



The Effect of Multi-Representation-Based Physics Learning on Students' Representation Translation Ability in Linear Motion Topics

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Abstract: The students' disinterest and low ability to understand and translate physics concepts are challenges in physics learning. One of the solutions in this field is to implement a learning approach that can enhance students' interest and deepen their understanding and ability to translate abstract concepts of physics. This study aims to investigate the effect of implementing multi-representation-based physics learning on students' representation translation abilities in linear motion. This study employs a quasi-experimental design with a non-equivalent control group pretest-posttest. This study involved 62 students from two eleventh-grade classes at senior high schools in Bandung, which were selected using purposive sampling. The experimental group received Lesh-Janvier multi-representation-based learning treatment, while the control group received conventional teacher-centered learning treatment. These research instruments include tests for representation translation ability and student response questionnaires. The results indicate that the representation translation ability of the experimental group shows a significant improvement, with an n-gain value of 0.74. Students' responses to the learning process were also positive. Hypothesis testing using IBM SPSS shows a significant result (Asymp. Sig. < 0.001) for the experimental group, indicating a significant difference. Thus, multi-representation-based learning positively affects students' representation translation abilities.

Keywords: multi representations, representation translation ability, linear motion.

▪ INTRODUCTION

Physics is the science that studies the laws of nature as the basis for the occurrence of physical phenomena related to matter and energy, the motion of particles and waves, interactions between particles, the properties of molecules, atoms, atomic nuclei, as well as larger-scale systems such as gases, liquids, and solids (Connerade, 2023; Park et al., 2019). The object of study in physics learning is inanimate objects and natural phenomena that are related to each other. This challenge requires students to understand abstract concepts and symbolic mathematical expressions that contrast real-world phenomena (Ainsworth et al., 2011; Rau, 2017).

The physics learning process in the Merdeka curriculum emphasizes students' understanding of physics and science process skills. The competencies that students must achieve after participating in physics learning are referred to as Learning Outcomes (CP), which have been identified to balance soft and hard skills, such as knowledge (cognitive), attitude (affective), and psychomotor skills (Kemendikbud, 2022). One of the skills that students must have is the representational ability to understand abstract physics concepts (Ainsworth et al., 2011). Representational abilities play a major role in physics learning because they help students to connect abstract concepts with experimental observation while also strengthening problem-solving and higher-level thinking skills (Opfermann et al., 2017; Worku et al., 2025). The development of representation skills is an important part of physics learning, which aligns with the goals of Profil Pelajar Pancasila: independence, innovation, critical thinking, creativity, and collaboration.

Effectively, students must understand the use of representations in explaining and translating a concept from one form to another (Cheng & Gilbert, 2009; Seufert, 2003). Janvier (1987) defines the translation of representation as the ability of students to connect one representation with another. Representation translation ability is not only about translating information from one form of representation to another and understanding the relationship between the two (Ainsworth et al., 2011; Leaf, 2017). This ability helps students understand concepts that are difficult to grasp through a single representation. The other representations can potentially provide a different perspective that can help overcome difficulties in understanding the concept (Ainsworth et al., 2011; Hasbullah et al., 2019; Larasati et al., 2019; Munfaridah et al., 2021; Rexigel et al., 2024).

Ideally, physics learning is expected to produce students with a deep understanding of concepts and the ability to translate information and understand the relationship between the two. However, there is often a difference between expectations and actual achievements. Many students still have difficulty connecting physics concepts with their application, and their problem-solving skills are still limited (Nielsen et al., 2022; Rau, 2017; Sari et al., 2023; Tamyiz et al., 2020; Worku et al., 2025). Research shows that even though students are used to seeing various representations, they still struggle to transform information between them (Munfaridah et al., 2021; Nielsen et al., 2022; Rexigel et al., 2024). For example, in a free-fall experiment, students can explain the movement of objects using conceptual diagrams, use mathematical equations to calculate the position and speed of falling objects, and explain the changes in their variables in tables or graphs. Students often do this kind of thing because they often find the use of representations, but translating information between representations is difficult. Such behavior indicates that students' conceptual understanding is fragmentary, so it is insufficient to support effective representation translation (Rau, 2017; Worku et al., 2025).

Based on a preliminary study at a senior high school in Bandung, an interview with a physics teacher revealed several problems that arise in the learning process of linear motion. The teacher states that most students have difficulty using physics concepts and formulas to work on the problem and the relationship between the physics concepts themselves. Students tend to just memorize formulas without really understanding the meaning of the physics behind them. Therefore, students often struggle to translate questions presented in graphs or narrative descriptions into other formats. The teacher mentioned that the learning approach used so far is still conventional, such as lectures, practicums, and working on the exercises. As a result, the physics learning appears monotonous. This results in a gap between the learning achievements and the expected competencies, along with the results achieved. The causes include traditional and less varied teaching methods, the lack of interesting learning media, and the differences in students' interest and motivation in physics.

