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The Multi-representation-based Module Development to Improve the Metacognition of Circular Motion

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Abstract

This study describes the analyses of multi-representation-based teaching modules' necessity, reliability, and practicality to improve the metacognition of circular motion material. This study employed R&D (Research and Development) with Borg and Gall's model. The population consisted of the students at Public Senior High School 1 Jayapura. The samples were 26 students from the ninth grade of Public Senior High School 1 Jayapura, which were determined by cluster random sampling. The data were collected through interviews, observation, documents, expert validation, questionnaires of students' responses, and pretest-posttest. The data was analyzed using expert validation results, student-response questionnaire analysis with the Likert scale, and N-gain analysis from the pretest-posttest. The results indicated that the teaching module implemented was not pertinent to the student's requirements. Nevertheless, the devised teaching module was practical and reliable, with a 90.16% and 77.21% success rate. Consequently, the researchers determined that the module developed based on the multi-representation of circular motion could improve the student's metacognition. In this study, researchers developed a multi-representation-based module that had the potential to enhance students' metacognitive knowledge.

Keywords: circular motion; metacognition; multi-representation; teaching module

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INTRODUCTION

The educational world, which schools embody, plays the most significant role in preparing the future generation of a nation with a wide range of knowledge and insight, as well as quality and competitiveness. The generation also requires metacognitive knowledge or metacognition (Versteeg et al., 2021; Wardana et al., 2021). Metacognition

refers to an individual understanding of the thought matters, the efforts of maximizing the thought, and the step selection to solve problems in various situations (Çini et al., 2023; O'Neil Jr & Brown, 1998). Individual metacognition is advantageous for managing one's actions to solve problems or challenges (Gunawan & Mudjiran, 2022; Güner & Erbay, 2021; Vorhölter, 2023).



Metacognition has emerged as a significant and influential factor in educational outcomes (Azevedo, 2020; Shen & Liu, 2011). Schools play a critical role in developing exceptional metacognition in the next generation. Consequently, the school learning process must be designed to cultivate and prepare students' metacognitive knowledge. One school lesson students' metacognitive knowledge. One school lesson that contributes to improving students' metacognition is physics.

Implementing the lesson requires relevant teaching modules for the teachers and students. The teaching module refers to the set of learning instruments to achieve the relevant learning competence and standards based on the curriculum (Maulida, 2022; Su & Zhong, 2022). A teaching module could be printed (Nurdyansyah, 2018; Skoufaki & Petrić, 2021).

Implementing the physics teaching module becomes the strategy for teachers to stimulate students to develop and improve their metacognition (Hapsari & Widodo, 2016). A teaching module is a lesson material set that teachers systematically organise (Hidyanto et al., 2016). The teaching module serves as a valuable resource for students and a guide for teachers in implementing their educational objectives. Nevertheless, the applied teaching module must be modified to accommodate the student's learning styles and requirements.

Every student has a unique learning style (Wang et al., 2020; Zulqarnain & Fatmahanik, 2022). Visual-type students have some learning preferences, such as observing, seeing figures or graphics and reading (Papadatou-Pastou et al., 2021; Sari et al., 2019). The auditory type students can spend time listening to the teachers' verbal lectures because they find the explanations understandable (Apriliyani, 2020). The kinesthetic type students can easily understand materials by practising (Yusro & Ardania, 2023).

It is crucial to have a teaching module that can accommodate all learning styles. In this study, developing a teaching module based on multi-representations for students is important (Nisa et al., 2020; Viyanti et al., 2021). Multi-representation is the term used to describe the various methods of presenting information, including graphics, diagrams, texts, and mathematics notations (Amin & Levrini, 2018; Gulkilik et al., 2020). Multi-representation provides the materials in verbal modes, figures, graphics, mathematics notations, and simulations (Abdurrahman, 2016; Mercan Erdogan et al., 2021; Prain & Waldrup, 2010).

