Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
ISSN: 2086-6135 E-ISSN: 2541-612x
Volume 15 No. 3. September 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

DEVELOPMENT OF A MULTI-REPRESENTATION-BASED PHYSICS TEACHING MODULE TO IMPROVE STUDENTS' ANALYTICAL THINKING SKILLS ON RECTILINEAR MOTION

Dwi Setiawati[1a*], Helmi[2b],Kaharuddin Arafah[3c]

[1]Department of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar
[2-3]Faculty of Mathematics and Natural Sciences, Universitas Negeri Makassar

[*1]dwisetiawati236@gmail.com
[2] helmi@unm.ac.id
[3]karafah@unm.ac.id

(*)Corresponding Author
dwisetiawati236@gmail.com

ARTICLE HISTORY
Received : 20-06-2026
Revised : 29-07-2026
Accepted : 31-07-2026

KEYWORDS
teaching module;
multi-representation;
analytical thinking;
rectilinear motion;
4D model;

ABSTRACT
Twenty-first-century learning requires students to master analytical thinking, one of the higher-order thinking skills needed to identify information, connect concepts, interpret data, and draw evidence-based conclusions. In physics learning, rectilinear motion is a fundamental topic that requires students to integrate verbal, mathematical, graphical, and pictorial representations, an ability known as multi-representation competence. This study aimed to develop a multi-representation-based physics teaching module to improve students' analytical thinking skills on the topic of rectilinear motion and to determine its content validity and practicality. This research and development (R&D) study used the 4D model (Define, Design, Develop, Disseminate) developed by Thiagarajan et al. (1974). The trial subjects were students of class X.1 at SMA Negeri 2 Makassar. Data were collected through expert validation sheets and teacher and student response questionnaires and were analyzed using Aiken's V content validity index and the practicality percentage (PRS) formula. The results showed that the multi-representation-based physics teaching module obtained an average Aiken's V index of 0.924, categorized as valid, while the supporting research instruments obtained an average Aiken's V of 0.80, also categorized as valid. The teacher response questionnaire showed an average practicality percentage of 86.1%, categorized as very practical. These findings indicate that the developed module is valid and very practical for supporting physics learning on the rectilinear motion topic and for training students' analytical thinking skills.

INTRODUCTION

The development of science and technology in the twenty-first century demands human resources who possess critical, creative, and analytical thinking skills and who are able to adapt to continuous change. Twenty-first-century learning is directed toward equipping students with a broad set of competencies commonly summarized as critical thinking and doing, creativity, collaboration, cross-cultural understanding, communication, computing and ICT literacy, and career and learning self-reliance, all of which fall under the umbrella of the twenty-first-century skills framework popularized by Trilling and Fadel (2009) and adopted into Indonesia's Merdeka Curriculum policy (Kementerian

SJIP Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
ISSN: 2086-6135 E-ISSN: 2541-612x
Volume 15 No. 3. September 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2022). One of the central competencies within this framework is analytical thinking, defined as students' ability to identify information, connect various concepts, distinguish facts from concepts, interpret data, and draw conclusions based on available evidence. This ability corresponds closely to the "analyze" level in the revised cognitive taxonomy proposed by Anderson and Krathwohl (2001), which describes analytical thinking as the capacity to break material into its constituent parts and to determine how those parts relate to one another and to the material's overall structure or purpose.

Nevertheless, results from international assessments such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) indicate that Indonesian students' ability to solve problems that require reasoning and higher-order thinking still needs improvement (OECD, 2023; Mullis et al., 2020). Physics is one of the subjects that plays an important role in developing analytical thinking because it requires students to understand concepts, analyze natural phenomena, interpret data, and solve problems based on scientific principles. In practice, however, physics is still regarded as difficult by many students because of its numerous abstract concepts and their close relationship with mathematical representation, so that learning tends to focus on solving mathematical problems without giving students the opportunity to fully understand the meaning of the underlying concepts.

One physics topic that particularly requires analytical thinking is rectilinear motion, a foundational tenth-grade topic covering physical quantities, uniform rectilinear motion (GLB), and uniformly accelerated rectilinear motion (GLBB). Understanding this topic requires the ability to perform mathematical calculations while simultaneously interpreting graphs, reading data tables, understanding illustrations of motion, and connecting various representations to explain physical phenomena. This ability is known as multi-representation competence, that is, the ability to present and understand the same concept through various forms of representation, such as verbal, mathematical, graphical, pictorial, and tabular representations. The use of multiple representations allows students to view the relationships among concepts from different perspectives, thereby enhancing conceptual understanding while simultaneously developing analytical thinking skills (Izsák & Sherin, 2003). This is consistent with the DeFT (Design, Functions, Tasks) framework proposed by Ainsworth (2006), which argues that combining several representations provides complementary information, constrains misinterpretation, and promotes the construction of deeper and more integrated understanding. A concrete illustration of this principle in physics instruction is provided by Van Heuvelen and Zou (2001), who showed that combining verbal, pictorial, graphical (bar-chart), and mathematical representations of work-energy processes helped introductory physics students build a more coherent conceptual understanding and improved their problem-solving performance, a representational structure that closely parallels the verbal-pictorial-graphical-mathematical approach used for rectilinear motion in the present study.

