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Improving students' physics representation competence with an Android-based representation training model

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ABSTRACT

Representational competence is vital for learning and solving problems in physics, yet many students struggle to master it, and teachers encounter challenges in fostering its development. This study addresses the issue by developing an Android-based training model focused on linear motion kinematics, designed using the analysis, design, development, implementation, and evaluation (ADDIE) research and development (R&D) framework and validated by experts. A total of 127 undergraduates participated through questionnaires, interviews, and observations. The model incorporates feedback and scaffolding to guide students' understanding and practice. Implementation results showed significant improvements in representational competence. N-Gain scores reached 0.35 (medium) in experimental group I and 0.61 (medium) in experimental group II. Statistical analysis using the Wilcoxon signed-rank test confirmed these gains were significant ($p<0.05$) with large effect sizes ($r=0.871$; $r=0.862$). Further, the Kruskal-Wallis's test revealed significant differences between groups, and Games-Howell post hoc analysis indicated that integrated classroom use was more effective than independent practice. Student responses demonstrated high practicality and positive engagement, reinforcing the model's usability. These findings highlight the novelty of an expert-validated, scalable Android-based platform as an accessible tool to enhance representational competence in physics education. Future research should investigate its broader application across physics topics and its long-term impact on learning outcomes.

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1. INTRODUCTION

Representational competency has gained attention in physics education research due to its crucial role in developing conceptual understanding. A strong knowledge of various physical, mathematical, and graphical representations allows students to understand natural phenomena holistically and deeply [1]–[5]. The development of representational competency also helps students understand and construct physics knowledge more effectively [6], [7]. Students can develop problem-solving and critical thinking skills by utilizing multiple representations such as diagrams, graphs, or mathematical representations [8]–[12]. Therefore, developing representational competency is crucial for understanding solid and applicable physics concepts.

Researchers found that students' representational competency, including in Indonesia, is relatively low. Students are weak in interpreting the graphs [13]–[15]. Students also have difficulty working on problems with mathematical and graphic representations [16], [17]. Students can determine the correct graph but not create one [18]–[20]. Students who solve the verbal format jump to the mathematical equations without visualizing the problem with sketches or drawings. Most students begin to identify the known and unknown variables and then write the equation [21]. Students are also weak in using various forms of representation [22].

Low representational competency impacts students' learning outcomes and problem-solving abilities. Several studies have shown that students with low learning outcomes and poor understanding of physics concepts also tend to have low representation competence [23]–[25]. Krawec [26] and Milinkovic *et al*. [27] conducted a study suggesting that students with low representational competency have difficulties dealing with problems. Therefore, improving representational competency is essential to enhance students' understanding and achievement of physics learning.

Various efforts have been made to improve students' representational competency. Some researchers apply specific learning models in the learning process in the classroom [28]–[30]. Various approaches to learning have also been made to improve students' representational competency. Scheid *et al*. [31] implemented representational activity tasks (RATs) designed to compare, resolve, and connect various representations. Research involving the introduction of graphs, graph creation, and graph interpretation has also been integrated into the learning process [15]. The interventions provided in these studies improved graphic representational competency and understanding of physics concepts. Maries *et al*. [2] provided scaffolding to help students solve problems on a specific physics topic. This research has an impact on increasing students' representational competency. Several other studies show that computer use can help students improve their representational competence [32]–[36].

While these efforts have yielded significant results, challenges remain, and opportunities exist. One major challenge is fostering students' willingness to exercise their representational competency. Continued efforts are needed to improve students' representational competency in learning kinematics of straight motion further. While many studies have addressed representation competence in physics learning, such as exploring its role in conceptual understanding [37], analyzing students' difficulties in using multiple representations [15], and discussing instructional strategies to enhance it [38] as well as its implementation in the Indonesian context, including classroom practices [20], teacher perceptions [34], and curriculum-related issues [20], unfortunately, no one has specifically developed an assistance model validated by experts in the context of education in Indonesia. In the Indonesian higher education context, the national curriculum emphasizes conceptual understanding in physics, yet many students struggle with graphical and mathematical representations. At the same time, mobile technology adoption is high among university students, making Android-based platforms particularly suitable for scalable learning interventions.

Representational competence in physics does not only rely on graphical skills but also on the ability to integrate verbal, mathematical, and diagrammatic forms. Prior studies highlight that the flexible use and translation across multiple forms of representation is essential for developing deep conceptual understanding and effective problem-solving. Although the present study emphasizes graph interpretation, the design of training activities should also take into account how various representational modes can be systematically combined. This view is supported by cognitive learning theories such as dual coding theory, which stresses the complementary roles of verbal and visual channels in strengthening memory, and cognitive load theory, which explains how appropriately designed scaffolding across multiple representations can reduce extraneous processing and promote meaningful learning.