The development of a teaching module based on multi-representation can improve students' metacognition (Nurmala, 2016). In 1976, John Flavell, a psychologist in the United States of America, first introduced metacognition (Wenda et al., 2021). Metacognition serves as an individual basis for applying and managing cognition during learning activities (Drigas & Mitsea, 2021; Telaumbanua, 2018).

The interview with the physics teachers at Public Senior High School 1 Jayapura showed that the students needed help understanding the physics material about the uniform circular motion (UCM) and the relativistic circular motion (RCM). The students needed help determining and using the relevant learning strategy based on their potential. These shortcomings happened because the applied teaching module needed to be explained. Many presented materials had mathematics representations, unclear descriptive explanations, and less stimulus to recognize the students' potential to support learning.

There are several results of literature studies related to the study that researchers conducted. In the first literature study, research is related to developing metacognition-based physics textbooks as alternative teaching

materials on particle dynamics material (Afriwardani, 2021). The second literature study discusses the development of metacognition-based physics modules on elasticity and simple harmonic motion (Winarti & Saputri, 2018). The third literature study is related to developing multi-representation-based learning modules in physics learning in high school (Setyandaru et al., 2017). The fourth literature study is related to developing problem-based learning modules to improve metacognitive knowledge of temperature and heat material (Al Farizi et al., 2023). The fifth literature study is related to developing metacognitive-based modules on simple harmonic vibration material (Isnaini & Mursid, 2016).

Based on the issues raised, the researchers attempted to develop a teaching module based on multi-representation to improve the students' metacognition of circular motion.

METHOD

This study employed the Research and development method based on Borg & Gall's model. The model is suitable for developing the teaching module based on SHS's multi-representation of physics learning (Siregar, 2023). As the first step, the researchers collected the data by analyzing the necessity, conducting a literature study, and conducting small-scale research (Saputro, 2021). As the second step, the researchers created the teaching material-related plans to develop as a teaching module based on multi-representation to improve the ninth graders' metacognition of circular motion. As the third step, the researchers develop the initial product. The final step was promoting the initial field test (Sugiyono, 2013).

This study was conducted in the odd semester of the 2023/2024 academic year. The research population consisted of the ninth graders of Public Senior High School 1 Jayapura in the academic year

2023/2024 during the odd semester. The research subjects were 26 students from a class, which were determined using cluster random sampling (Arieska & Herdiani, 2018).

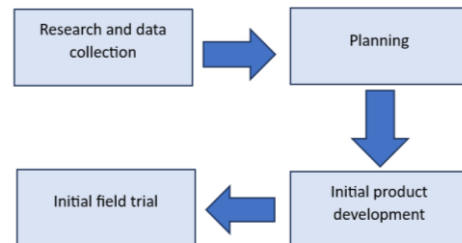


Figure 1. Research procedures

Data were collected through observation, interview, documentation, and pretest-posttest. The applied research instruments were the validation sheet, material rubrics, media, and module language to measure the reliability of the developed module. The researchers also used the rubrics of the students' response questionnaire about the module's implementation based on multi-representation and the rubric to assess the student's metacognition.

The data were analyzed using a Likert scale to validate the module. Then, the data were presented qualitatively and quantitatively to measure the module's reliability. The data obtained from the students' response questionnaires were a Likert scale for each positive and negative statement. The students' response sheet results were used to determine the practicability category of the developed module. Then, the N-gain test was applied to determine the increased metacognition achievements before and after using the developed module based on the pretest-posttest mean scores (Martawijaya et al., 2023). If the N-gain value is more than 0.7, it is in the high category. The N-gain value is more than or equal to 0.3 and less than or equal to 0.7; it is in the moderate category. The N-gain value between 0 and 0.3 is in the low category, and the N-

gain value equal to zero is in the failed category.

RESULT AND DISCUSSION

The developed product is a multi-representation-based module to improve the metacognition of the ninth graders about circular motion at Public Senior High School 1 Jayapura. This study employed the Research and Development method with Borg & Gal's model, which consists of ten stages (Mushlihah et al., 2018). However, the researchers only applied four initial stages to develop and produce a valid and reliable product.