In the development of the learning process, an educator plays a role in facilitating the needs of their students. Therefore, physics learning always gets attention from physics educators who make the best efforts for their students. One of the efforts in physics teaching that can meet the needs of students is learning through multi-representation. The reason for using multi-representation in physics teaching is to structure physics, which uses mathematical modeling to describe phenomena and to explain the relationships between variables (Opfermann et al., 2017; Rau, 2017). Using multi-representation in

physics learning is important because it offers different ways to communicate and think about ideas, helping students understand concepts better and solve physics problems (Munfaridah et al., 2021; Nielsen et al., 2022; Rexigel et al., 2024; Treagust et al., 2017; Widianingtiyas et al., 2015). Through multi-representation-based learning, students are expected to gain a deeper understanding of concepts and skills in thinking and communicating, as well as increased interest and motivation to learn (Ainsworth et al., 2011; Wayan District et al., 2021; Worku et al., 2025). Therefore, using multi-representation-based physics learning in schools becomes a solution to stimulate students' representation translation abilities.

Claude Janvier investigated the use of multi-representation in-depth and created a book on representation problems in mathematics learning. According to Janvier (1987), students need to understand a concept from various points of view, through different representations, such as verbal, visual, and symbolic. Janvier emphasized the importance of representation translation. Janvier's model highlights the importance of active learning in the multi-representation learning process. Students are not just passive recipients of information but they actively build their understanding through exploration, transformation, and integration.

On the other hand, Lesh (1979) argues that the multi-representation learning model is a learning approach that emphasizes the presentation of information in various forms of representation, such as verbal, visual, and kinesthetic. This approach assumes that individuals have different ways of learning and that presenting information in different forms of representation can help students better understand concepts. The Lesh model indicates that if a student understands an idea, they must be able to make representation translations. The combined model of Lesh and Janvier for multi-representation learning utilizes the strengths of both individual approaches to create a robust framework for enhancing representation translation abilities.

Previous research has shown that multi-representation-based learning improves students' understanding and skills. Wayan District et al. (2021) and Worku et al. (2025) evaluated the effect of multi-representation-based learning models on conceptual understanding and problem-solving skills in the topic of electricity. The results indicate that this approach can significantly improve students' understanding of concepts and problem-solving skills compared to traditional models. Furthermore, Nielsen et al. (2022) reported that students achieve a better conceptual understanding when they succeed in translating representations. The use of various representations in physics learning not only improves understanding and mastery of concepts but also encourages students' creativity (Muhammad Aminuddin et al., 2024; Munfaridah et al., 2021; Rexigel et al., 2024; Talib & Amiroh, 2023). Students who learn using various representations, such as visual, verbal, math, and kinesthetic, better understand physics concepts than those using only one representation (Ainsworth et al., 2011; Arnal-Palacián et al., 2020). Therefore, it can be concluded that multi-representation-based learning can stimulate and improve students' representation translation abilities.

Based on the background above, this study aims to investigate the effect of multi-representation-based learning using the Lesh-Janvier model on students' representation translation abilities, particularly linear motion. This topic was chosen because it covers abstract physics concepts and requires an innovative and constructive learning approach. Furthermore, this study endeavors to ascertain the enhancement of students'

representation translation skills both before and after the learning process. This study fills the gap in the existing literature by investigating the multi-representation learning model of Lesh-Janvier and the aspect of representation translation. Although several studies have investigated multi-representation-based learning, there has been no review specifically focusing on how the multi-representation-based learning model can be used to develop students' representation translation abilities. Therefore, this study offers a specific approach to fill the gap in the existing literature.

▪ **METHOD**

Participants

The population in this study was all eleventh-grade students of SMA Negeri 22 Bandung for the 2024/2025 academic year. The determined using purposive sampling techniques. The sampling is determined based on the classes provided by the school or teacher and classes the topic of linear motion will be studied. The sample in this study consists of 62 students from two eleventh-grade classes of SMA Negeri 22 Bandung. Class XI-5 served as the control group, whereas class XI-7 was the experimental group. The average age of students in both classes is around 16 years old.

Research Design and Procedures

The method employed in this study is quantitative. The research design was quasi-experimental, with a non-equivalent control group pretest-posttest design. This design involved two groups of subjects, namely the experimental group (EG) and the control group (CG), who were given a pre-test of the representation translation ability before receiving treatment. After that, the experimental group (EG) was given treatment using the Lesh-Janvier approach for multi-representation physics learning. In contrast, the control group (CG) was given treatment using conventional teacher-centered physics learning. Following the treatment, we administered a post-test to both groups to assess the enhancement of each representation's translation ability.

