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Measuring Critical Thinking Skills with Online Instrument in Circular Motion Concept

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Abstract

The critical thinking skills need to be possessed by every student, and its evaluation requires the right measuring tool., while the critical thinking assessment has not used the right instrument. This study aims to produce an instrument to measure critical thinking skills in a circular motion. The method using Research and Developmentassimilated from Gall, Gall, & Borg and Sugiyono, adjusting to the purpose and time, so the steps are 5. The R&D steps are research and information collection, planning, developing a preliminary form of product, limited field test, and product revision. The developed instrument consists of 10 conceptual essay questions. The result from expert validation of construction, substance, and language aspects is very valid in each aspect, with 86.1%, 81.7%, and 75%. The result from field testingin 32 students is tested with Anates software and has a reliability of 0.77 in a high category. The validity result gets eight valid questions. Those eight valid questions have discrimination power which is medium, good, and very good. The difficulty levels are medium and hard. The average value of the student's score on the instrument is 43.69 shows that the students have medium skills of critical thinking in a circular motion. This study implies that the final product of the instrument consists of eight conceptual essay questions in the google form.

Keywords: circular motion; critical thinking skills; online instrument

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INTRODUCTION

Students with thinking ability critically are one of the most important skills to have in the truth-seeking process to make decisions in aworld surrounded by various information, data, and events that can be easily accepted due to the rapid development of the world of technology. Understanding and solving problemswill be easier for students with critical thinking skills (Aminudin, Rusdiana, Samsudin, Hasanah, & Maknun, 2019). Critical thinking enables students to face problems and challenges in an organized manner and be able to design solutions (Pradana, Parno, & Handayanto, 2017). In line with Bialik & Fadel (2015), the 21st century needs the skill of critical thinking because knowledge only is not enough to develop in the real world, so critical thinking skills have been established as the key component of education in recent years (Mitrevski & Zajkov, 2012). Thus, The Minister of Education and Culture in Regulation

No. 21 of 2016 contains that students must possess the competencies of the ability to think and act critically (Kemdikbud, 2016). The OECD (Organization for Economic Co-operation and Development) displayed the results of the 2018 Program for International Student Assessment (PISA) study. It revealed that students' scientific abilities were ranked 69th out of 77 countries with a low percentage (below Level 2) as one of the highest PISA participating countries (GPS, 2021). It proves that Indonesian students' critical thinking skills are low.

Students' skills can be developed through appropriate learning and assessment (Nurdini, 2019), while the availability of instruments to measure critical thinking skills is still rare and limited (Negoro, Rusilowati, Aji, & Jaafar, 2020). Based on preliminary research, The physics teacher of class X stated that questions with critical thinking skills need to be developed because they are important in training children's logical reasoning. In contrast, critical thinking skills assessments carried out so far have not used clear instruments. According to Lloyd & Bahr (2010), critical thinking skills is very important and so broad that it requires the right measuring tool. Students' presence of competency in an activity can be known through teacher measurements, so in education, the significant factor is a measurement (Mabruroh & Suhandi, 2017).

The instrument of measuring the skill of thinking critically has been developed by some developers before. Verawati, Prayogi, Yusup, & Taha (2020) developed the instrument validated in content and construct by experts and its reliability. It focuses on the domain content that fits to be assessed in thinking critically, items and the skill indicators, and the content close to daily phenomena, which is fluid material in the form of essay tests. Sya'bandari, Firman, & Rusyati (2017) developed the instrument on Matter and Heat material for grade VII, validated by experts in education, content, and media. The final instrument consists of 30 multiple choice questions with eight elements of thinking critically. The instrument of thinking critically developed by Putri, Nevrita, & Hindrasti (2019) is in biology; specifically, it is on Digestive System. The instrument, which consists of 10 essay questions, is valid in content and construct by experts, also valid and reliable based on field testing on 33 students with critical thinking indicators by Ennis. Kartimi & Liliasari (2012) developed the instrument of thinking critically in Thermochemistry. The questions are in the form of multiple choices. The instrument integrates the specific purpose of learning and the skill of thinking indicators critically Ennis. The difference between this study and those is the developed instrument is in circular motion physics material, online conceptual questions and is designed to be fulfilled the parameter instrument criteria.

