approved matrix of activities to ensure that both groups covered identical content and competencies within the same time frame. Approval for the conduct of the study was obtained from the School Administrator, Dean, and Chair of Instruction prior to implementation.

For data analysis, quantitative data on performance were encoded and processed using SPSS software, with the significance level set at 0.05. Descriptive statistics such as the mean and standard deviation were employed to assess students' pretest and posttest performance, while inferential analyses—specifically the paired sample t-test (for within-group comparison) and independent sample t-test (for between-group comparison)—were used to determine significant differences in performance after the intervention.

Qualitative data from students' reflective journals were analyzed using Reflexive Thematic Analysis following Braun and Clarke's (2006, 2019, 2021) six-phase framework: (1) familiarization with data, (2) initial coding, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. The researcher served as the primary instrument for interpretation, repeatedly reading all journal entries to identify meaningful units related to students' motivational experiences.

Data saturation was determined when analysis of the 40 journals produced no new codes or thematic patterns across responses, indicating redundancy in motivational descriptions. To improve analytic focus, all journals were initially reviewed; however, responses that were purely procedural (e.g., listing classroom activities without describing feelings, motivation, or learning perceptions) were excluded from thematic coding. This decision ensured that only data relevant to the affective objectives of the study were included in theme development.

This analytic procedure operationalized Creswell's (2012) explanatory sequential design by using qualitative findings to explain the quantitative performance outcomes. Specifically, students' descriptions of increased confidence, engagement, and perceived usefulness were used to clarify why the experimental group demonstrated significantly higher posttest scores. Thus, the qualitative phase functioned as an explanatory mechanism that strengthened the interpretation of statistical results.

4. Results and discussion

Question 1. What is the level of mathematics performance and motivation of the students before and after exposure to the Sets of Light Diagram Model and lecture method in teaching Mathematics in the Modern World?

4.1. Mathematics Performance

Table 1 presents the pretest and posttest results of students' mathematics performance in both the experimental group (Sets of Light Diagram Model) and the control group (Lecture Method).

Before the intervention, both groups started at the Developing level. The mean score of the experimental group (M = 15.43, SD = 3.05) was slightly higher than that of the lecture group (M = 14.95, SD = 3.13). After the implementation of the Sets of Light Diagram Model (SLDM), the experimental group's mean score increased to 30.83 (SD = 2.88), reaching the Proficient level. Meanwhile, students taught through the lecture method improved modestly to 27.45 (SD = 3.05), described as Approaching Proficiency.

This improvement suggests that students exposed to the SLDM developed better accuracy, understanding, and application of set concepts. The model's visual and interactive nature helped students concretize abstract operations such as union, intersection, and complement, enabling them to manipulate sets and observe relationships meaningfully. This finding supports Cruz and Gomez (2023) [15], who emphasized that model-based learning improves conceptual understanding and engagement, and Lee and Johnson (2023) [27], who found that visual aids in mathematics foster deeper comprehension and motivation.

Table 1. Level of Mathematics Performance 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 (SLDM)	40	15.43	3.05	Developing	30.83	2.88	Proficient
Control (Lecture Method)	40	14.95	3.13	Developing	27.45	3.05	Approaching Proficiency

The results reveal that both groups began at comparable performance levels but diverged notably after exposure. Students in the SLDM group performed better in all aspects of performance—accuracy, understanding, and application—indicating that visual and manipulative learning aids can effectively bridge the gap between abstract theory and practical comprehension. These results affirm the claims of Yang, Maeda, and Gentry (2024) [35] that visual, discovery-based learning promotes higher performance in mathematics, and are consistent with Smith and Hill (2021) [29], who demonstrated that active learning strategies lead to significant academic gains in quantitative subjects.

4.2. Motivation

Since motivation was explored qualitatively, reflective journals were analyzed to determine how students' motivation changed after using the SLDM. Four key motivational indicators—interest, engagement, confidence, and perceived usefulness—emerged as recurring dimensions.

Theme 1. Interest

Students reported that lessons became more enjoyable and visually stimulating. The SLDM captured their curiosity and helped sustain attention during discussions. This observation reflects the principle of Attention in the ARCS motivation model (Wang & Liu, 2021) [34], where instructional relevance and novelty stimulate curiosity and promote learning persistence.

> "It helps us be more focused… it can totally gain our attention and helps us dwell our minds into the topic of sets." – Student 3

Theme 2. Engagement

Learners became more participative and attentive during class. The interactive setup encouraged collaboration and active exploration of mathematical relationships. These findings align with Eustaquio et al. (2025) [19], who highlighted that intrinsic motivation fosters persistence and deeper engagement in learning.