This study was conducted in the odd semester of the 2024/2025 academic year. The study was conducted throughout four sessions, amounting to 8 x 40 minutes. This study advances a composite multi-representation translation model based on the work of Lesh and Janvier. The combined stages of the Lesh-Janvier multi-representation model include mapping, interpretation, coordination, transformation, and application.

This study followed a three-stage procedure: the preliminary stage, the implementation stage, and the final stage. In the preliminary stage, the researcher conducts a literature study, develops research instruments, and performs validation and trials of the instruments. In the implementation stage, the researcher administered pre-test of representation translation abilities to both the experimental and control groups. After that, the experimental group was given a multi-representation-based learning treatment by the researcher, while the control group was given a conventional learning treatment by a physics teacher. In the final stage, the researcher administered post-test to both groups to gauge the improvement in their representation translation abilities following the treatment. In addition, in the experimental group, the researcher also provided a questionnaire to determine students' responses to multi-representation-based learning. Then, analyzed the data from the final stage to assess the effectiveness of learning and its impact on students' representation translation abilities.

Instrument

This study uses test and non-test instruments, namely representation translation ability tests and student response questionnaires. The representation translation ability test instrument consists of 15 multiple-choice questions with five alternative answers. The researcher developed pre-test and post-test items, validated by three expert lecturers and one physics teacher. The results indicate that the average Aiken validity value is 0.96 (valid).

In addition, the instrument went through trials on 40 students, and the results were analyzed using the Rasch model with the help of the Winsteps application version 5.7.1. The results showed: (1) the unidimensionality of 15 items had a raw variance explained by measure value of 35.2% (adequate), and the unexplained variance 1st contrast eigenvalue was 2.3 (good); (2) fit item 15 items meet the criteria of 'suitable'; (3) the Cronbach alpha value was 0.85 (very good); (4) item reliability value was 0.75 and person reliability was 0.76, which included in the 'fairly reliable' category; and (5) item measure three items in the easy category, seven items are categorized as moderate, and five items are categorized as difficult. The grid of representation translation abilities used in this study can be seen in Table 1.

Table 1. Representation translation question grid

Concept	Question Number	Forms of Representation Translation	Aspect of Representation Translation Ability
Distance & Displacement	1	Image - Mathematics	Transformation
	2	Verbal – Image	Mapping
Average Speed & Velocity	3	Verbal – Graphic	Application
	4	Graphic – Verbal	Interpretation
Acceleration	5	Graphic - Mathematics	Transformation
	6	Table – Verbal	Coordination
Uniform Linear Motion	7	Table - Mathematics	Transformation
	8	Image – Graphic	Transformation
Uniformly Accelerated Linear Motion	9	Mathematics - Verbal	Interpretation
	10	Image - Mathematics	Application
Free Fall Motion	11	Mathematics - Table	Coordination
	12	Table – Graphic	Transformation
Vertical Motion	13	Verbal - Mathematics	Mapping
	14	Graphic – Table	Transformation
	15	Mathematics - Graphic	Coordination

A non-test student questionnaire instrument was used to determine students' responses to the multi-representation-based physics learning process. This questionnaire consists of 7 questions developed by researchers with three indicators: (1) attention, (2) satisfaction, and (3) relevance. This questionnaire underwent a content validation process by one expert lecturer and one physics teacher. The results stated that the questionnaire was valid in terms of content and suitable for use in the research. The questionnaire uses a Likert scale with options: Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), and Strongly Disagree (SD). The matrix of the student response questionnaire used in this study can be seen in Table 2.

Table 2. Student response questionnaire grid

Indicator	Observed Aspects	Number
Attention	Students' interest in multi-representation-based physics learning	1. 3
Satisfaction	Students' attitudes towards multi-representation-based physics learning	2. 7
Relevance	The relationship of multi-representation learning to students' translational and cognitive abilities	4. 5. 6

Data Analysis

The pre-test and post-test data obtained were then analyzed to determine the influence of learning on students' representation translation abilities, using the IBM SPSS statistical application version 30.0 for Windows. Data analysis was carried out by the Wilcoxon hypothesis test. To ensure a normal or homogeneous distribution of the data, we first conducted a normality test and a homogeneity test.

The decision-making criteria in statistical analysis are based on those of Santoso (2014). The technique used to test normality in this study is the Shapiro-Wilk test with a significance level of $\alpha=0.05$. Based on the significance value (Sig.) of the SPSS output results, if the Sig. ≥ 0.05 , then the test score data comes from a normally distributed population. Meanwhile, if the Sig. < 0.05 , then the test score data comes from a population that is not normally distributed.