This study aims to develop an Android-based training model to address students' low representational competence in physics, especially in interpreting, constructing, and linking graphical, mathematical, and verbal representations of linear motion. Such difficulties hinder their conceptual understanding and problem-solving. Although various instructional strategies have been tried, no expert-validated Android-based model exists to support Indonesian students outside class. Considering the widespread use of mobile technology and its potential for personalized learning, this research develops a practical and scalable model to overcome these challenges. The research questions are: i) what is the structure of the Android-based representational exercise model? ii) how do students respond to its use? iii) what is its effectiveness in improving students' representational competence? Based on these questions, the next section explains the methodological framework using the analysis, design, development, implementation, and evaluation or ADDIE model to design, validate, and test the application.

2. METHOD

This study employed a research and development or R&D approach using the ADDIE development model [39]. The ADDIE model was chosen because it provides a structured framework for developing learning tools, supports dynamic instructional practices, and offers a clear, step-by-step product development process, as in Figure 1. This research was conducted at a university in Surabaya, Indonesia. The primary focus of the developed training model is graph comprehension within the topic of linear motion kinematics.

Multiple-choice items were used for all in-app exercises due to software constraints, although students' representational competency was evaluated using essay-format questions.

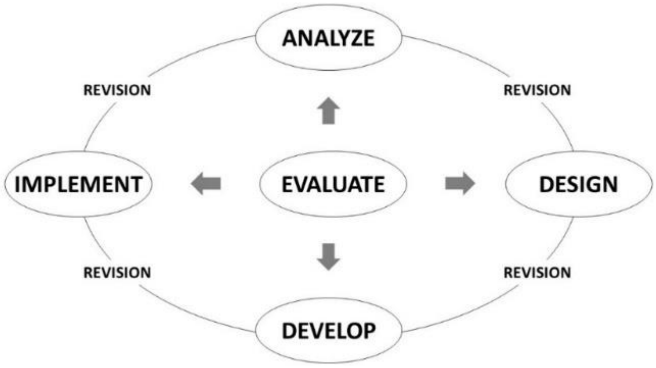


Figure 1. ADDIE model diagram

2.1. Participants

A total of 127 undergraduate physics education students who had completed an introductory physics course participated in this study. The participants consisted of 52 males and 75 females, selected through cluster random sampling. In the initial needs analysis stage, 57 students completed the representation competency test. The pilot test during the design stage involved ten students. For the implementation stage, students were divided into three groups: the control group (14 students), experimental group I (59 students), and experimental group II (54 students).

2.2. Instruments

The study used several instruments. A representation competency pre- and post-test which consists of five essay questions adapted from the test of understanding graphs in kinematics or TUG-K [41] (Cronbach's alpha=0.701). A needs analysis test of seven essay items to identify students' baseline difficulties in representation (Cronbach's alpha=0.623). The third is validation rubrics for expert review of the app's content and media. Lastly are student questionnaires to evaluate practicality and satisfaction.

2.3. Procedures

2.3.1. Analyze

A needs analysis was conducted on 57 students using a seven-item representation competency test covering verbal, graphic, diagrammatic, and mathematical representations as in Table 1. Responses were scored using a rubric developed by Etkina *et al*. [40]. The average score was 1.06 (out of 3), with 61.4% of students classified as having low competency. Interpreting graphs was identified as the most significant challenge.

Table 1. Needs analysis instruments (Cronbach alpha=0.623)

No	Type representation	Biserial coefficient	Power of difference	Level of difficulty
1	Diagram-verbal (DV)	0.546	0.36	0.64
2	Diagram-table (DT)	0.736	0.80	0.37
3	Diagram-graphic (DG)	0.626	0.29	0.13
4	Graphic-mathematic (GM)	0.667	0.31	0.11
5	Graphic-verbal (GV1)	0.280	0.20	0.70
6	Graphic-verbal (GV2)	0.519	0.22	0.15
7	Diagram-mathematic (DM)	0.701	0.38	0.37

2.4. Design

Based on the needs analysis, the training model was designed with a focus on graphical interpretation in linear motion kinematics. The initial version was developed in paper format and piloted using the think-aloud protocol with ten students. Feedback and scaffolding were refined after interviews revealed confusion over long or unclear prompts.

2.5. Development

Based on the model design stage data, an Android application featuring representational exercises equipped with feedback and scaffolding was developed. At this stage, media and material expert validation was carried out. Media validation ensures that the application interface is easy to use and attractive, while material validation ensures that the content presented is accurate and relevant to the curriculum. The instrument used in media validation is an assessment sheet covering appearance, navigation, and readability. The instrument used in material validation uses an assessment sheet, which includes the suitability of the content with physics concepts, the level of clarity of representation, and suitability to the level of student understanding. The training model was validated by three experts who assessed the media's feasibility and the material's correctness through a Likert scale. The validation criteria are carried out according to the five-point scale calculation as in Table 2 [41]. After the validation process, the application was distributed to 113 students to collect feedback on the practicality of using the Android-based training model. The model's practicality was measured using a questionnaire that included aspects of appearance, effectiveness of scaffolding and feedback, ease of use, user satisfaction, and user experience in understanding the concept of linear motion kinematics through the application.

