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Analysis of the Development of Critical Thinking Instruments Test in Physics

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ABSTRACT
The critical thinking instrument is an instrument that contains essential indicators of thinking to test critical thinking ability. The purpose of this study is to examine instrument development methods, test instrument forms, question indicators, instrument feasibility tests, research subjects, instrument application media, analysis of test instrument results, learning models, and physics theory. This research is study library research applying the Bibliometric method. The research step is collecting and selecting secondary data of research articles through Publish or Perish (PoP) application using Google Scholar and Scopus databases in 2016-2020. Then, completing paper attributes through Mendeley software, visualizing data mapping based on title and abstract field using VOS viewer software, and analysing and describing research study topics. The study results show that critical thinking test instruments can be developed through research and development (R&D) Design development models. The form of the question created is a multiple-choice, open-ended-essay, description test, and diagnostic test regarding the indicators of critical thinking that Ennis and Facione have put forward. The problem developed is testing the instrument's feasibility through the validity and reliability of the problem. Valid problem instruments will be tested on students, students, and pre-job teachers assisted by paper-test media and the web, along with applications with often-tested physics materials, namely optics.

Keywords: *Critical thinking, Test instruments, Physics.*

1. INTRODUCTION

Education requires contextual learning that requires critical thinking, creative thinking, and communicatively [1]. Indonesia experienced a decrease in the quality of education through PISA (Programme of International Student Assessment) survey results in 2018 [2]. One component of PISA is critical thinking skills. The average science value of Indonesian students is still below that of the OECD (Organization for Economic Cooperation and Development) countries. It indicates that the critical thinking skills of Indonesian students are still low. Therefore, it is necessary to improve the quality of education and develop critical thinking skills [3].

Critical thinking is a problem-solving skill by conducting observation and communication by involving alternative solutions from various points of view to obtain information and argumentation [4]. According to Facione [5], individuals have a high critical thinking ability to interpret, analyze, evaluate, interfere, and explain. They can diagnose a problem (interpretation). They can analyze information by linking it with concepts and materials (analysis). Evaluate statements, opinions, or arguments that can be an alternative solution to problem-solving (evaluation). Draw conclusions based on data and information that has been identified (interference). Explain the results of problem-solving (explanation).

According to Ennis in [6], individuals are highly critical thinking and meet five aspects: simple explaining, determining the basic decision making, drawing conclusions, further clarification, and predicting and combining information.

The device to identify knowledge and thinking ability is evaluation [7]. Assessment of critical thinking test instruments is qualitative and contextual to explore the thought process to solve problems by linking and constructing data to conclude. A qualitative question is a question that can identify the meaning of physics connected with the concept of physics. At the same time, contextual questions contain context in daily life to apply in life [8]. Therefore, critical thinking assessment is

crucial because it can measure the understanding of concepts that can be used as indicators of learning success to meet competency standards [9].

Given the importance of the development of critical thinking test assessment instruments in measuring critical-thinking ability, it is necessary to map the review of research results on the development of critical-thinking test instruments that have been conducted. Bibliometric analysis techniques do mapping with the topic of development methods, instrument forms, instrument indicators, instrument feasibility, research subjects, media, implementation results of critical thinking test instruments, materials, and learning models.

2. METHODS

This study uses the data retrieval method through library research (literature study) by applying the Bibliometric analysis method. Bibliometric is a methodology for analysing and evaluating scientific article literature through mathematical and statistical approaches [10]. Data collection techniques through Publish or Perish (PoP) were conducted in July 2021 to generate secondary data of research results of journal articles and preceding conferences from Scopus and Google Scholar databases with title and keyword searches. Data search using the title "Instrument Test Critical Thinking" with the keyword "physics" and the title "Critical Thinking Test Instrument" with the keyword "physics" generates 40 metadata in the form of journal articles, preceding articles, and thesis. Metadata results are copied to Microsoft excel and selected with limitations in journal articles, preceding articles, and continue with research topics and objectives, resulting in 17 journal articles and eight preceding articles. The selection results are imported into Mendeley to complement the title and abstract attributes and the author, keywords, and publication journal. Then, it is exported in the form of a RIS (Research Information System) document. After that, it visualized to VOS viewer based on "title and abstract field" to map the research variables using the method of calculating total counting by setting the minimum item similarity as much as 2, so that from 421 items obtained interrelationship 62 items between articles. The visualization results are mapped into 8 clusters by forming a network. They were next, sorting and analysing the items on the visualization cluster from several research topics. Then, describe each research topic by reviewing each literature that has been collected.