Next, a homogeneity test was carried out to determine whether two or more sample data groups came from populations with the same variance (homogeneous). The technique used in this study was to test the homogeneity of variance with the Levene Statistics test. The Levene test tests variance homogeneity if the data tested does not need to be normally distributed but is continuous. Based on the Sig. Based on the mean value of the SPSS output, if the Sig. Based on Mean ≥ 0.05 , the data group comes from a population with the same variance (homogeneous). Meanwhile, if the Sig. Based on Mean < 0.05 , the data group comes from a population with different variances (non-homogeneous).

Last, the Wilcoxon test was performed to determine whether a statement or hypothesis about a population is true or false. The Wilcoxon test was performed if one of the statistical assumptions of the normality test was not met. According to Santoso (2014), the decision-making criteria in the Wilcoxon test based on *Asymp Sig. (2 – tailed)* SPSS output results are as follows.

(H₀) : If the *Asymp Sig. (2 – tailed)* ≥ 0.05 (no effect of multi-representation-based learning on students' representation translation abilities).

(H₁) : If the *Asymp. Sig. (2 – tailed)* < 0.05 (an effect of multi-representation-based learning on students' representation translation abilities).

A normalized gain calculation was carried out to analyze the effectiveness of learning in improving students' abilities before and after learning. Normalized gain is a comparison between the actual gain score, the gain score obtained by the student, and the maximum gain score, which is the highest gain score the student may obtain (Hake, 1999). According to Hake (1999), the interpretation of the average value of n-gain is categorized into three levels: (1) if the average value of n-gain $\langle g \rangle < 0.3$, then it is categorized as low; (2) if the average value of n-gain $0.30 \leq \langle g \rangle \leq 0.70$, then it is categorized as moderate; (3) if the average value of n-gain $\langle g \rangle > 0.7$, then it is categorized as high.

▪ RESULT AND DISSCUSSION

The research data were obtained from the results of the pre-test and post-test conducted in the experimental group and the control group. Based on the research results of the research and data collection, descriptive analysis and quantitative analysis were carried out with prerequisite test stages in the form of normality test and homogeneity test. Next, we conducted hypothesis testing using the Wilcoxon test.

To compare the effectiveness of multi-representation-based learning compared to conventional learning, a normalized gain (n-gain) calculation was carried out. The average result of n-gain in students' representation translation ability regarding linear motion is presented in Figure 1.

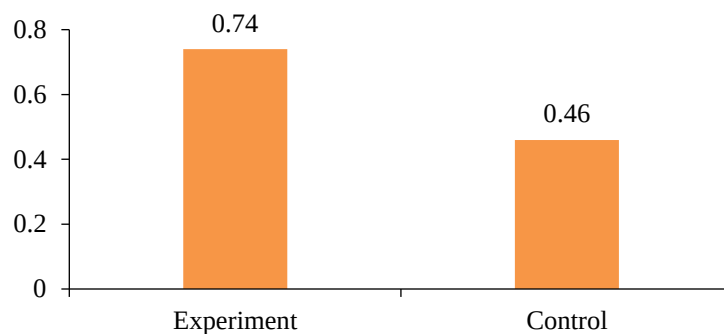


Figure 1. Average score of n-gain students' representation translation ability

The average n-gain of the experimental group was 0.74 (high category). Meanwhile, the average n-gain of the control group was 0.46 (moderate category). Thus, it can be concluded that the improvement of students' representation translation ability in linear motion obtained higher results after being given multi-representation learning treatment than the group given conventional learning treatment.

Students received training in the interpretive skills of representations, which include mapping, interpretation, coordination, transformation, and application. The improvement of each aspect of the students' representation translation ability regarding linear motion is presented in Figure 2.

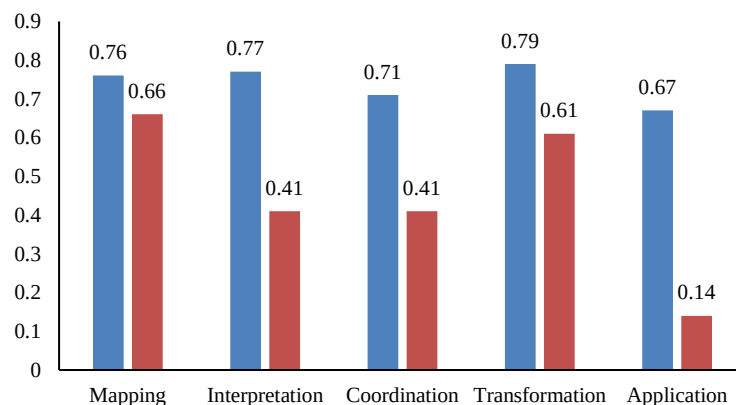


Figure 2. Average n-gain results of each aspect of students' representation translation ability

The average n-gain results of the experimental group for the four aspects of representation translation were significantly increased > 0.70 (high category). This evidence shows that Lesh-Janvier's multi-representation-based learning effectively develops more than one aspect of representation translation ability. The control group obtained an average n-gain for four aspects of representation translation in the range of 0.3 to 0.7 (moderated category). This result shows that conventional teacher-centered learning is not enough to support the development of comprehensive representation translation abilities.