The students' representational competence improvement was assessed through tests administered before and after using the application. The test instrument consisted of five essay questions as in Table 3 adapted from the TUG-K. These questions were designed to measure students' ability to understand and translate various representations of linear motion kinematics, including verbal, mathematical, and graphical representations. Three physics lecturers were consulted about the content validity of the instrument. At the same time, its reliability was analyzed using Cronbach's Alpha coefficient, which yielded a value of 0.701, indicating that the instrument has an acceptable level of reliability. The pre-test and post-test results were then analyzed quantitatively to determine the effectiveness of the training model in improving students' representational competence.

Table 2. Five-scale actual score conversion

Formula	Interval score	Category
$x_i + 1.8SBi < \bar{x}$	$3.4 < \bar{x}$	Very good
$x_i + 0.6SBi < \bar{x} \leq x_i + 1.8SBi$	$2.8 < \bar{x} \leq 3.4$	Good
$x_i - 0.6SBi < \bar{x} \leq x_i + 0.6SBi$	$2.2 < \bar{x} \leq 2.8$	Enough
$x_i - 1.8SBi < \bar{x} \leq x_i - 0.6SBi$	$1.6 < \bar{x} \leq 2.2$	Less
$\bar{x} \leq x_i - 1.8SBi$	$\bar{x} \leq 1.6$	Very less

Table 3. Representation competency test instrument

No	Biserial coefficient	Power of difference	Level of difficulty
1	0.715	0.32	0.63
2	0.622	0.35	0.55
3	0.634	0.32	0.57
4	0.711	0.56	0.76
5	0.741	0.33	0.48

2.6. Implementation

The implementation stage aims to see the effectiveness of the Android-based representation training model. The implementation of the Android-based representation training model was carried out at a university in Surabaya, Indonesia. This study involved 127 students, consisting of 52 males and 75 females, who were taking an introductory physics course. The students were selected based on the cluster random sampling technique. In this study, the control group consisted of 14 students, experimental group I consisted of 59 students, and experimental group II consisted of 54 students. The control group followed the learning process using the lecture method without using the developed application. The experimental group I students followed the learning process with the lecture method but used the application independently after the lecturer explained the kinematics of linear motion. Experimental group II students followed the learning process with the lecture method and used the application at the end of the learning process with the help of basic physics lecturers. Students in both experimental groups were given one week to learn the Android application.

2.7. Evaluation

The evaluation stage aims to determine the effectiveness of the Android-based representation training model that has been developed in improving students' representation competencies. The evaluation was conducted through a series of pre-tests and post-tests given to the control and experimental groups. Quantitative analysis employed N-Gain scores to assess individual learning outcomes, while non-parametric tests (Wilcoxon signed-rank, effect size calculations, Kruskal-Wallis, and Games-Howell post hoc) were used to examine statistical significance and group differences. Although the in-app exercises were multiple-choice, the post-tests required essay responses to assess deeper conceptual understanding and multi-representational reasoning. This mismatch between training and assessment formats was noted as a limitation. Furthermore, usability feedback from students was collected through a questionnaire. Although the scaffolding and feedback features were generally well received, some students noted that some scaffolding steps were too lengthy and time-consuming. Additionally, the application lacks remediation features for students struggling with specific questions, which may limit personalized learning. The results of this evaluation phase provide empirical support for the effectiveness of the model and formative input for future refinements to the training model.

3. RESULTS

This study produces an Android-based representation competency trainer. The application can be accessed through an Android-based smartphone without being connected to the internet so that it can be utilized for independent learning. The application is distributed to students after the lecturer explains the material about linear motion kinematics and is carried out during class hours. This application has been equipped with questions and explanations using various types of representations in each problem, as well as providing more specific feedback regarding the mistakes made by students as shown in Figure 2. Figure 2(a) shows the main interface of the application displaying representation-based questions; Figure 2(b) presents an example of multiple representations used in a single problem; Figure 2(c) illustrates the feedback provided after students submit their answers; and Figure 2(d) depicts the detailed explanation designed to help students understand their errors and improve their conceptual understanding.