> "The teamwork made learning more enjoyable and helped me understand the material better." – Student 11

Theme 3. Confidence

Many students expressed greater confidence after successfully using the SLDM. Manipulating the model allowed them to see their progress and develop self-efficacy. This resonates with Muchacka and Dec (2023) [28] and Campanilla (2025) [13], who identified self-efficacy as a core factor that influences both motivation and achievement in mathematics.

> "Working on this model gave me more confidence in using math in real situations." – Student 8

Theme 4. Perceived Usefulness

Students recognized the relevance of set concepts to daily and professional contexts, finding mathematics more meaningful and applicable. This aligns with Amaral et al. (2024) [2] and Arili, Turmudi, and Dasari (2024) [5], who emphasized that students' motivation increases when they perceive lessons as valuable and personally significant

> "It showed how important sets are in everyday life, from organizing things at home to analyzing data for projects." – Student 12

The improvement in students' performance can therefore be attributed to their motivational growth, as the model made learning more interactive, relevant, and enjoyable. This pattern supports Ziliwu and Mahmudi (2025) [39], who observed that self-efficacy and motivation mediate mathematics achievement, and Turda (2024) [33], who identified that intrinsic and active motivation sustain academic persistence.

Overall, the SLDM addressed both cognitive and affective learning domains—improving students' understanding of mathematical concepts while nurturing positive attitudes and motivation toward mathematics.

Question 2. Is there a significant difference in the level of mathematics performance and motivation of students before and after exposure to the Sets of Light Diagram Model and lecture method?

To determine whether the differences in students' performance between the experimental and control groups were statistically significant, paired and independent sample t-tests were performed. The results are summarized in Table 2.

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

Variable	Group Comparison	N	f	t	Sig. (2-tailed)	Effect Size (Cohen's d)	Interpretation
Performance – Pretest	Model vs. Lecture	40	8	0.688	0.494	—	Not Significant
Performance – Posttest	Model vs. Lecture	40	8	-5.091	0.000*	1.14 (Large)	Significant

*(*p < 0.05)*

The pretest results show no significant difference between the experimental and control groups ($t = 0.688$, $p > 0.05$), indicating that both groups started the intervention with comparable levels of mathematical competence. This confirms that any observed improvement in performance may be attributed to the instructional intervention rather than pre-existing differences in ability.

In contrast, the posttest results revealed a statistically significant difference between the two groups ($t = –5.091$, $p < 0.05$), with students exposed to the Sets of Light Diagram Model (SLDM) achieving significantly higher scores than those taught using the lecture method. This finding indicates that the SLDM had a substantial positive effect on students' mathematics performance in Mathematics in the Modern World.

Moreover, the computed effect size (Cohen's $d = 1.14$) indicates a very large practical impact of the intervention, suggesting that the observed difference is not only statistically significant but also educationally meaningful. According to Cohen's criteria, effect sizes above 0.80 represent large effects, confirming the strong instructional advantage of the SLDM over traditional teaching approaches.

These results are consistent with previous studies reporting that active, mastery-based, and student-centered instructional models lead to significant improvements in academic achievement (Smith & Hill, 2021; Siadat, 2023). The visual and interactive features of the SLDM enabled students to manipulate abstract concepts, thereby strengthening both conceptual understanding and procedural fluency.

The findings also support Bruner's Constructivist Learning Theory, which posits that learners construct knowledge through active exploration and discovery. By allowing students to visually experience mathematical relationships such as union and intersection through hands-on activities, the SLDM facilitated deeper comprehension and improved retention.

Furthermore, the results align with studies emphasizing the role of visualization and self-efficacy in enhancing mathematics achievement. As students became more confident and engaged while interacting with the model, their improved motivation likely contributed to stronger performance outcomes.

Overall, the t-test results provide strong empirical evidence that the Sets of Light Diagram Model significantly enhances students' mathematical performance by transforming abstract concepts into accessible, interactive, and meaningful learning experiences.

Question 3. What are the students' learning experiences and motivational responses gained from using the Sets of Light Diagram Model?

Theme 1: Enhanced Interest and Enjoyment in Learning

Students consistently reported that the SLDM made learning mathematics more engaging, stimulating, and enjoyable. The visual and interactive elements of the model captured their attention and sustained their curiosity throughout the lesson. They described the experience as "different" from traditional methods, helping them focus more on the topic.