3. RESULTS AND DISCUSSION

Based on the interrelationship and similarity of words in the title and abstract with the method of calculation of the whole counting produces the visualization of the results of bibliometric analysis seen in Figure 1.

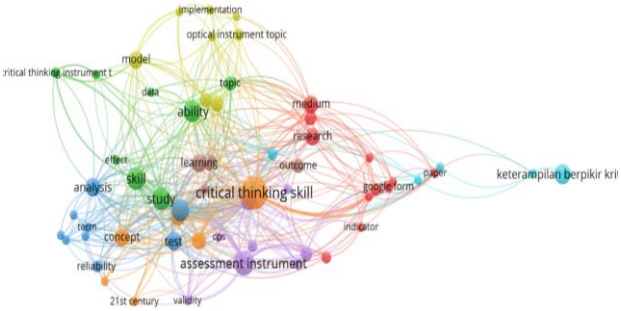

Figure 1 Network Visualization of the critical-thinking test instrument.

Based on the visualization in figure 1, 8 clusters of mapping results are arranged by sorting the items so that they become topics of discussion according to the research topic in Table 1.

Table 1. Cluster mapping results

Clusters	Colour	Topics
1	red	Indicator, optical instrument, paper, research, tier diagnostic test
2	green	Ability, critical thinking instrument, CTIT, effect, research method, skill, study, topic
3	blue	Analysis, critical thinking, reliability, student critical thinking, test, undergraduate, university, validation
4	yellow	Critical thinking ability, effectiveness, Implementation, inquiry, PBL STEM, physics lesson
5	purple	Aspect, assessment instrument, CPS, critical thinking assessment, physic, validity
6	Light blue	Critical thinking skills, learning model, senior high school student
7	orange	Concept, critical thinking skill, problem, student critical thinking,
8	brown	Critical thinking test instrument, graphic organizer media, learning, outcome

Based on the items in the cluster, it can be mapped into topics such as development methods, critical thinking skills assessment instruments, indicators of problem development, question validity, research subjects, testing media, critical-thinking skills, learning to improve critical-thinking skills, and materials often used for the

development of critical-thinking problems described as follows.

3.1 Development Methods

The development methods used by researchers to develop critical-thinking skills test instruments vary as in the following table.

Table 2. Way of developing critical-thinking skills test instrument

Research methods	Author
Research and Development (R&D) Design	[11] [12] [13] [14] [15]
Borg and Gall (seven steps)	[16] [17]
4D Stage	[18] [19]
Qualitative descriptive	[20] [21] [22]
Quasi-Experimental Design	[23] [24]
The mixed method with sequential exploratory design	[8] [25]
Borg and Gall (three steps)	[26]
Borg and Gall (ten steps)	[27]
ADDIE	[6] [28] [29]
Adda	[30]
Oriondo and Antonio	[31] [32]

Based on Table 2, the most used development method is R&D Design. Borg and Gall's development is a development by applying ten steps: (1) Information collection; (2) Planning; (3) Initial product development; (4) Product trials; (5) Revision of product test results; (6) Retesting of the product; (7) Product finish; (8) Field test; (9) Final product enhancements; (10) Dissemination and Implementation (Borg and Gall, 1983), however, in some studies there is a simplification of stages according to the needs. Then, the 4D method simplifies the R&D method by being four steps only [33]. Meanwhile, qualitative descriptive research develops object-oriented scientific products and visualizes the phenomena of life with data exploration, data description, and data explanation [34]. ADDIE is a development model through five steps: Analyze (analysis and literature studies), Design (instrument design), Development (instrument development), Implementation (instrument testing), Evaluation (assessing results). It is a development model through five steps: needs analysis and library studies through literature, product design to be developed isomorphic product development, product testing applied to students, and evaluation is carried out by assessing the results that have been implemented [6]. ADDA (Analyze, Design, Development, Applied) simplifies the ADDIE development model until the application or implementation stage. The mixed-method with sequential exploratory design is qualitative and quantitative research mixed-method used to train, develop, test new instruments [35].

3.2. Critical Thinking Skills Assessment Instrument

Critical thinking skills assessment instrument developed there are several forms of assessment instruments with the following details.