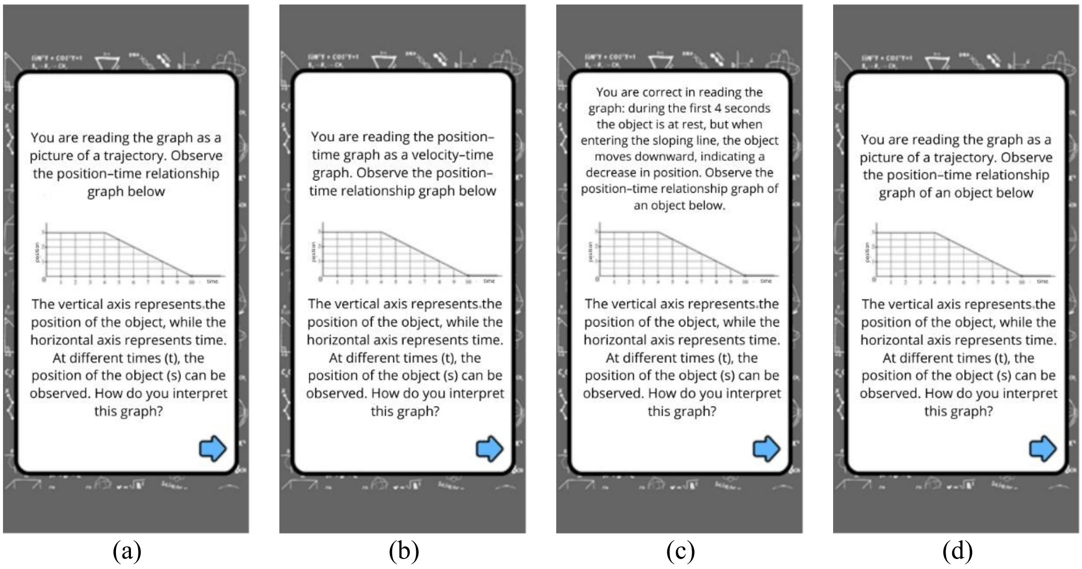


Figure 2. Example of student feedback when selecting the wrong answer option (a) feedback explaining position–time graph interpretation, (b) feedback on velocity-related graph misinterpretation, (c) feedback for misunderstanding constant position before motion, and (d) feedback reinforcing correct reading of position-time relationships

This development research is based on the ADDIE research procedure, which consists of several stages. The first stage of this development research is analysis. A needs analysis was conducted through a test of 57 students who had taken an introductory physics course. The results obtained showed that the average representation score was 1.06. Of these results, 38.60% of students were in the “medium” competency category, and 61.40% were in the “low” category. The lowest score was 0, and the highest was 2 (with a maximum score of 3). No students were in the high representation competency category. Based on the type of representation, the high category representation was GV 1 (score 2.09). The medium category representations were DV (score 1.91), DT (score 1.12), and DM (score 1.11). Low-categorized representations are GV2 (score 0.44), DG (score 0.39), and GM (score 0.33). The results of the needs analysis stage identify students' difficulties in understanding verbal, mathematical, and graphic representations of the concept of linear motion kinematics.

The second stage of this research is the design stage. The results of the design stage show that the scaffolding and feedback that was developed have helped students understand and solve problems related to the graphical representation of the kinematics of linear motion. Through trials with the think-aloud technique, it was identified that students experienced an improvement in connecting information between various forms of kinematic representation, such as position-time and velocity-time graphs. However, some students still had difficulty interpreting changes in graph slope and its relationship to the concept of acceleration. Semi-structured interviews revealed that the scaffolding provided was able to guide students gradually in structuring their understanding, although some parts needed to be clarified to be more effective. In addition, the feedback provided was considered helpful in correcting misconceptions and directing students toward more appropriate answers. Based on these findings, the scaffolding and feedback design was revised to improve the clarity of instructions and the suitability of the level of difficulty before being implemented in the Android-based model.

The third stage of this research is the development stage. Based on the results of the design stage, a draft representation training model with application characteristics was developed. The application consists of five main questions presented as graphical representations. Each question is equipped with feedback to determine whether the student answered correctly or incorrectly. The feedback is also equipped with an explanation of student errors in choosing answer options. This feedback can be a reflection for students on how to understand a graph. Each problem has three kinds of scaffolding to help students answer the main problem correctly. Students who answer the main problem correctly will be redirected to the discussion page containing various representations. Students can choose the type of representation they want for the discussion. At the end of the application, students can view their score—the way the application works can be described in Figure 3.