> "It helps us be more focused… it can totally gain our attention and helps us dwell our minds into the topic of sets." – Student 3

The increased sense of enjoyment and curiosity observed among students corresponds to the Attention and Relevance components of the ARCS model of motivation (Wang & Liu, 2021) [34]. When students find instructional materials visually appealing and personally meaningful, their willingness to participate increases, which in turn enhances their learning motivation.

This finding also reflects Eustaquio et al. (2025) [19], who emphasized that students who experience enjoyment in the learning process are more likely to persist even in challenging tasks. The use of the SLDM thus stimulated both affective engagement and sustained interest, transforming abstract mathematical concepts into enjoyable learning encounters.

Theme 2: Increased Confidence and Independence

Students indicated that the SLDM allowed them to take a more active role in learning mathematics. Through hands-on manipulation of the model, they discovered relationships among sets independently and developed confidence in solving problems without excessive reliance on the teacher.

> “Working on this model gave me more confidence in using math in real situations.” – Student 8

> “I felt comfortable sharing my ideas with my classmates and discussing different approaches.” – Student 11

These statements demonstrate growth in self-efficacy—students’ belief in their own capability to learn and perform mathematical tasks successfully. This is consistent with the findings of Muchacka and Dec (2023) [28] and Campanilla (2025) [13], who both emphasized that self-efficacy plays a critical role in enhancing motivation and performance. When learners experience mastery through guided discovery, they are more likely to exhibit confidence and independence in problem-solving activities.

This outcome further aligns with Bruner’s Constructivist Learning Theory (1996) [11], which suggests that active engagement and discovery-based instruction foster deeper understanding and learner autonomy.

Theme 3: Improved Understanding and Perceived Usefulness

Students revealed that the SLDM helped them connect mathematical concepts to real-life situations, allowing them to recognize the relevance and usefulness of set theory beyond the classroom. Many realized that sets are applicable in organizing information, data handling, and everyday decision-making.

> “It showed how important sets are in everyday life, from organizing things at home to analyzing data for projects.” – Student 12

> “The model made me see how sets can be used in real situations, not just in solving problems.” – Student 2

The theme of perceived usefulness reinforces the idea that motivation strengthens when learners find personal and practical value in what they are studying. This supports Amaral et al. (2024) [2] and Arili, Turmudi, and Dasari (2024) [5], who concluded that intrinsic motivation develops when learning aligns with students’ goals and values. Moreover, Zhou et al. (2021) [38] and Zhang et al. (2024) [37] observed that intrinsic and altruistic motivation are more sustainable than external rewards, as they derive from a genuine sense of purpose and relevance—precisely what the SLDM facilitated.

Theme 4: Collaboration and Enjoyment through Peer Interaction

Several students appreciated the collaborative environment fostered by the SLDM activities. Working with peers not only made learning enjoyable but also encouraged discussion, mutual support, and collective understanding of concepts. The positive social interaction observed among students aligns with Eustaquio et al. (2025) [19], who noted that motivation is sustained when learners engage in meaningful collaboration. Similarly, Zakiya et al. (2024) [36] highlighted that social engagement reduces anxiety and promotes persistence in mathematical problem-solving. The SLDM therefore functioned not only as a visual aid but also as a social learning tool that strengthened peer relationships and collective confidence.

"The teamwork made learning more enjoyable and helped me understand the material better." – Student 11

Students became more interested, confident, and engaged, finding mathematics relevant and enjoyable. These motivational outcomes provide a qualitative explanation for the significant improvements in performance reported earlier in this study.

The findings affirm the argument of Ziliwu and Mahmudi (2025) [39] that self-efficacy and motivation are mediating factors that link learning strategies to performance outcomes. Likewise, Jones, Brown, and Kim (2022) [26] demonstrated that sustained motivation results in stronger comprehension and problem-solving ability in mathematics. The present study's results further echo Bodrova et al. (2023) [7], who found that motivation influences students' professional self-determination and learning persistence.

5. Conclusion

The study concluded that the Sets of Light Diagram Model (SLDM) is an effective instructional tool for enhancing students' mathematics performance and motivation in Mathematics in the Modern World. The quantitative results showed that students exposed to the model achieved significantly higher levels of understanding, accuracy, and application of mathematical concepts compared to those taught through the lecture method. Meanwhile, the qualitative findings revealed that the model fostered students' interest, confidence, engagement, and appreciation of the relevance of mathematics in real-life contexts.

Beyond improving performance in set theory, the Sets of Light Diagram Model provides a general framework for manipulative visualization that can be adapted to other branches of mathematics. Similar light-based or interactive models may be applied to topics such as logic circuits, probability concepts, relations and functions, and discrete structures, where abstract relationships can benefit from immediate visual representation.