Trilling & Fadel (2009) reveal aspects of students' abilities in thinking critically, including reasoning effectively, using systems thinking, and making judgments and decisions. Facione & Gittens (2016) state that certain cognitive skills are central to critical thinking. These cognitive skills include interpretation, analysis, evaluation, inference, explanation, and self-regulation. Aspects of indicators and sub-indicators between Trilling & Fadel (2009) and Facione & Gittens (2016) have similarities to each other, but this study reduces indicators by Facione & Gittens (2016). This is due to the selection of aspects and the formulation of more detailed indicators and reflective thinking process activities that can be easily applied in learning the circular motion of physics. In addition, with the limited time that the researcher

has, it is not possible to develop an instrument using all existing indicators.

The instrument developed in this study is an essay test to measure critical thinking skills on circular motion. Circular motion is one of the most important physics topics. However, it is considered difficult for students (Finley, Stewart, & Yarroch, 1982), the most challenging for teachers and students, and several misconceptions have been identified (Volfson, Eshach, & Ben-abu, 2020). Murdani & Sumarli (2018) found that 83.0% of high school and college students occurred a misconception that an object moves in a circular motion with a constant speed and constant velocity. Besides that, 58.7% of students thought that the larger the distance of an object from its rotary axis, the larger the angular velocity is. Mutsvangwa (2020) research found that factual and conceptual misunderstandings are the most challenging misconceptions that students have. Students tend to mix the concepts of tangential velocity and angular velocity in a circular motion. Syuhendri, Jafaar, & Yahya (2014) found that 18.15% of students have a misconception about the existence of centrifugal force.

Critical thinking skills are a thinking process that can support students' conceptual understanding (Sari, Parno, & Taufiq, 2016) and affect students' misconceptions by completing tests (Fitriani, 2019). The criteria for a good test item instrument consist of reliability, validity, power of discrimination, and the difficulty level of the questions (Arifin, 2017a).

Science and technology development causing the information and communication technology (ICT) development rapidly also affects education to improve the quality of learning (Amin, Mahmud, & Muris, 2016). ICT can influence Online assessment for institutions of education, teachers and students. It gives many benefits that can be used for formative also summative assessment. It is easier to generate, distribute, and assess until it gives feedback (Astalini, Darmaji, Kurniawan, Anwar, & Kurniawan, 2019). Students can use online assessment to target their future from their understanding. It has also been shown that taking tests can enhance their achievement more than having additional material studies, even when the tests do not provide feedback (Jordan, 2013). This study intends to produce an online instrument to measure critical thinking skills on circular motion material that is valid, reliable, has discrimination powers, and has various levels of difficulty.

METHOD

Research and Development (R&D) is used as the type of research in this study. The development steps consist of 5 stages, assimilated from Gall, Gall, & Borg (2003) and Sugiyono (2016). The steps are research and information collection, planning, a preliminary form of product development, limited field test, and product revision. The R&D steps in this study are shown in Figure 1.

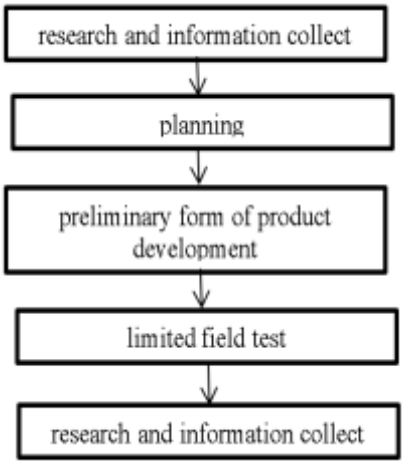

Figure 1 R&D Steps

The limited field testing to determine the quality of the question parameters was carried out on 32 students of class X who had learned

about circular motion material. The results of the analysis instrument in limited fieldtesting are revised if they do not reach the criteria for selecting items of the questions.