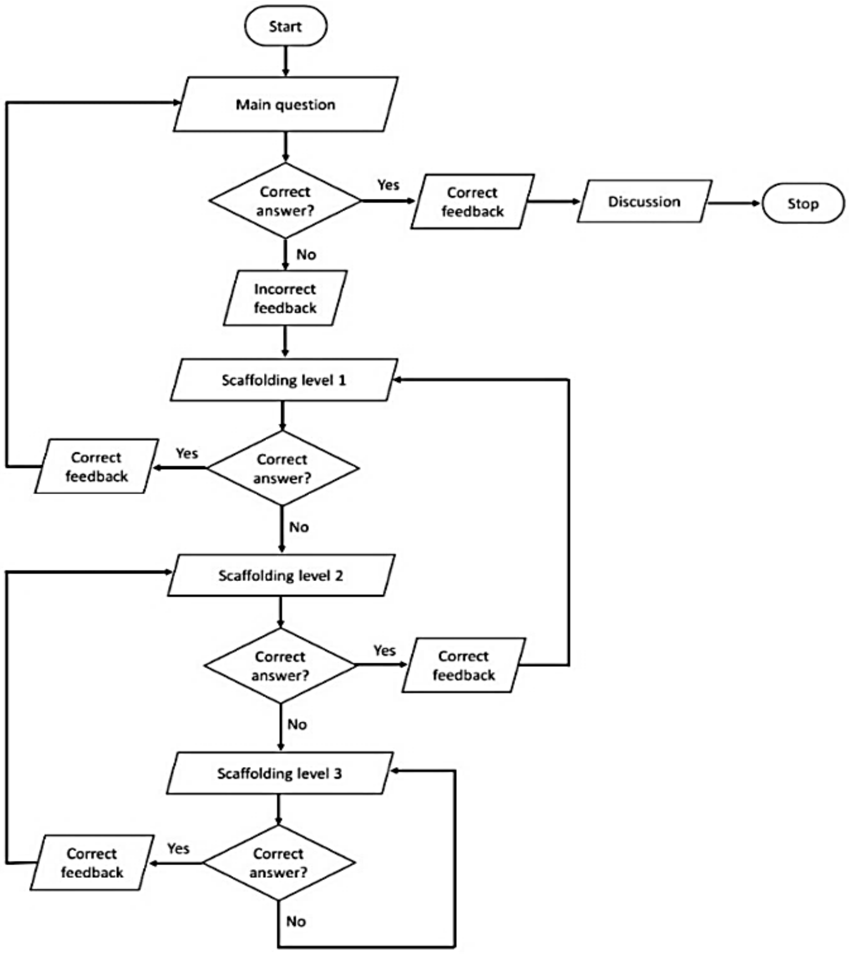


Figure 3. Flowchart of how the application works

Before being used by students, a focus group discussion or FGD was held to obtain input and was also validated by three senior lecturers. Based on the results of the FGD, feedback was received, for instance: i) the application should be equipped with discussions featuring various representations; ii) feedback should include correct and incorrect responses and brief explanations of the mistakes made by students based on their answer choices; iii) the scaffolding developed should be able to build various other representations to understand the main problem discussed. In addition to the FGD, the developed exercise model was also validated. The validation results show that the representational practice model can be used as in Table 4.

Based on the input from the focus group discussion and the validator, the revised Android-based representation training model was distributed to 113 students to obtain feedback on its practicality. One hundred-five students completed and submitted the questionnaire. In general, students did not experience any difficulties in using the application. Students' responses to the developed application can be seen in Table 5.

Table 4. Validation assessment of the android-based representation exercise model

Type of assessment	Assessment aspects	V1	V2	V3	Average	Criteria
Material	Feasibility of content	3.80	3.40	3.80	3.67	Very good
	Feasibility of images and language	3.60	3.40	3.60	3.53	Very good
Media	Visual display	3.67	3.17	3.67	3.50	Very good
	Ease of use	4.00	4.00	4.00	4.00	Very good
	Language	4.00	3.50	3.00	3.50	Very good
	Software engineering	3.50	3.50	3.75	3.58	Very good

Table 5. Student's response to the developed application

No	Description	Percentage			
		Strongly agree	Agree	Disagree	Strongly disagree
View					
1	Attractive Android-based app design	54.29	45.71	0.00	0.00
2	The language used in Android-based applications is easy to understand	55.24	44.76	0.00	0.00
3	The writing used in Android-based applications can be read clearly	56.19	43.81	0.00	0.00
4	The presentation of images in Android-based applications is engaging and clear	51.43	48.57	0.00	0.00
5	The composition of the color selection in the Android-based application is attractive	66.67	33.33	0.00	0.00
Usability					
1	Android-based applications can be used to practice various kinds of representations	68.57	30.48	0.95	0.00
2	Android-based applications can be used to evaluate	45.71	52.38	1.90	0.00
3	Android-based apps can be used to understand the meaning of graphs better	73.33	26.67	0.00	0.00
Ease					
1	Android-based apps are easy to install	80.00	18.10	0.00	1.90
2	Android-based apps are easy to use	79.05	19.05	0.00	1.90
3	Android-based apps are practical to use	87.62	11.43	0.95	0.00
Satisfaction					
1	Satisfaction felt after using the Android-based application	82.86	14.29	1.90	0.95
2	Android-based apps are fun to use in learning activities	43.81	56.19	0.00	0.00