Table 3. Critical-thinking skills assessment instrument form

Instrument Shape	Author
Open Ended-Essay	[6] [8] [11] [17] [20] [22] [23] [25] [29]
Two-Tier Diagnostic Test	[19] [21] [31]
Multiple Choice	[16] [26] [28] [30]
Description-test	[27]
Four-Tier Diagnostic Test	[13]
Critical Thinking (CT-Test)	[14] [15]

Based on Table 3, critical thinking test instruments are often developed in open-ended essays because essays are more comprehensive than multiple choice. In the instrument of the essay test, students will be required to explore the mindset by linking and constructing information to solve and draw conclusions from the problem [8]. A diagnostic test is a multiple-choice test instrument with reasoning and confidence so that students can identify and evaluate issues on the problem.

3.3. Critical Thinking Skills Assessment Instrument Indicators

Based on the instruments form developed in table 3 and table 4, critical thinking assessment instruments must also meet critical thinking skill indicators, but some researchers use different critical-thinking references. Critical-thinking assessment instruments are other than generally written test instruments because the questions used are qualitative in the form of physical meanings of physical and contextual concepts in the form of phenomena and applications in daily life to identify the understanding of the concept of physics [25].

Table 4. Critical thinking test instrument indicators

Adept	Author	Aspects	Indicator
Ennis	[6] [8] [11] [16] [18] [19] [20] [21] [23] [25] [28] [29] [30]	1. Basic clarification	The focus of questions, analysis of arguments, and identification of facts
		2. The basis of decision making	Considering the authenticity of the source as well as observation and evaluation of observation results
		3. Interference	Conclude induction or deduction
		4. Further clarification	Identification of assumptions
		5. Strategy and tactics	Merging information and reason considerations
CT	[14] [15]	1. Hypothesis Testing	Interachievement of relationships between variables, analysis of the need to conclude, identification of the application of causality
		2. Argument Analysis	Identify how essential arguments are through causal relationships and test the validity of experiment results
		3. Reasoning	Evaluate the validity of the data and study an ambiguous
		4.Likelihood and uncertainty analysis	Predict the possibilities that occur and understand the need for additional information to make decisions
		5. Problem solving and decision making	Identify the best troubleshooting and evaluation of troubleshooting solutions
Facione	[13] [17] [22] [27]	1. Achievement	Identify problems, data achievement
		2. Analysis	Problem solutions
	[31] [32]	3. Interference	Hypotheses, experimental design, and drawing conclusions
		4. Explanation	Identify errors or evaluations

Based on Table 4, the critical thinking indicator developed by Ennis (1985) is often used as a reference. [25] suggests choosing Ennis because each aspect contains a complete indicator. Each test instrument is composed of initial information and questions to stimulate students' critical thinking to relate them between reading and questions.

3.4. Testing Process and Feasibility of Critical Thinking Test Instruments

Instruments developed will be tested for feasibility and validity of instruments reviewed from several aspects of validity, reliability, differentiation, and difficulty levels. Testing is conducted through test instrument trials and analytical techniques used statistically. In the picture, the distribution of instrument feasibility by some authors.

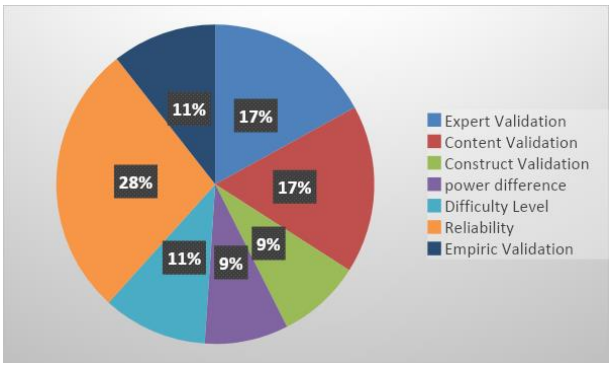

Figure 2 Mapping the test process and feasibility of critical thinking test instruments.

3.5. Research Subjects

Already valid instruments will be implemented to measure critical thinking skills. In table 1, there is a student item because most researchers implement test instruments for high school students. However, there are some studies testing test instruments to college students as listed in table 1 and also pre-position teachers with the following details.

Table 5. Research subjects

Education Level	Author
College	[6] [28] [29]
Pre-office Teacher	[15]

3.6. Media Implementation of Test Instruments

Most researchers use data retrieval media in the form of paper tests. However, one study developed by [26] based on the web using Codeigniter framework is a framework page to create a website efficiently. Some menus can make it easier for programmers to develop the web [36]. Then, there is research-based on CAT (Computer Adaptive Test) by creating the application PhysTCriTS (Physics Test Critical Thinking Skill). The application program can facilitate assessment and time efficiency because the assessment results will be immediately visible.