The instrument used is a questionnaire and question test. Questionnaires were used during preliminary research to determine the responses of teachers and students to the necessity for the instrument to measure the skills of critical thinking on circular motion, as well as during expert validation to determine the quality of instruments in the aspect of construction, substance, and language according to 3 experts. The experts decide whether the instrument is suitable to use with little or no revision or is not suitable to use. The test questions are used to determine the quality of the question item parameters (validity, reliability, power of discrimination, and difficulty level).

Critical thinking indicators reduce indicators formulated by Facione & Gittens (2016) according to the needs and formulations of sub-indicators that are easy to apply in learning circular motion physics at a constant speed. The analysis of the question items uses Anates software. Through Anates, the validity and level of difficulty categories can be read directly, but the reliability and discrimination power is consulted with the criteria in Tables 2 and 3.

Table 1 Critical thinking skills indicator

Critical Thinking Indicator	**Critical Thinking SubIndicator**
Inference	Alternative estimating Conclusion drawing
Evaluation	Credibility of a claim assessing
Affirmation	Arguments stating

Determination of the interpretation of the test reliability coefficients (r_{11}) is presented in Table 2.

Table 2 Reliability category

Reliability Coefficient	**Reliability Level**
$0.00 < r_{11} \leq 0.20$	Very low
$0.20 < r_{11} \leq 0.40$	Low
$0.40 < r_{11} \leq 0.60$	Medium
$0.60 < r_{11} \leq 0.80$	High
$0.80 < r_{11} \leq 1.00$	Very high

(Maenani & Oktova, 2015)

Interpretation of the discrimination power index is with the criteria in Table 3.

Table 3 Discrimination power index category (Rosidin, 2017)

Discrimination Power Index	**Classification**	**Interpretation**
Negative sign	No discrimination	No power difference
< 0.20	Poor	Weak
$0.20 - 0.39$	Satisfactory	Medium
$0.40 - 0.69$	Good	Good
$0.70 - 1.00$	Excellent	Very good

RESULTS AND DISCUSSION

The results of the product developed in this research are in the form of the test instrument to measure critical thinking skills in circular motion consisting of 10 conceptual questions presented in an online google form with a stimulus in the form of video-narrative, picture-narrative, and conceptual illustrations. The results of expert validation are displayed in Table 4.

Table 4 The result of expert validity

Aspect	**Rating**	**Category**
Substance	86.1%	Very valid
Construction	81.7%	Very valid
Language	75.0%	Very valid
Total	81.6%	Very valid

The results of expert validation were obtained for each aspect in the very valid category, which means that

the questions are suitable to use with a few suggestions for improvement as follows:

- In the question grid, adjusting critical thinking indicators with circular motion indicators and predictors, equated active verbs, specifying indicators, and putting operational verbs at the beginning of the sentences except for predictors.
- It was paying attention to the details of the conditions in the problem by providing information so that it does not bring up multi-interpretative answers.
- They were improving the redaction of the question and adding the necessary notation so that they did not bring up various examples.
- We are paying attention to the logical context of the question.
- We are completing the instructions for the questions.

The test results on 32 students were analyzed using Anates software to determine the instrument quality, and the reliability result was 0.77 in the high category. The result of the analysis of validity (V), discriminating power (DP), and level of difficulty (LD) are shown in Table 5.

Table 5 The result of analysis question item

Questions	V	DP	LD	Decision
1	Very Significant	Verywell	Medium	Accepted
2	Significant	Good	Medium	Accepted
3	Significant	Medium	Medium	Accepted
4	Significant	Good	Hard	Accepted
5	Invalid	No power difference	Veryeasy	Thrown
6	Significant	Good	Hard	Accepted
7	Very significant	Verywell	Medium	Accepted
8	Invalid	Weak	Medium	Thrown
9	Very significant	Verywell	Medium	Accepted
10	Significant	Good	Hard	Accepted

Based on the item analysis through Anates (Table 5), from 10 questions, eight valid questions were obtained with significant and very significant significance. Eight valid questions have medium, good, and very good discrimination power and medium and hard levels of difficulty. Decision making is based on the item parameter criteria, and those are items that cannot be used if they are not valid (Fanani, Djati, & Silvanita, 2016), have weak discrimination power and have no discrimination power (Kadir, 2015), as well as very hard and very easy questions (Bagiyono, 2017).