In the application aspect, each group obtained a lower average n-gain compared to the previous aspect. While students demonstrated proficiency in manipulating mathematical formulas, they struggled to apply the formula's physical meaning to solve problems. In addition, students' limited experience with multi-representation physics problems makes them quite complex, leading to longer completion times and a tendency to guess answers.

Overall, it can be concluded that multi-representation-based learning can provide more significant improvements in various aspects of student representation translation. This finding is in line with Janvier's theory (1987), which emphasizes the importance of multi-representation exploration to form an in-depth understanding of concepts.

To further test the influence of learning, a hypothesis test was carried out through the prerequisite test of normality and homogeneity. The results of the normality test are presented in Table 3.

Table 3. Shapiro wilk normality test results of representation translation ability

Normality Test				
Group		Statistic	Df	Sig.
Experiment	Pre-Test	0.931	31	0.047
	Post-Test	0.775	31	< 0.001
Control	Pre-Test	0.946	31	0.117
	Post-Test	0.845	31	< 0.001

Based on Table 3, it can be seen that the data from the pre-test results of the experimental group obtained a significance value of 0.047 (< 0.05), and the control group obtained a significance value of 0.117 (≥ 0.05). Thus, it can be concluded that the data for the pre-test results of the experimental group were not normally distributed. In contrast, the data of the pre-test results in the control group were normally distributed. In addition, the data from the post-test results of the two groups obtained a significance value of < 0.001 (< 0.05). Thus, it can be concluded that the data from the post-test results of the two groups were not normally distributed. The results of the variance homogeneity test are presented in Table 4.

Table 4. Homogeneity test results of representation translation ability

Homogeneity Test		
Test	Levene Statistic	Sig. Based on Mean
Pre-Test	16.333	< 0.001
Post-Test	1.039	0.312

Based on Table 4, it can be seen that the pre-test results of the two groups obtained a *Sig. Based on Mean* < 0.001 (< 0.05) with *Levene Statistic* 16.333. This means that the pre-test of the two groups was not homogeneous. As for the post-test results, the two groups obtained *Sig. Based on Mean* 0.312 (≥ 0.05) with *Levene Statistic* 1.039. This means the post-test results for the two groups were homogeneous.

Based on the results of the normality and homogeneity test, it was obtained that the pre-test and post-test data of students obtained results that were not distributed normally. Therefore, the test was continued using a non-parametric statistical test with the *Wilcoxon test*. The results of the *Wilcoxon test* were presented in Table 5.

Table 5. Wilcoxon test results of representation translation ability

Group	Wilcoxon Test	
	Z	Asymp. Sig. (2-tailed)
Experiment	-4.708	< 0.001
Control	-4.874	< 0.001

Based on Table 5, it can be seen that the experimental group obtained Asymp.Sig. (2-tailed) < 0.001 (< 0.05) with a Z value of -4.708. This means that there was an average difference between the results of the pre-test and post-test of the representation translation ability in the experimental group. In addition, the control group obtained Asymp.Sig. (2-tailed) < 0.001 (< 0.05) with a Z value of -4.874. This means that there was an average difference between the results of the pre-test and post-test of the representation translation ability in the control group. We can conclude that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. Thus, it can be interpreted that there is a positive effect of multi-representation-based physics learning on students' representation translation ability regarding linear motion.

Furthermore, based on the results of the questionnaire given to the experimental group after participating in the learning, it was found that the majority of students gave positive responses. 35.95% of students strongly agreed (SA), 50.69% agreed (A), 12.90% were undecided (U), 0.46% disagreed (D), and 0.00% strongly disagreed (SD). These results show that Lesh-Janvier's multi-representation-based learning is well-received by students and gives a positive impression on their learning process. High learning engagement and motivation were positively correlated with the success of representation in multi-representation-based learning (Doyan et al., 2018; Latifah et al., 2024).

The results of the study show that Lesh-Janvier's multi-representation-based physics learning has a significant positive effect on students' representation translation ability on linear motion topics. This finding was in line with the average result of the experimental group's n-gain, which reached 0.74 (high category). This improvement indicates that Lesh-Janvier's multi-representation learning effectively encourages students to understand abstract physics concepts through various forms of representation.

Although the results of this study showed a positive effect, it is necessary to admit that there were limitations in terms of generalization. This study uses purposive sampling techniques, so the sample used was not representative of the population. In addition, the design of this study was a non-equivalent control group, which has limitations in controlling external variables. The initial differences between the experimental group and

the control group could not be eliminated through randomization, so they could affect the final result.