Based on the questionnaire results, most students responded positively to the developed application. Students noted that the feedback was helpful in their understanding of the graphs, as it provided more specific information rather than just indicating right or wrong, which is typically the case in conventional multiple-choice feedback. Some of the student responses are provided as the following:

"This application helps me understand linear motion kinematics better."
"The app is easy to use and has an intuitive interface."
"Scaffolding features help to understand the relationship between physics representations."
"Automated feedback provides better insight into mistakes made."
"The application can be developed to contain more learning materials."
"Applications can be provided in general market applications (in the Google Play Store or other application stores) to make it easier to disseminate, and the installation process does not have to go through application sharing."
"The application can also be developed for use on iOS."

The subsequent stage was the implementation, which aimed to evaluate the effectiveness of the Android-based representation training model. In this phase, the control group did not use the application, while students in experimental group I were given initial guidance on how to install the media and then practiced using the application independently for one week. Students in experimental group II also received installation instructions, but they were additionally allotted 60 minutes to complete exercises in the application, followed by a group discussion session. Afterward, they continued exploring the application independently for one week. At the end of the period, students from both experimental groups completed a questionnaire to assess their learning experiences and the usefulness of the media. Changes in students' representational competence before and after the treatment were first examined using N-Gain analysis, as in Table 6. To further test the significance of the observed improvements, the Wilcoxon signed-rank test was conducted after the N-Gain analysis, providing evidence of the effectiveness of the treatment. In addition, effect sizes were calculated to indicate the magnitude of improvement, which showed stronger effects in the experimental groups compared to the control group.

In the control group, 85.71% of students showed changes in representational competency in the low category, while 14.29% were in the medium category. In experimental group I, 30.51% of students experienced changes in the low category and 69.49% in the medium category. In experimental group II, 66.67% of students achieved improvements in the medium category and 33.33% in the high category. Changes in students' representational competency for each problem are illustrated in Figure 4. Compared to the control group and experimental group I, students in experimental group II demonstrated a greater increase in representational competency across the test items. The Wilcoxon signed-rank test confirmed that these improvements were statistically significant, with $z=-3.072$ ($p=0.002$) for the control group, $z=-6.693$ ($p<0.001$) for experimental group I, and $z=-6.337$ ($p<0.001$) for experimental group II. Furthermore, effect size analysis indicated large effects in all groups ($r=0.821$, $r=0.871$, and $r=0.862$, respectively), showing that the observed improvements were not only significant but also had strong practical impacts, with the largest effects found in the experimental groups.

Table 6. Results of the analysis of changes in representational competency among students

Characteristics	Total	Pre-test mean (SD)	Post-test mean (SD)	N-Gain	Category	z	p-value	Effect size (r)
Control group	14	32.29 (8.84)	41.00 (12.25)	0.13	Low	-3.072	0.002	0.821 (large)
Experiment group I	59	28.44 (9.61)	53.49 (8.11)	0.35	Medium	-6.693	0.000	0.871 (large)
Experiment group II	54	25.79 (5.88)	71.16 (13.21)	0.61	Medium	-6.337	0.000	0.862 (large)

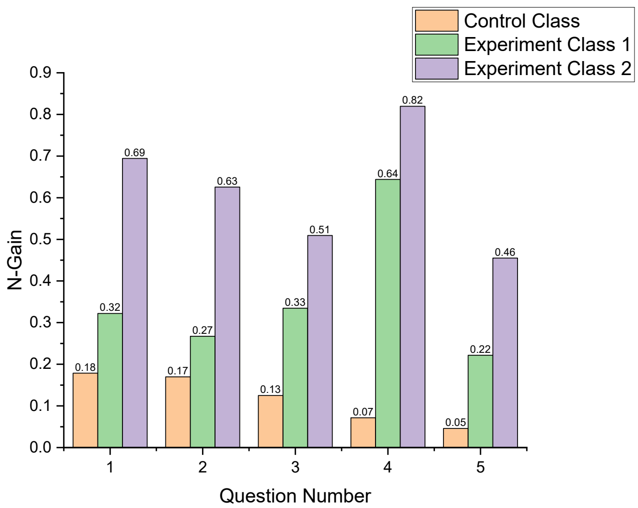
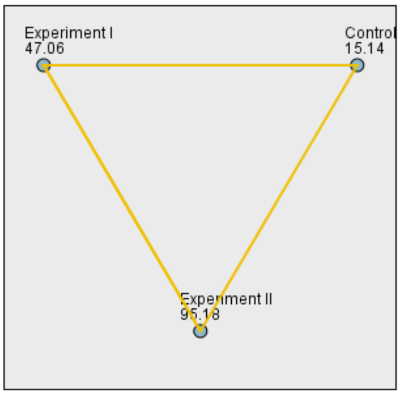


Figure 4. There was a significant increase in representation competence for the experimental group compared to the control group

Figure 5 presents the Kruskal-Wallis's test results, which compare changes in students' representational competence before and after the treatment. Based on the p-value, there is a significant difference in changes in students' representational competency between the control group, experimental group I, and experimental group II. In addition, post-hoc analysis using the Games-Howell test in Table 7 was conducted to identify the treatment that gave the best results. Based on the mean difference value, it can be seen that the treatment given to the experiment II group can improve students' representational competency better than the experiment I group.