The needs analysis results in this study indicated that the teachers and students used teaching materials in textbooks or modules whose presentation methods did not align with the student's requirements. A very valid feasibility interpretation was obtained for the Multi-representation-based Module on circular motion material as a whole, with a percentage of 93.6% from language expert validators, material expert validators, and media expert validators. Based on the overall student response questionnaire analysis, the practicality of utilizing the Multi-representation-based Module on the circular motion material was determined to be 77.21% with a good interpretation. Additionally, the N-Gain analysis of the pre-test and post-test data yielded a value of 0.52 with moderate criteria.

The data were collected by interviewing the physics teachers as the first step. The interview was used to collect information related to the applied learning source for the students, the learning process, and the student's metacognition of circular motion. The information that was obtained regarding the students' learning sources includes the following: 1) the printed books or modules sold at the school cooperation or other relevant printed books and Internet source material; 2) the difficulties that the

students face in navigating the circular motion as a result of the limited learning sources; 3) the misconceptions that the students have regarding the independently studied materials from the given learning sources, such as the Internet.

The interview results about the related learning process of the students to learn the circular motions include: 1) a few enthusiastic students who are eager to learn the materials about the uniform circular motion and relativistic circular motion; 2) the difficulties of the students to understand and analyze the differences between uniform circular motion and relativistic circular motion; 3) the difficulties of some students about the given materials from the textbook or module due to limited explanations, descriptions, and illustrations but full of equations about circular motion; 4) the incapacities of some students to reach the learning accomplishment; and 5) some inactive students in learning circular motion.

The interview results about the students' metacognition while learning circular motion include: 1) the difficulties of some students to understand the relevant learning strategy for further implementation; 2) inaccurate learning strategies to solve the given problems; and 3) the unawareness of the students about their strength and their weakness while learning circular motion.

The literature-searching activity was conducted to find related materials about the multi-representation of circular motion and the concept of developing the teaching module. Based on the first step, the subsequent step was - planning the research. The researchers designed the multi-representation-based module about circular motion. Then, the researchers planned the research time. The following is the framework of the pre-made module design.

The title of the module material is written on the upper cover. The module

developed by the researcher is entitled Kinematics of Circular Motion. The material in this module is in accordance with the lesson of the eleventh grade of senior high school, which is written on the lower right of the module cover. As for the bottom left of the cover, the author's name and the lecturer who assisted the author during the module preparation are listed.

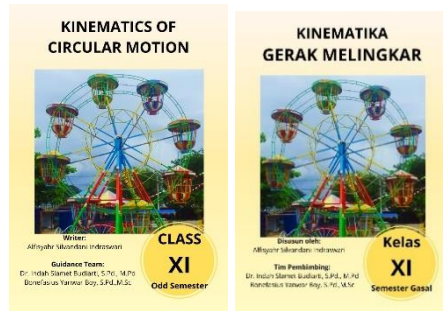


Figure 2 Product design

The third step deals with the initial product development. The Multi-Representation-based Module is based on the characteristics of the applied module. The module's design has some components, such as a cover, user guideline, table of contents, conceptual map, learning achievement, learning objective, material explanation, question example, question item, assessment, keyword, glossary, and bibliography. The multi-representation module was developed using the Canva application.

Multi-representation is defined as a way of presenting in various forms, such as graphs, diagrams, texts and mathematics (Amin & Levrini, 2018). Multi-representation can be used to explore a concept scientifically, which can be presented verbally, in equations, or in graphic form (Krisnaningsih & Hariyono, 2022). In addition to verbal, graphic, diagram, and equation forms, multi-representation can also be in images. The module was useful in improving the students' metacognition. Table 1 shows the aspects and the indicators of the metacognition of uniform circular motion.

Table 1 The indicators of uniform circular motion metacognition

No	Aspect	Indicators
1.	Factual Knowledge	The implementation of uniform circular motion
2.	The conceptual knowledge	The interpretations of the model, symbol, sign, or applied terms to concepts
3.	The Procedural Knowledge	The Implementation of the relevant procedure with the applied method to solve the question

Table 1 shows three questions with three aspects. They are factual, conceptual, and procedural knowledge. The first indicator is in the first question. The second indicator is in the second question, while the third indicator is in the third question. Based on the pretest, the results meet the indicators. The results show that the students had low metacognition before using the developed teaching module. Table 2 shows the aspects and the indicators of the relativistic circular motion.