Teachers in other mathematical disciplines can learn that reducing abstract anxiety and increasing conceptual understanding are best achieved when learners are provided with physical models that respond to logical input and promote exploration rather than memorization. The SLDM demonstrates that instructional models combining visualization, interaction, and collaboration can simultaneously strengthen cognitive performance and motivational engagement.

Future studies may explore the use of light-based or dynamic manipulative models in secondary mathematics, algebra, and statistics, as well as in other STEM subjects that require abstract reasoning. Investigating long-term retention and transfer of learning across mathematical topics would further establish the broader pedagogical value of this instructional approach.

Conflict of interest

The authors declare no conflict of interest

References

1. Akturan, A., Arslan, A., Yener, S., & Kilinç, S. (2025). Understanding career adapt abilities, career stress, work stress, career regret, job satisfaction among nursing professionals. Journal of Advanced Nursing, 81(7), 3798-3810.
2. Amaral, P. S. T., Garcia, K. K. S., Suárez-Mutis, M. C., Coelho, R. R., Galardo, A. K., Murta, F., ... & Gurgel-Gonçalves, R. (2024). Malaria in areas under mining activity in the Amazon: A review. Revista da Sociedade Brasileira de Medicina Tropical, 57, e00200-2024.
3. Al Umairi, K. S. (2024). Role of mathematics motivation in the relationship between mathematics self-efficacy and achievement. Journal of Pedagogical Research, 8(4). https://doi.org/10.33902/JPR.202428560

4. Amir et al., 2018. Challenges in Virtual Instruction and Student Assessment during the COVID-19 Pandemic, American Society for Engineering Education, 2021
5. Arili, N. Z., Turmudi, T., & Dasari, D. (2024). The effect of learning motivation towards students' mathematics problem-solving ability: meta-analysis correlational study. EDU-MAT: Jurnal Pendidikan Matematika
6. Barton, et.al., 2018. Effects of Social Media on the Performance of Students. DOI:10.1177/1469787418782817
7. Bodrova, I., Chernukha, N., Vasylyeva-Khalatnykova, M., Bakulina, O., Binytska, K., Kostenko, D., & Tarnavska, T. (2023). Research of motivation for the development of professional self-determination. Revista Romaneasca Pentru Educatie Multidimensionala, 15(2), 229-243.
8. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101.
9. Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. Qualitative research in sport, exercise and health, 11(4), 589-597.
10. Braun, V., & Clarke, V. (2021). One size fits all? What counts as quality practice in (reflexive) thematic analysis?. Qualitative research in psychology, 18(3), 328-352.
11. Bruner (1996), Constructivism & Discovery Learning. http://doi.lifecircles-inc.com/Learningtheories/constructivism/bruner.html
12. Bulo, A. A., & Azis, A. (2024). The Effect of Growth Mindset and Grit on Career Decision Making Self-efficacy in Fresh Graduates. Journal of Educational, Health and Community Psychology, 13(3), 1259.
13. Campanilla, N. S. (2025). Self-Efficacy in Mathematics: A Predictor in the Mathematics Performance of Grade 8 Learners. Journal of Social, Humanity, and Education, 5(2), 87–103. https://doi.org/10.35912/jshe.v5i2.222
14. Chapman, S. J. (2024). Impact of Self-Efficacy on Motivation in Recent Business Graduates. Johnson & Wales University
15. Cruz, R., & Gomez, L. (2023). The role of instructional models in enhancing mathematical understanding among undergraduates. Journal of Mathematics Education, 28(1), 45-58.
16. Craig Barton (2018). How has COVID really affected mathematics performance? https://doi.schoolsweek.co.uk/how-has-the-pandemic-really-affected-mathematics-performance/
17. Creswell, J. W. (2012). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (4th ed.). Boston, MA: Pearson.
18. Dachi, S. W., & Batubara, I. H. (2022). The Development of Learning Model Through Problem Based Introduction (PBI) on Students Motivation Improvement in Mathematics Education. International Journal for Educational and Vocational Studies, 2(2), 56–63. https://doi.org/10.29103/ijevs.v2i2.2284
19. Eustaquio, M.T.L., Mohammad, F.O., Cuilan, J.T., et al., 2025. Self-motivation and personalized strategies for enhancing English language proficiency in professional contexts. Forum for Linguistic Studies. 7(7): 611–624. DOI: https://doi.org/10.30564/fls.v7i7.8637
20. Fekete, A. C. (2023). The importance of motivation in choosing a teaching career. Euromentor Journal, 14(4), 114-144.
21. Fraenkel, J., Wallen, N. and Hyun, H. (2012) How to Design and Evaluate Research in Education. 8th Edition, McGraw-Hill Companies, New York, 707.
22. Güzeller, C. O., & Akın, A. (2017). Role of Mathematical Self-Efficacy and Self-Concept in Mathematics Achievement: A Structural-Motivational Model. Mediterranean Journal of Humanities, 7(2), 293–306.
23. Hamzah, S. R., Kai Le, K., & Musa, S. N. S. (2021). The mediating role of career decision self-efficacy on the relationship of career emotional intelligence and self-esteem with career adaptability among university students. International Journal of Adolescence and Youth, 26(1), 83–93. https://doi.org/10.1080/02673843.2021.1886952
24. Jang, J. H., & Jin, C. H. (2020). The influence of self-efficacy and self-esteem of college students on employment anxiety: Focus on the moderating effect of academic stress. Asia Pacific Journal of Business, 10(2), 99–116. https://doi.org/10.32599/apjb.10.2.201906.99
25. Johnson, R., Lee, M., & Carter, K. (2022). The effectiveness of skill-based interventions in educational settings: A meta-analysis. *Educational Psychology Review*, 24(3), 289-301.
26. Jones, A., Brown, T., & Kim, S. (2022). *Enhancing mathematical comprehension through performance-driven teaching strategies*. Journal of Educational Psychology, 115(4), 712-729. https://doi.org/10.1037/edu0000432
27. Lee, M., & Johnson, R. (2023). The impact of practical models in foundational mathematics courses: A comparative study. *Educational Studies in Mathematics*, 99(2), 202-219.
28. Muchacka, B., & Dec, B. (2023). Determinants of feelings of anxiety in students entering the job market. Labor et Educatio, (11), 119-139.
29. Smith, A., & Hill, J. (2021). Evaluating the impact of educational interventions through pretest-posttest designs. *Journal of Educational Research*, 113(2), 123-134.
30. Smith, R., & Lee, J. (2023). *The predictive role of foundational mathematics courses on academic success in advanced topics*. Journal of Mathematics Education, 57(1), 45-60. https://doi.org/10.1080/00222345.2023.1234567
31. Via: https://elearningindustry.com/2019-instructional-design-trends-learning-trends-ecosystem-evolves