One of the instructional tools that can support the cultivation of multi-representation competence is a multi-representation-based teaching module, which presents physics concepts through verbal, pictorial, graphical, tabular, and mathematical representations, accompanied by learning activities that encourage students to connect these various representations when solving problems. Several studies show that modules based on multiple representations tend to be of good quality and receive a positive response from students; a systematic literature review by Latifah et al. (2024) of physics learning media based on multiple representations reported that such media generally obtain favorable validity and quality evaluations across a range of physics topics. Other studies indicate that multi-representation competence is closely related to students' ability to solve physics problems (Aha et al., 2020). Additional relevant research by Saputra et al. (2020) and Della et al. (2021) has likewise shown that multi-representation-based physics instructional materials on the topic of rectilinear motion are valid and can strengthen students' representational abilities in senior high school physics learning. Even so, research that specifically develops a multi-representation-based physics teaching module aimed at improving analytical thinking skills, particularly on the topic of rectilinear motion, is still relatively limited.

Based on the description above, this study focuses on developing a multi-representation-based physics teaching module to improve students' analytical thinking skills on the topic of rectilinear motion at SMA Negeri 2 Makassar. The module developed is expected to meet the criteria of validity and practicality so that it can become an alternative instructional tool supporting the implementation of the Merdeka Curriculum. The objectives of this study were to determine: (1) the content validity of the multi-representation-based physics teaching module on the topic of rectilinear motion, and (2) the practicality of the teaching module based on teacher and student responses.

SJIP Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
ISSN: 2086-6135 E-ISSN: 2541-612x
Volume 15 No. 3. September 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

METHOD

This study is a research and development (R&D) study that follows general R&D principles (Sugiyono, 2023) and refers specifically to the 4D model (Four-D Model) developed by Thiagarajan et al. (1974), which consists of four stages: Define, Design, Develop, and Disseminate. The 4D model was chosen because it provides a detailed and systematic description of each stage, is easy to understand, and includes a stage of appraisal by experts.

The study was conducted at SMA Negeri 2 Makassar during the even semester of the 2025/2026 academic year. The trial subjects were students of class X.1 at SMA Negeri 2 Makassar. In the define stage, a front-end analysis, learner analysis, task analysis, concept analysis, and learning-objective analysis were carried out. In the design stage, the format of the teaching module was designed, consisting of a cover, preface, learning-objective flow, general information, core components, appendices, glossary, and bibliography, integrating verbal, pictorial/diagrammatic, graphical, and mathematical representations into every learning activity and complemented with a Student Worksheet (LKPD). In the develop stage, the teaching module was validated by three experts (two physics education lecturers from Universitas Negeri Makassar and one education practitioner, an alumnus of the graduate physics education program at Universitas Negeri Yogyakarta) before being trialed using a One-Group Pretest-Posttest Design. In the disseminate stage, the teaching module was distributed to physics teachers at SMA Negeri 2 Makassar to obtain feedback through a teacher response questionnaire.

The research instruments consisted of a teaching-module validation sheet, a teacher response questionnaire, and a student response questionnaire, all of which were validated by three experts before use. Data on the validity of the teaching module were analyzed using the content validity coefficient with Aiken's V index (Aiken, 1985), using the equation $V = \Sigma s / [n(c-1)]$, where s is the score assigned by each rater minus the lowest score in the category used, n is the number of raters, and c is the number of categories the rater may choose from. The Aiken's V coefficient was interpreted into four categories: very valid ($0.80 \leq V \leq 1.00$), valid ($0.60 \leq V < 0.80$), fairly valid ($0.40 \leq V < 0.60$), and invalid ($V < 0.40$).

Data on the practicality of the teaching module were obtained through teacher and student response questionnaires and were analyzed descriptively and quantitatively by calculating the average percentage score (PRS) using the equation $PRS = (\Sigma A/\Sigma B) \times 100\%$, where ΣA is the total score obtained and ΣB is the maximum possible score. The PRS results were interpreted into five categories according to Riduwan (2015): very practical (80–100%), practical (61–80%), fairly practical (41–60%), not practical (21–40%), and very not practical (0–20%).