The Lesh-Janvier model emphasizes the systematic use of multi-representations to encourage a profound understanding of concepts. This combined model integrates the strengths of each approach to form a comprehensive framework for developing students' representation translation abilities. Janvier (1987) emphasized the importance of translation between representations in learning, which requires students to construct knowledge independently. Similarly, Lesh (1979) also says that conceptual understanding is the ability to translate one representation into another. Understanding concepts through different forms of representation cannot be achieved from just one perspective. Therefore, we need strategies that enable students to explore, connect, and meaningfully transform various forms of representation. This is realized through multi-representation learning stages, including mapping, interpretation, coordination, transformation, and application.

Applying the Lesh-Janvier stage to linear motion topics in the experimental group encouraged students' active involvement in the representational thinking process. This can assist students in providing a rich and structured learning experience. At the mapping stage, the teacher demonstrates the concept of movement, which can stimulate students to answer the perceptual questions asked. Students map concrete representations (images/videos) to abstract representations. This stage aids students in identifying a fundamental physics concept, motion, which they can transform into various representations. Then, at the interpretation stage, students understand the meaning of the representation of the phenomenon that has been displayed by the teacher. The teacher asked students to verbally represent the magnitude of physics in straight motion. This stage helps students connect conceptual meanings with abstract representational forms.

In the coordination stage, students relate the verbal representations that have been made before to the mathematical representations. Students relate the concept of distance and time of a moving object to the concept of speed. This stage builds relationships between representations. In the next transformation stage, students change the representation of concepts, namely verbal and mathematical, to visual representations, namely tables and graphs. This stage is the core of the ability to translate representations. Students' ability to switch between representational forms is critical while tackling complex physics problems. The stages of coordination and transformation in learning train students to build meaning and relationships between concepts through directed activities. These results were in line with the statement of Hubber & Tytler (2017) that multi-representation learning processes designed by paying attention to the diversity of representation formats and their functions have the potential to build a deep understanding. Finally, in the application stage, students apply the concepts of straight motion to the questions in different situations. This stage shows the extent to which students can apply their representation translation abilities to solve problems.

The results of this study were consistent with earlier research showing that a multi-representation-based learning approach can significantly improve students' cognitive abilities and problem-solving in physics learning (Munfaridah et al., 2021; Worku et al., 2025). These results confirm that the multi-representation approach is not only relevant for linear motion matter but can also be adapted to various abstract physics topics. Furthermore, these findings show that Lesh-Janvier's multi-representation model

improves representation translation capacity as well as conceptual understanding. Previous studies have not thoroughly discussed this aspect.

In addition, the positive response of students to this learning shows that this approach can increase student involvement and interest in learning, which has been a challenge in learning physics (Hasbullah et al., 2019; Theasy, 2023). This increase in engagement was in line with the findings of Rexigel et al. (2024) that varied representations can provide richer and more meaningful learning contexts, thereby increasing student motivation. It also supports constructivism theory, which argues that meaningful learning experiences can increase learning motivation and form stronger conceptual understanding (Ainsworth et al., 2011; Latifah et al., 2024).

While most studies support the effectiveness of multi-representation-based learning, some studies have found results that are not entirely aligned. The study by Arnal-Palacián et al. (2020) on the phenomenology of infinite limits shows that the use of multi-representation actually confuses students who do not have a strong conceptual basis, thus hindering their understanding. When students are faced with too many representations without direction in connecting them, this can lead to a high cognitive load and hinder the learning process (Rau, 2017; Seufert, 2003). To optimize the effectiveness of this approach, teachers must ensure that the representations employed complement one another and promote the knowledge construction process.

Several important interrelated factors influence the translation ability of students' representations, in addition to the direct influence of the learning model. First, students with higher abstract thinking and logic abilities tend to understand the relationships between representations more easily. This is in line with the findings of Khairunnisa et al. (2023), who concluded that the ability to translate representations correlates with the level of concept mastery and mathematical thinking ability. Second, students who are used to seeing and using various representations, such as graphs, tables, pictures, and mathematical equations in physics learning, tend to be more flexible in moving between representations. This is in line with the findings of Kohl & Finkelstein (2008), which state that students who are used to using various representations in solving physics problems perform better in concept translation.

The third is the learning strategy applied by the teacher. Teachers who explicitly teach the interconnectedness of representations, as well as provide translation exercises in various forms, might help students understand concepts from different perspectives. The use of multi-representation is not only presented but also actively discussed by teachers and students, having a positive effect on representation skills (Rau, 2017; Treagust et al., 2017). Fourth, students who show a high interest in learning tend to be more active in exploring the representations presented and are more willing to try to translate them. This feature is evident in the findings of the student questionnaire, where the indicators of attention and satisfaction show a positive response to the multi-representation approach. Fifth, the characteristics of abstract physics material. In abstract concepts, systematic learning is needed that facilitate students in integrating information from various representations. Representations that are too complex and not explicitly directed can lead to a high cognitive load and hinder conceptual understanding (Arnal-Palacián et al., 2020).