The distribution of students' skills in the critical thinking result as measured by the instrument based on the category from Yanti, Suana, Maharta, Herlina, & Distrik (2019) is displayed in Table 6. Based on Table 6, the average value of students working on the developed instrument is 43.69, which means that, on average, students have medium critical thinking skills. Following Sumarni, Supardi, & Widiarti (2018) and (Arifin, 2017b), students can practice their skills of thinking critically by the instruments with critical thinking indicators.

Table 6 The Students' Critical Thinking Skills

Category	Score	Total students
Very high	80-100	2
High	60-80	4
Medium	40-60	14

Low	20-40	5
Very low	0-20	7

The comparison of the results of this development with the results of other researchers' development is shown in Table 7.

Table 7 Comparison of development results

Nyeneng & Suyanto (2021)	Measuring Critical Thinking Skills with Online Instrument in Circular Motion Concept	This study aims to produce an instrument to measure critical thinking skills that are valid, reliable, have different strengths, and have different levels of difficulties. The validity of the experts in construction, substance, and language are very valid. The product was tested on 32 students and obtained high reliability. The final product consists of 8 descriptive questions that are valid, reliable, have sufficient, good, and excellent discriminating power, and also have the medium and hard levels of difficulties.
Aminudin et al. (2019)	Measuring Critical Thinking Skills of 11th Grade Students on Temperature and Heat	This research intends to measure the skills of thinking critically about the material of temperature and heat. Respondents consist of 29 students. The instrument consists of 5 description questions with five indicators. The average value of students' critical thinking skills was 31 in the low category.
Pradana et al. (2017)	Development of Critical Thinking Ability Test on Geometry Optical Materials for Physics Students	This research intends to create questions of criticalthinking. The developed questions consist of 15 descriptive questions with good category logical validity, and empirical validity consists of 11 valid questions and four invalid questions. The student'scritical thinking skills shown by the result were in a low category.

It can be proven from Table 7 that the product has met good quality items, including expert and empirical validity, reliability, power of discrimination, and different level of difficulties. In research by Aminudin et al. (2019) and Pradana et al. (2017), the measurement of students' critical thinking skills is in a low category, and empirical analysis is only on validity. In preliminary research, information was obtained that the teacher had attempted to learn critical thinking through interactions between teacher and students, but 51.9% of the students still find it difficult, and 81.5% lack understanding of the concept. However, the average score showed that the students had medium critical thinking skills. In line with Sugiarti, Kaniawati, & Aviyanti (2017), students' thinking skills can be improved by assessment, so that assessment is not only helpful in examining the students' skills. However, the students' critical and creative thinking skills can also be

developed from the assessment that can provide stimulation to students (Herpiana & Rosidin, 2018). Based on Puspitaningrum, Wasis, & Prastowo (2021), the test question with multiple representations (visual, verbal, mathematical) is easier for students to develop, increase interest, and practice the skills of higher-order thinking, in which critical thinking is a component of the skills of higher-order thinking. The students' skills of thinking critically and creatively can be developed with the stimulation provided by the instrument.

The product developed includes questions with reducing indicators of thinking critically from Facione & Gittens (2016) consisting of inference, evaluation, and affirmation. The inference indicator with the alternative estimating sub-indicator is in item number 4, as shown in Figure 2.

Figure 2 Alternative estimating question

In question number 4, students' thinking process begins when describing the direction of the tangential velocity at each position. Students must be careful in drawing the tangential velocity, which is the same vector length and perpendicular to the trajectory radius. Then students criticize that the direction of the tangential velocity will be the direction of the stone when it is released. Students will find the right direction of tangential velocity to hit the target, which leads directly to the target.