Table 2 The indicators of relativistic circular motion metacognition

Aspect	Indicators
Factual Knowledge	The implementation of uniform circular motion
The conceptual knowledge	The interpretations of the model, symbol, sign, or applied terms to concepts
The Procedural Knowledge	The Implementation of the relevant procedure with the applied method to solve the question

Table 2 shows three questions with three aspects. The students received three questions with three aspects. The first indicator is in the third question. The second indicator is in the first question, while the third is in the second. The

fourth step was the initial trial run. This step is the trial run test of the developed module with the initial design result to determine the validity and practicability of the module implementation as the teaching material. The obtained data from the language validator found six qualities: directness, communicative content, dialogic and interactive content, relevance to the student development, relevance to the language principle (excellent grammar) and accurate use of symbols, icons, and terms.

Table 3 shows the score percentage of the developed product based on the language expert validator. Then, the researchers classified the scales as observed in Table 3. The module's validity criteria were met when the language expert's obtained validity results reached 95.5%, which was classified as extremely valid. Each interpretation is classified as "extremely valid." Then, the implementations of symbols, icons, and terms received a percentage, with each interpretation being extremely valid.

Table 3 The data of the validity results by the language expert validator

Aspect	Percentage
Directness	96.5%
Communicative content	90%
Dialogic and interactive content	90%
The relevance to student development	100%
The relevance to the language principle	100%
The accurate use of symbols, icons and terms	96.5%

The language expert validator's validation results received a percentage of 98%, with the interpretation extremely valid, generally. Therefore, the researchers concluded that the multi-representation teaching module about the circular motion teaching material had a valid category to use. The validity results in the material expert validator's data show two

aspects, namely the material and the language.

Table 4 The data of the validity results of the material expert validator

Aspects	Percentage
Content or material	86.6%
Language	100%
Mean	93.3%

Table 4 shows the assessment percentage of the developed module by the validator. The obtained validation results from the material validator show a percentage of 93.3% with the interpretation of extremely valid. The two assessment aspects from the material aspect of the developed product are 86.6% for the content with the interpretation of valid and 100% for the language with the interpretation of extremely valid.

The validation results of the material expert validator obtained a percentage of 93% with the interpretation of extremely valid, generally. Therefore, the researchers concluded that the developed module was valid and reliable based on the material aspect. The data of the validity results from the media expert found four aspects: the module design display, consistency, graphics, and figures.

Table 5 The data of the validity results of the media expert validator

Aspects	Percentage
The display of the module design	90%
Consistency	90%
Graphics	93%
Figure implementation	95%
Mean	92%

Table 5 shows the percentage of the developed product assessment by the validator. The validation of the media expert reached 92%, with the interpretation being extremely valid. The four assessed aspects were: 90% for the module design display with the interpretation of extremely valid; 90% for the consistency with the interpretation

of valid; 93% for the graphic with the interpretation of valid; and 92% for the figure with the valid interpretation. In general, the validation results of the material expert validator obtained a percentage of 82.5% with the interpretation of extremely valid.

Therefore, the researchers concluded that the developed module was valid based on the material aspect. The three validations, from the language, material, and media experts, found that the developed module obtained a percentage of 90.16%, with the interpretation that it was extremely valid and reliable to use.

The physics teachers also validated the language and not only the material and media experts. The obtained language validation results from the teacher reached 82% in the category of extremely valid, 95% for material validation with an interpretation of extremely valid, and 82.85% for media validation with an interpretation of extremely valid. After getting the approval of the experts and the teachers, the researchers revised the module based on the validator's suggestions.