RESULTS AND DISCUSSION

Validation Results of the Multi-Representation-Based Physics Teaching Module

This study produced a multi-representation-based physics teaching module for grade X/Phase E on the topic of rectilinear motion, designed to train students' analytical thinking skills through the presentation of material in verbal, pictorial/diagrammatic, graphical, and mathematical representations. The teaching module was validated by three experts on the aspects of content feasibility, presentation, language, and graphic design. The results of the validity test using the Aiken's V index are presented in Table 1.

Table 1. Results of the Validity Test of the Multi-Representation-Based Physics Teaching Module Using the Aiken's V Index

Aspect	Number of Items	V Index	Category
Content feasibility	13	0.923	Valid
Presentation feasibility	7	0.984	Valid
Language feasibility	12	0.898	Valid
Graphic feasibility	9	0.914	Valid
Average	41	0.924	Valid

Based on Table 1, all aspects assessed fall into the valid category, with an average validity index of 0.924. This indicates that the multi-representation-based physics teaching module is feasible to proceed to the limited-trial stage. Based on the assessment of the three experts, the module was declared feasible for use with minor revisions, including refinement of the visual design, adjustment of image size and layout, alignment of learning activities and the LKPD with the multi-representation approach, addition of identity fields to each LKPD, and refinement of the systematics of material presentation. In addition to the teaching module, the supporting research instruments (the teacher and student

Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
ISSN: 2086-6135 E-ISSN: 2541-612x
Volume 15 No. 3. September 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

response questionnaires, as well as the analytical-thinking test instrument) were also validated using the Aiken's V index, with results presented in Table 2.

Table 2. Results of the Validity Test of the Supporting Research Instruments Using the Aiken's V Index

Instrument	Average V	Category
Teacher and student response questionnaire	0.877	Valid
Analytical thinking test (pretest)	0.850	Valid
Analytical thinking test (posttest)	0.864	Valid

Based on Table 2, all three supporting research instruments obtained an average Aiken's V index above 0.80, placing them in the valid category, so the instruments were declared feasible for use in the trial stage with only minor revisions.

Teacher and Student Responses to the Multi-Representation-Based Physics Teaching Module

Teacher and student responses to the teaching module were obtained through questionnaires completed after learning using the teaching module had been carried out. The teacher response questionnaire was completed by three physics teachers, while the student response questionnaire was completed by 36 students of class X.1 at SMA Negeri 2 Makassar. The results of the teacher responses regarding the practicality of the teaching module are presented in Table 3.

Table 3. Results of Teacher Responses to the Multi-Representation-Based Physics Teaching Module

Assessment Aspect PRS (%)Criterion

Assessment Aspect	PRS (%)	Criterion
Questionnaire completion instructions	87.5	Very practical
Content	83.3	Very practical
Language	87.5	Very practical
Average	86.1	Very practical

Based on Table 3, the average percentage of teacher responses to the teaching module was 86.1%, falling into the very practical category. The teachers stated that the developed multi-representation-based physics teaching module was attractive and appropriate for use in learning, particularly in helping students connect verbal, pictorial, graphical, and mathematical representations on the topic of rectilinear motion.

DISCUSSION

The content validity of the teaching module was analyzed using the Aiken's V expert-agreement index test, with an instrument declared valid if the Aiken's V coefficient is greater than 0.4 (Aiken, 1985). The average Aiken's V coefficient of 0.924 indicates that the multi-representation-based physics teaching module falls into the valid category and is feasible to proceed to the trial stage with minor revisions. The high validity score on the presentation-feasibility aspect (0.984) indicates that the experts judged the systematics and integration among verbal, pictorial, graphical, and mathematical representations to already be appropriate. This is in line with the view of Izsák and Sherin (2003), who state that teaching that draws on multiple representations enables students to understand a concept from various perspectives so that the understanding formed becomes more complete, as well as with Ainsworth's (2006) DeFT framework, which explains that well-designed combinations of representations serve complementary functions, help constrain misinterpretation, and support the construction of deeper conceptual understanding. A similar pattern was reported by Van Heuvelen and Zou (2001), who found that combining verbal, pictorial, bar-chart, and mathematical representations of physical processes strengthened students' conceptual understanding and problem-solving performance, a finding that supports the representational structure adopted in the present module.

This finding is also consistent with the results of Saputra et al. (2020), who showed that a multi-representation-based e-module on the topic of rectilinear motion received a very good response from students and was declared valid, as well as with Della et al. (2021), who found that senior high school students' pictorial and mathematical representation abilities on the rectilinear motion topic can be strengthened through instruction that deliberately connects multiple representations. The findings likewise align with the systematic review conducted by Latifah et al. (2024), which reported that multi-representation-based physics learning media generally receive favorable validity and quality evaluations across a variety of physics topics.