Pairwise Comparisons of Group



Each node shows the sample average rank of Group.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Control-Experiment I	-31.916	10.937	-2.918	.004	.011
Control-Experiment II	-80.033	11.034	-7.253	.000	.000
Experiment I-Experiment II	-48.117	6.929	-6.944	.000	.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Figure 5. Results of Kruskal-Wallis's test

Table 7. The result of Games-Howell test

(I) group	(J) group	Mean difference (I-J)	Std. error	Sig.	95% confidence interval Lower bound	95% confidence interval Upper bound
Control	Experiment I	-0.21345*	0.03560	0.000	-0.3047	-0.1222
	Experiment II	-0.48045*	0.04047	0.000	-0.5807	-0.3802
Experiment I	Control	0.21345*	0.03560	0.000	0.1222	0.3047
	Experiment II	-0.26700*	0.02663	0.000	-0.3305	-0.2035
Experiment II	Control	0.48045*	0.04047	0.000	0.3802	0.5807
	Experiment I	0.26700*	0.02663	0.000	0.2035	0.3305

Note: *. The mean difference is significant at the 0.05 level.

4. DISCUSSION

This study developed a valid and practical Android-based representation training model. The trial received a positive response from students. The analysis results show that using Android-based representation training models in classroom learning can improve representation competence by 66.67% in the medium category and 33.33% in the high category. Meanwhile, if this training model is used without classroom learning, it can increase representation competence by 30.51% in the low category and 69.49% in the medium category. The findings indicate that implementing an Android-based representation training model in the learning process can enhance students' representation competence. These results align with research conducted by Crompton and Burke [42], suggesting that mobile-based learning can increase student engagement and motivation. Using the android-based representation training model also provides opportunities for repeated practice, essential for strengthening students' representation competencies. These results align with research conducted by Edelsbrunner *et al*. [6], which states that students who diligently practice representation competence will improve their abilities. Furthermore, the Wilcoxon signed-rank test confirmed that the observed improvements were statistically significant across all groups, with the strongest significance in the experimental groups. Effect size analysis also demonstrated large practical effects (r=0.821 for the control, r=0.871 for experimental group I, and r=0.862 for experimental group II), indicating that the gains were not only statistically significant but also meaningful in practice. The larger effect sizes in the experimental groups reinforce the conclusion that the integration of feedback and scaffolding in the Android-based model substantially strengthened students' representational competence compared to traditional learning. Students can develop a deeper and holistic understanding of complex physics concepts through consistent and purposeful practice in representational competency.

This training model is equipped with feedback that supports the effectiveness of increasing students' representational competency. The improvement occurs because the feedback explains students' errors when selecting answer options for the given problems. These findings align with the report by Omilani and Ogbonna [43], which states that feedback facilitates reflective discourse and encourages critical reflection. In addition, feedback improves the quality of learning and informs what students need and what to do [44], [45]. Feedback should be direct to help students immediately recognize their mistakes [46]. However, while the feedback feature is useful, the current implementation lacks remediation elements that could help students who continue to struggle after receiving initial guidance. Feedback on this exercise model can be a reflection for students on understanding a graph.

The feedback developed by scaffolding can provide gradual support that helps students build understanding and skills more effectively. These results are in line with other studies, which implied that the use of scaffolding can help students overcome their conceptual challenges [2], [47], [48]. Another study highlighted that students who receive guidance and scaffolding during the learning process are more efficient and progress significantly in solving problems [49]. Moreover, while feedback and scaffolding support most learners, students who continue to struggle would benefit from remediation features. Future versions of the application could include adaptive pathways or tailored hints, enabling more personalized support for diverse learners.

At the end of the problem, students get an explanation of the solution with various types of representations. The use of multi-representations in the discussion aims to adjust the needs of students to deepen their conceptual understanding. These findings align with previous research, which concludes that incorporating various learning technologies with multiple representations helps transform concepts into different forms, thereby enhancing conceptual understanding. Understanding the relationship between different representations involves multiple processes [50]–[52]. However, it is important to clarify that the core exercises in this model focus exclusively on graph comprehension, while other representation types (e.g., verbal, mathematical, and diagrammatic) are only used in explanations. This focus significantly limits the scope of representational competency addressed by the model.