The researchers examined the revised module with limited tests by comparing the pretest and post-test to obtain the N-gain. Additionally, the researchers provided the students with a response questionnaire (Maskar et al., 2021). The module's practicality as a teaching material for learning activities is assessed through student response questionnaires, while the improvement in students' metacognitive knowledge is assessed through tests (Abdi et al., 2023). Based on the data from the students collected with the questionnaire, the obtained percentage was 77.21% with excellent category. Therefore, the practicality of the developed module in terms of circular motion was excellent.

The obtained N-gain was from the students' pretest and posttest at the first and second meetings, with the sub-

materials of uniform circular motion and relativistic circular motion.

Table 6 The obtained n-gain based on the pretest-posttest

The Codes of the Students	N-gain Score	
	UCM	RCM
1.	0.61	0.2
2.	0.54	0.2
3.	0.64	0.6
4.	0.61	0.5
5.	0.54	0.2
6.	0.54	0.6
7.	1	0.5
8.	0.57	0.25
9.	0.64	0.5
10.	0.54	0.5
11.	0.61	0.6
12.	0.54	0.2
13.	0.61	0.3
14.	1	0.2
15.	0.54	0.3
16.	0.54	0.2
17.	0.61	0.4
18.	1	0.8
19.	0.45	0.5
20.	0.6	0.3
21.	1	0.2
22.	0.61	0.2
23.	0.45	0.2
24.	0.8	0.8
25.	0.64	0.2
26.	0.64	0.75
Mean	0.64	0.41

The pretest-posttest conducted on the students during their first meeting with the UCM sub-material yielded an N-gain of 19% for the high category, 81% for the moderate category, and no students in the low category. In general, the sub-material of UCM achieved an N-gain of 0.65 when subjected to the moderate criterion. The sub-material in the second meeting was RCM, which was classified as high (19%), moderate (35%), and low (46%). The N-gain graphics are presented in Figure 3, as derived from the UCM and RCM materials.

The sub-material of RCM obtained the N-gain of 0.41 with the moderate criterion, while the N-gain of the UCM obtained a percentage of 0.64 with the moderate criterion. Both UCM and RCM obtained the N-gain of 0.52 with moderate criterion for all materials. The value of the obtained N-gain of the students from the UCM is higher than the N-gain of the RCM. This matter occurs due to the difficulty level of the RCM sub-material. This material is more complicated than the UCM material.

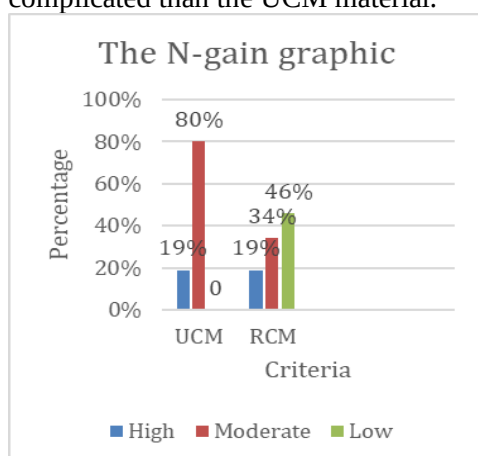


Figure 3 The graphic of n-gain with the materials of UCM and RCM

The data analysis of the student responses yielded 77.21%, with an excellent interpretation. The N-gain result of 0.53 supports the results and proves the moderate category. This situation shows that the students' metacognitive levels are excellent. Therefore, the module developed for circular motion material is practical for use in physics learning (Hahn & Klein, 2023).

CONCLUSION

The analysis results of the teacher and student necessity in using the teaching material and the module were separate from the student necessity, as evidenced by the development of the physics module for physics based on multi-representation for the material of circular motion. The multi-representation-based

module for the material of circular motion was found to be valid to use, with a percentage of 93.6% based on all validators, including language, material, and media validators. The multi-representation-based module for the circular motion was practicable, with a response questionnaire of the students indicating a percentage of 77.21% with an interpretation of excellent. The N-gain, based on the pretest-posttest, was 0.53 with a moderate criterion. It is anticipated that developing this multi-representation-based module will improve students' metacognition in circular motion material.

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