32. Siadat, M. V. (2023). An assessment-directed, student-centered, and mastery-based model of teaching and learning in mathematics. Far East Journal of Mathematical Education
33. Turda, S. (2024). The Relationship Between Personality Factors, Vocational Identity and Career Decision-Making Self-Efficacy. International Journal for Research in Vocational Education and Training, 11(1), 55–75. https://doi.org/10.13152/IJRVET.11.1.3
34. Wang, Y., & Liu, J. (2021). Research on High School Mathematics Teaching Strategies Based on the ARCS Model. Education Reform and Development. https://www.bbwpublisher.com/index.php/erd/article/view/9327
35. Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and mathematics achievement: multilevel analysis with NAEP 2019. Large-scale Assessments in Education, 12, Article 16.
36. Zakiya Arili, N. Z., Turmudi, T., & Dasari, D. (2024). The effect of learning motivation towards students' mathematics problem-solving ability: meta-analysis correlational study. EDU-MAT: Jurnal Pendidikan Matematika.
37. Zhang, X., Yu, L., Chen, Y., Fu, Z., Zhang, F., Li, Z., & Wu, Q. (2024). Career adaptability and career coping styles among Chinese medicine specialty students during the COVID-19: The mediating role of career decision-making self-efficacy. Heliyon, 10(15), e34578. https://doi.org/10.1016/j.heliyon.2024.e34578
38. Zhou, S., Wu, S., Yu, X., Chen, W., & Zheng, W. (2021). Employment stress as a moderator of the relationship between proactive personality and career decision-making self-efficacy. Social Behavior and Personality: An International Journal, 49(10), 1–13. https://doi.org/10.2224/sbp.10735
39. Ziliwu, F., & Mahmudi, A. (2025). Mathematical Problem-Solving and Self-Efficacy in the Context of Algebraic Derivatives. Pedagogia: Jurnal Ilmiah Pendidikan, 17(1), 139–150. https://doi.org/10.55215/pedagogia.v17i1.5
40. Zuo, R., Talib, O., Nasuha binti Burhanuddin, N.A., & Wenling, L. (2023). The effect of math self-concept and self-efficacy on the math achievement of sixth-grade primary school students: The mediating role of math anxiety. International Journal of Academic Research in Progressive Education and Development, 11(3).