From a theoretical perspective, this limitation underscores the need to situate representational training within broader cognitive frameworks. Dual coding theory suggests that students benefit most when verbal and visual representations are integrated, as this dual-channel processing facilitates retention and transfer. Similarly, cognitive load theory emphasizes the importance of instructional designs that distribute information across multiple modes in order to minimize unnecessary cognitive load. Applying these frameworks, future iterations of the Android-based training model should embed verbal, mathematical, and diagrammatic exercises alongside graphical tasks. Such integration would allow students not only to interpret graphs but also to construct, compare, and connect different representational forms in a coherent manner, thereby fostering higher-order representational competence.

Another critical limitation lies in the use of multiple-choice questions for all training exercises. While the evaluation of student gains was based on essay-format tests, the training relied solely on multiple-choice items, which may not adequately capture students' deeper understanding or ability to construct representations. This discrepancy could affect the interpretation of learning outcomes and should be considered in future model refinements. To address this limitation, future iterations of the model should diversify assessment and training formats. Instead of relying solely on multiple-choice exercises, incorporating open-ended tasks, interactive simulations, or construction-based activities would allow students to demonstrate deeper representational reasoning and problem-solving processes. Such formats are better aligned with the essay-based evaluation used in this study and may provide a more authentic measure of representational competence. Increasing representational competency will be more effective if the Android-based representation training model is used after the classroom session. Students should be given 60 minutes to complete the exercises in the application. Following this, the lecturer can provide additional explanations related to the exercises. Students should then have a further week to practice using the application, allowing them to understand better and master the material.

The developed model has similarities with other training models in that it can provide feedback. However, it offers advantages over other models. The feedback includes not only right and wrong responses but also specific adjustments based on the student's errors in choosing the answer options. It provides brief explanations related to students' mistakes. The scaffolding has been tailored to the needs of students based on the initial test results. Lastly, is the exercise model accessible anytime and anywhere? Nevertheless, despite its practicality, the model's accessibility remains limited because it is not yet available on Google Play or the Apple Store. To enhance replicability and wider adoption, future dissemination should include publishing the application on official platforms or at least providing a demo link for educators and researchers.

In general, the results of this study have several important implications in the development of technology-based learning models: i) the integration of Android-based models in physics learning can improve students' understanding of kinematics concepts through multi-representation exercises; ii) Scaffolding and adaptive feedback must be designed by considering various levels of student understanding to be more effective in supporting the learning process; and iii) direct interaction with lecturers is still needed, especially in explaining more complex concepts that are difficult to understand only through digital media. Finally, although the application has been validated by experts and tested on a limited scale, further longitudinal studies are needed to determine the long-term impact of this model on students' representational competence and knowledge retention. Future research should also explore its application to other physics topics beyond linear motion kinematics and consider the integration of artificial intelligence (AI) to enhance adaptability, personalization, and scalability of the training model.

5. CONCLUSION

An Android-based representation training model has been developed to improve students' representation competence in understanding the concept of linear motion kinematics. This training model is designed with feedback and scaffolding features that aim to assist students in translating and connecting various forms of representation in physics. However, the model's primary focus is on graphical representations, while other forms (verbal, mathematical, or pictorial) are used only in explanatory sections. This limited scope should be taken into account when interpreting the model's impact on broader representational competence.

The results showed that the developed training model improved students' representation competence. The pre-test and post-test analysis showed a significant increase in students' understanding of the representation of linear motion kinematics. In addition, students responded positively to the use of the application, especially in the aspects of ease of use, effectiveness of scaffolding, and presentation of interesting material. Nevertheless, although students appreciated the scaffolding feature, its current length poses usability challenges and should be refined to enhance efficiency without reducing conceptual clarity.

One notable limitation is the exclusive use of multiple-choice questions in the training model, which may restrict its ability to assess students' deeper understanding of representational competence. This is particularly important considering that essay-based instruments were used in the evaluation process. Furthermore, this study still has several limitations, including the concept coverage, which is still limited to linear motion kinematics, and the absence of remediation features to support students who struggle with the material.

Student responses showed high practicality; however, the application is still unavailable on official platforms like Google Play or the Apple Store, limiting its broader accessibility. Future studies are recommended to expand the exercise model to more physics concepts, incorporate diverse representations and problem types, and enhance scaffolding efficiency. Longitudinal research is also needed to examine retention and transfer of representational skills over time, as tracking student performance beyond pre- and post-tests would provide stronger evidence of the model's long-term effectiveness and scalability. Further testing is also necessary to assess its sustained impact on students' representational competence in physics learning. Future research should also explore adapting this model to other physics domains such as Newton's laws or energy conservation, demonstrating its scalability beyond linear motion kinematics.

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C : **C**onceptualization
M : **M**ethodology
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R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [SK], upon reasonable request.

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