3.7. Critical Thinking Skills Analysis

The implementation process has been implemented, the next step is to analyze the results of product implementation, but some studies develop test instruments to limit trials to assess the feasibility of the instrument without analyzing the results of performance, along with the results of analysis of critical thinking skills.

Table 6. Critical thinking skills analysis.

Author	Analysis Results
[31] [26] [22]	The participants were still not mastering all aspects, with a high level of critical thinking on the part of data achievement during low critical-thinking on the identification aspect of the problem. However, in the results of Arini's study (2018), the lowest level of critical thinking in the analysis aspect
[6] [28] [29]	Critical thinking rates are still relatively low, with an average yield of 9.71 from a maximum score of 20 and a percentage of 35.70% in the "very low" category with a primary clarification indicator with the highest rate while the lowest decision-making basis
[25]	Students had a "moderate" level of critical thinking with an average of 69.25 out of 100 with high critical-thinking indicators on essential clarification and the lowest on inference
[23]	The highest critical thinking indicators on considering the credibility of a source and the lowest at deciding on an action
[16]	The distribution of high thinking skills of students is nine students belong to the category of "high", 38 students belong to the category of "medium", 13 students category "low", and ten students category "very low". The average yield is 62.41, with the "high" category
[13]	Critical thinking ability of all indicators is still relatively low
[21]	Lowest category on strategy and tactics indicators, while highest on essential clarification
[15]	The level of critical thinking in the Reasoning category is very high, while in the Analysis Argument category is very low

3.8. Innovative Learning to Improve critical thinking skills

Based on table 8, critical-thinking skills are still low, but this can be used as a basis for planning learning to improve critical-thinking skills. The assessment instrument can be used as a formative assessment instrument that is a form of measurement efforts of students from the beginning to the end of learning to test the improvement of ability [37]. Testing is conducted during education with initial learning given pre-test, then, provide feedback by applying learning model. Furthermore, it will be given a post-test to analyze the improvement of critical thinking ability. Here, the learning model used with the following.

Table 7. Formative assessment instrument results

Author	Innovative Learning	Result
[8]	STAD (Student Teams Achievement Division), Problem-based Instruction, learning cycle 5E	There is an increase in the test value of critical thinking tests
[23]	PBL (Problem Based Learning)	This research produced a high size effect to improve critical thinking skills
[24]	Inquiry-Discovery Learning	Learners experience an increase in critical thinking test scores
[18]	Jigsaw with Adobe Flash Media	Learners experience increased critical thinking

3.9. Physics Theory

In testing the assessment of critical thinking test refers to one or more theories because it will focus on knowing the understanding of certain physical concepts, along with the theory that is often used.

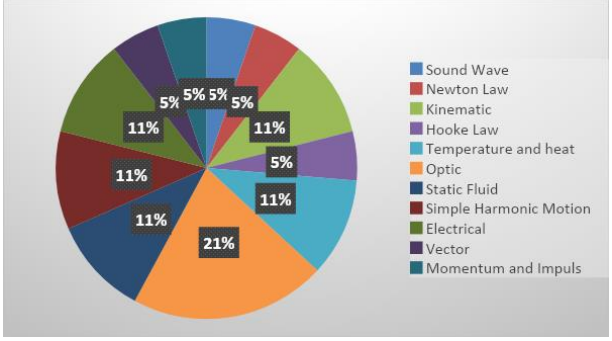

Figure 3 Distribution of critical-thinking test instrument testing materials.

4. CONCLUSION

Literature review results that have been presented above can be concluded that the development of critical thinking test instruments can be developed through the development model of R&D Design. The form of the question created is a multiple-choice, open-ended-essay, description test, and diagnostic test regarding the indicators of critical thinking that Ennis and Facione have put forward. The problem set is testing the instrument's feasibility through the validity and reliability of the problem. Valid problem instruments will be tested on students, students, and pre-job teachers assisted by paper-test media and the web along with applications with often-tested materials, namely optics.

AUTHORS' CONTRIBUTIONS

All authors conceived and designed this study. All authors contributed to the process of revising the manuscript, and at the end all authors have approved the final version of this manuscript.

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