▪ CONCLUSION

Based on the research that has been conducted, it can be concluded that Lesh-Janvier's multi-representation-based learning provides a significant improvement in students' representation translation abilities. The analysis of the experimental group revealed an average improvement score of 0.74 (which is considered high), and the hypothesis test results were significant (Asymp. Sig. < 0.001), indicating a noticeable difference in the average after the learning process. The experimental group that used multi-representation-based learning showed higher results on the translational ability of the representation compared to the control group.

These findings provide implications for physics learning practices in the classroom. Physics teachers need to consider using multi-representation-based learning strategies. This research contributes to strengthening the pedagogical foundation of the use of the Lesh-Janvier combined multi-representation model in the context of physics learning. The limitations of this study's results suggest that the multi-representation approach should be changed to focus more on how to apply concepts, as this study found that application had a lower improvement score compared to other aspects. This shows the need to strengthen the stages of applying concepts in the context of real life so that students are better able to apply their representation knowledge in solving physics problems. In addition, it is highly suggested to conduct further research with a more rigorous experimental design and a wider range of participants to test the consistency of the effectiveness of the multi-representation approach in a broader context.

▪ REFERENCES

- Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to learn in science. *Science*, 333(6046), 1096–1097. <https://doi.org/10.1126/science.1204153>
- Aminuddin, M., Asim, Z. S., & Irawati, A. (2024). Multi-representation approach in improving 1-dimensional kinematics conceptual understanding. *Universal Education Journal of Teaching and Learning*, 1(2), 41–45. <https://doi.org/10.63081/uejtl.v1i2.34>
- Arnal-Palacián, M., Claros-Mellado, J., & Sánchez-Compañía, M. T. (2020). Infinite limit of sequences and its phenomenology. *International Electronic Journal of Mathematics Education*, 15(3), em0593. <https://doi.org/10.29333/iejme/8279>
- Cheng, M., & Gilbert, J. K. (2009). Towards a better utilization of diagrams in research into the use of representative levels in chemical education (hal. 55–73). https://doi.org/10.1007/978-1-4020-8872-8_4
- Connerade, J.-P. (2023). The atom at the heart of physics. *Atoms*, 11(2), 32. <https://doi.org/10.3390/atoms11020032>
- Doyan, A., Taufik, M., & Anjani, R. (2018). *Pengaruh pendekatan multi representasi terhadap hasil belajar fisika ditinjau dari motivasi belajar peserta didik*. *Jurnal Penelitian Pendidikan IPA*, 4(1). <https://doi.org/10.29303/jppipa.v4i1.99>
- Hake, R. R. (1999). Analyzing Change/Gain Scores. 16(7), 1073–1080.
- Hasbullah, H., Halim, A., & Yusrizal, Y. (2019). *Penerapan pendekatan multi representasi terhadap pemahaman konsep gerak lurus*. *Jurnal IPA & Pembelajaran IPA*, 2(2), 69–74. <https://doi.org/10.24815/jipi.v2i2.11621>