The sub-indicator draws a conclusion from the inference indicator, one of which is in question number 2, as shown in Figure 3. In question number 2, the students' thinking process begins when critiquing the illustrations and question narration. In the illustration, it can be seen that the two cars have different distances from the centre of the track (they have different radius). Then, students are asked to be careful in understanding the question. The acceleration in question is the acceleration that changes due to a change in the direction of the velocity, namely the centripetal acceleration. This is because the car goes through a curved path, not straight, so the speed direction will change even though the value is the same. Students are led to use the equation of acceleration in answering this question so that students will find the relationship between the centripetal acceleration and the radius. Thus, students can conclude that the centripetal acceleration of the two cars, in this case, which is not the same.

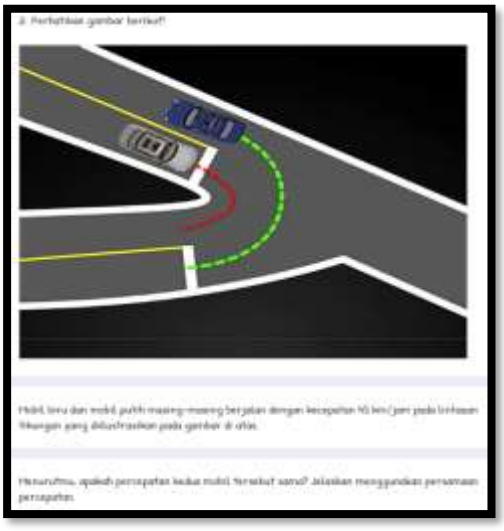

Figure 3 Conclusion drawing question

Evaluation indicator with sub-indicator assesses the credibility of a claim, one of which is in item number 7 with a display as shown in Figure 4. In question number 7, the students'

thinking process begins when they identify the quantities in the problem and are associated with daily life. The travel time of the fan blades in one rotation is the period quantity, and the rotational speed is related to the angular velocity. After that, students will think about the relationship between angular velocity and period, which are inversely proportional. Then, students will find that to obtain the minor period. The angular velocity should be in the largest setting. Thus, students can judge whether the statement is wrong or not credible.

Figure 4 Assess credibility of a claim question

Figure 5 State arguments question

The affirmation indicator with sub-indicator states the argument, one of which is in question number 3 with the question displayed in Figure 5. In question number 3, the students' thinking process begins when students relate the relationship between linear speed and radius and the concept of angular velocity. Then students will state their arguments based on the concept. Students are led to strengthening their argument statements by describing the vectors of tangential velocity and angular velocity experienced by each passenger in this case. Students will be careful in describing each vector in their argument statements based on concepts that pay attention to the relationship between linear velocity and angular velocity with radius.

Based on the description of the substance of the question that uses each of the critical thinking sub-indicators used in this study, it can be seen that students' thinking processes in sharpening and bringing up their skills of thinking critically. This can be stimulated when analyzing questions both in illustrations/pictures/videos and narrations and when linking in concepts that have been taught. In addition, to bring up the expected sub-skills, students are also guided in answering the question through the commands contained in the problem, such as linking with equations or describing vector quantities that exist in a circular motion at a constant speed.

The final result of this product is an instrument to measure critical thinking skills in circular motion material. It consists of 8 essay questions that have met the quality of good item parameters. The questions arevalid and reliable, then it has excellent, good, and sufficient power of discrimination and has a medium and hard level of difficulty. The product is presented in a google form by acontextual stimulus. Thus, this

product can be applied to measure students' critical thinking in learning physics.

CONCLUSION

The instrument to measure the skills of critical thinking in circular motion has met the quality of the item parameters 1) expert validation on the construction, substance, and language aspects of each at the very high category, 2) high reliability, 3) have medium, good, and very good distinguishing power, and 4) have a medium and hard level of difficulty. The average value measured by this instrument is 43.69, which indicates the students' critical thinking skills in the medium category. This study implies that the final product consists of 8 questions presented in a google form with a contextual stimulus. The skills of critical thinking can be measured by the instrument developed in this study. The results of this study can be an example for teachers to develop questions with critical thinking indicators. It is recommended to use indicators that have been tested.

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