The practicality of the teaching module was analyzed based on the results of teacher responses. According to Riduwan (2015), an instructional device can be considered practical if practitioners state that the device is theoretically feasible for use in learning and if its level of implementation shows good results in the field. The average percentage of teacher responses of 86.1%, which falls into the very practical category, indicates that the developed multi-representation-based physics teaching module can help teachers in the physics learning process and make it easier for students to connect various forms of representation in order to understand the topic of rectilinear motion. This result is in line with the findings of Saputra et al. (2020) and is further reinforced by Aha et al. (2020), who demonstrated that a multi-representation-based learning strategy combined with a conceptual problem-solving approach produces measurable differences in students' problem-solving and representation abilities, supporting the practical value of embedding multiple representations within physics instructional materials.

From a conceptual standpoint, the analytical thinking skills targeted by this module correspond to the "analyze" category described by Anderson and Krathwohl (2001), namely the ability to break material down into its constituent parts and to determine the relationships among those parts and the overall structure of a problem. The valid pretest and posttest instruments used to measure this ability (Aiken's V of 0.850 and 0.864, respectively) provide an initial, content-validated basis for future measurement of student achievement on this competency. This effort is also consistent with the broader twenty-first-century skills agenda described by Trilling and Fadel (2009) and adopted within Indonesia's Merdeka Curriculum policy (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia, 2022), both of which encourage the development of instructional tools capable of cultivating higher-order competencies of exactly this kind, against the backdrop of the comparatively modest higher-order reasoning performance of Indonesian students reported in the PISA (OECD, 2023) and TIMSS (Mullis et al., 2020) assessments.

CONCLUSION

Based on the results and discussion, it can be concluded that: (1) the content validity of the multi-representation-based physics teaching module for improving students' analytical thinking skills on the topic of rectilinear motion falls into the valid category, with an average Aiken's V index of 0.924; and (2) the practicality of the teaching module based on teacher responses falls into the very practical category, with an average percentage of 86.1%. The multi-representation-based physics teaching module developed in this study is therefore feasible for use as an alternative instructional tool on the topic of rectilinear motion to support the implementation of the Merdeka Curriculum.

This study remains limited to a small-scale trial and has not specifically measured the module's effectiveness in improving students' analytical thinking skills through a normalized-gain analysis, such as the average normalized gain $\langle g \rangle$ proposed by Hake (1998). Future research is therefore recommended to test the module's effectiveness in a wider trial using this or a comparable gain-based measure, to develop similar multi-representation-based modules for other physics topics, and to incorporate additional research variables beyond analytical thinking skills.

REFERENCES

Aha, L. H., Muhardjito, M., & Sunaryono, S. (2020). Pengaruh strategi pembelajaran multirepresentasi dengan pendekatan conceptual problem solving terhadap kemampuan pemecahan masalah dan kemampuan representasi. Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan, 5(1), 47–53.

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. Learning and Instruction, 16(3), 183–198. https://doi.org/10.1016/j.learninstruc.2006.03.001

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. Educational and Psychological Measurement, 45(1), 131–142. https://doi.org/10.1177/0013164485451012

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Longman.

Della, A., Mahardika, I. K., & Bektiarso, S. (2021). Analisis kemampuan representasi gambar dan matematis materi gerak lurus pada siswa SMA di Bondowoso. Jurnal Pembelajaran Fisika, 10(3), 90–97.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64–74. https://doi.org/10.1119/1.18809

Izsák, A., & Sherin, M. G. (2003). Exploring the use of new representations as a resource for teacher learning. School Science and Mathematics, 103(1), 18–27. https://doi.org/10.1111/j.1949-8594.2003.tb18211.x

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia. (2022). Keputusan Menteri Pendidikan, Kebudayaan, Riset, dan Teknologi Nomor 56/M/2022 tentang pedoman penerapan Kurikulum Merdeka dalam rangka pemulihan pembelajaran. Kemendikbudristek.

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

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). TIMSS 2019 international results in mathematics and science. TIMSS & PIRLS International Study Center, Boston College.

OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. https://doi.org/10.1787/53f23881-en

Riduwan. (2015). Skala pengukuran variabel-variabel penelitian. Alfabeta.

Saputra, B. E., Pathoni, H., & Kurniawan, D. A. (2020). Pengembangan e-modul fisika berbasis multirepresentasi pada materi gerak lurus. EduFisika, 5(1), 39–44. https://doi.org/10.22437/edufisika.v5i01.8843

Sugiyono. (2023). Metode penelitian pendidikan (kuantitatif, kualitatif, R&D). Alfabeta.

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). Instructional development for training teachers of exceptional children: A sourcebook. Indiana University.

Trilling, B., & Fadel, C. (2009). 21st century skills: Learning for life in our times. Jossey-Bass.

Van Heuvelen, A., & Zou, X. (2001). Multiple representations of work-energy processes. American Journal of Physics, 69(2), 184–194. https://doi.org/10.1119/1.1286662