- Hubber, P., & Tytler, R. (2017). Enacting a representation construction approach to teaching and learning astronomy (hal. 139–161). https://doi.org/10.1007/978-3-319-58914-5_7
- Janvier, C. (1987). Problems of representation in the teaching and learning of mathematics. Lawrence Erlbaum Associates, Inc.
- Kemendikbud. (2022). *Capaian pembelajaran mata pelajaran matematika fase A - Fase F*. Kementerian Pendidikan dan Kebudayaan Riset dan Teknologi Republik Indonesia, 21.
- Khairunnisa, K., Darhim, D., Priatna, N., & Juandi, D. (2023). *Pengembangan instrumen kemampuan translasi representasi matematis mahasiswa pada materi program linear*. JNPM (Jurnal Nasional Pendidikan Matematika), 7(2), 240. <https://doi.org/10.33603/jnpm.v7i2.8051>
- Kohl, P. B., & Finkelstein, N. D. (2008). Patterns of multiple representation use by experts and novices during physics problem solving. *Physical Review Special Topics - Physics Education Research*, 4(1), 010111. <https://doi.org/10.1103/PhysRevSTPER.4.010111>
- Larasati, A. D. P., Ibnu, S., & Santoso, A. (2019). *Model problem based learning dengan pendekatan multi representasi untuk meningkatkan kemampuan memecahkan masalah siswa dengan tingkat self-efficacy berbeda*. Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan, 4(6), 828. <https://doi.org/10.17977/jptpp.v4i6.12548>
- Latifah, R. N., Sutopo, S., & Hidayat, A. (2024). Physics learning media with multirepresentation: a systematic literature review. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 10(2), 353–366. <https://doi.org/10.21009/1.10212>
- Lesh, R. (1979). Mathematical learning disabilities: considerations for identification, diagnosis and remediaton. ERIC/SMEAC.
- Munfaridah, N., Avraamidou, L., & Goedhart, M. (2021). The use of multiple representations in undergraduate physics education: what do we know and where do we go from here? *Eurasia Journal of Mathematics, Science and Technology Education*, 17(1), em1934. <https://doi.org/10.29333/ejmste/9577>
- Nielsen, W., Turney, A., Georgiou, H., & Jones, P. (2022). Meaning making with multiple representations: a case study of a preservice teacher creating a digital explanation. *Research in Science Education*, 52(3), 871–890. <https://doi.org/10.1007/s11165-021-10038-2>
- Opfermann, M., Schmeck, A., & Fischer, H. E. (2017). Multiple representations in physics education (D. F. Treagust, R. Duit, & H. E. Fischer (ed.); Vol. 10, Nomor July). Springer International Publishing. <https://doi.org/10.1007/978-3-319-58914-5>
- Park, W., Yang, S., & Song, J. (2019). When modern physics meets nature of science. *Science & Education*, 28(9–10), 1055–1083. <https://doi.org/10.1007/s11191-019-00075-9>
- Rau, M. A. (2017). Conditions for the effectiveness of multiple visual representations in enhancing stem learning. *Educational Psychology Review*, 29(4), 717–761. <https://doi.org/10.1007/s10648-016-9365-3>

- Rexigel, E., Kuhn, J., Becker, S., & Malone, S. (2024). The more the better? a systematic review and meta-analysis of the benefits of more than two external representations in STEM Education. *Educational Psychology Review*, 36(4), 124. <https://doi.org/10.1007/s10648-024-09958-y>
- Sari, D. I., Sirait, J., & Habellia, R. C. (2023). *Analisis kemampuan representasi gerak lurus peserta didik sma di kota pontianak*. *Jurnal Pendidikan Informatika dan Sains*, 12(1), 23–33. <https://doi.org/10.31571/saintek.v12i1.5606>
- Seufert, T. (2003). Supporting coherence formation in learning from multiple representations. *Learning and Instruction*, 13(2), 227–237. [https://doi.org/10.1016/S0959-4752\(02\)00022-1](https://doi.org/10.1016/S0959-4752(02)00022-1)
- Singgih Santoso. (2014). *Panduan lengkap SPSS Versi 20 Edisi Revisi*. PT Elex Media Komputindo.
- Talib, A. H., & Amiroh, D. (2023). *Pengaruh pendekatan multi representasi dengan model discovery learning untuk meningkatkan penguasaan konsep kalor*. *DIFRACTION*, 4(2), 52–57. <https://doi.org/10.37058/diffraction.v4i2.6588>
- Tamyiz, M., Ismet, & Yusup, M. (2020). *Analisis kemampuan siswa dalam membuat grafik pada pokok bahasan kinematika di SMA N 1 Indralaya*. *Jurnal Literasi Pendidikan Fisika*, 1(02), 145–151. <https://doi.org/10.30872/jlpf.v1i2.263>
- Theasy, Y. (2023). *Analisis kesulitan belajar fisika siswa sma melalui kemampuan multirepresentasi pada pembelajaran tatap muka masa transisi COVID-19*. *Variabel*, 6(1), 16. <https://doi.org/10.26737/var.v6i1.4337>
- Treagust, D. F., Duit, R., & Fischer, H. E. (2017). Multiple representations in physics education (D. F. Treagust, R. Duit, & H. E. Fischer (ed.); Vol. 10). Springer International Publishing. <https://doi.org/10.1007/978-3-319-58914-5>
- Wayan Distrik, I., Imam Supardi, Z. A., Jatmiko, B., & Yuberti. (2021). The effects of multiple representations-based learning in improving concept understanding and problem-solving ability. *Journal of Physics: Conference Series*, 1796(1), 012044. <https://doi.org/10.1088/1742-6596/1796/1/012044>
- Widianingtiyas, L., Siswoyo, S., & Bakri, F. (2015). *Pengaruh pendekatan multi representasi dalam pembelajaran fisika terhadap kemampuan kognitif siswa SMA*. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 01(1), 31–38. <https://doi.org/10.21009/1.01105>
- Worku, D. T., Ejigu, M. A., Gebremeskal, T. G., & Kassa Gogie, T. (2025). Assessing the impact of multiple representations based instruction integrated with formative assessment practice on secondary school students' problem-solving performance in Physics. *Research in Science & Technological Education*, 1–26. <https://doi.org/10.1080/02635143.2025.2469062>