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Design and Validity of Cognitive Conflict-Based Teaching Materials Integrating Virtual Laboratories to Improve Concept Understanding of Waves

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Abstract
Learning physics shows that students' understanding of concepts is still low, and there are misconceptions. One solution to overcome this problem is to create conflict-cognitive-based physics teaching materials that integrate virtual laboratories. The purpose of this research was to produce valid cognitive conflict teaching materials. The type of research was development research using the Plomp model. The preliminary research instruments were in the form of concept tests and questionnaires. Meanwhile, a self-evaluation sheet was used at the development stage, and a validation sheet used three validators. The self-evaluation data analysis technique used percentage techniques, while the validity used the Aiken's V formula. At the preliminary research stage, it was found that more than 30% of students experienced misconceptions, and 40% of students did not understand the concept. From questionnaires to teachers, it was found that learning was still teacher-centred, and ICT facilities had not been used optimally. At the development stage, a prototype of teaching materials was designed using the cognitive conflict-based learning model stages. The self-evaluation test results obtained a score of 85, which was categorized as very good, while in the expert review test, the value of all componentswas 0.81 was categorized as very valid and capable of being tested for practicality and effectiveness tests in learning.

Keywords: Cognitive Conflict; Concept of Waves; Misconception; Virtual Laboratory

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INTRODUCTION
Education is a planned effort in the learning process for individuals to develop and grow into human beings with quality and character. Education in Indonesia is expected to be able to produce quality and highly competitive Human Resources. Therefore, the government continues to improve the quality of education, one of which is

improving the quality of learning in schools by improving the education system. As has been done by the government, with several revisions to the curriculum in recent years, giving birth to the 2013 revised Curriculum 2017. In 2013 revised 2017 curriculum, four things will be achieved, namely building character, improving students' skills in solving high-level analytical problems or HOTS (Higher Order Thinking Skills), forming literacy skills in students, and improving 21st-century skills commonly known as 4C skills (communication, collaboration, critical thinking, and creativity). One of the subjects that support 4C skills in the learning process is physics learning.

Physics learning will be more optimal if it uses the right strategies, learning models and teaching materials to help students improve understanding of concepts in the learning process. One of the mistakes that are often encountered in learning physics is understanding concepts. One of the factors causing misunderstanding and low understanding of concepts in students is textbooks, learning contexts, teaching methods by educators and factors from the students themselves (Audina, Jamal, & Misbah, 2017; F Mufit & Fauzan, 2019). The reality in the field shows that the quality of physics learning in schools is still very low. This can be seen from the initial study by giving educators questionnaires and concept comprehension test questions to students conducted at SMAN 13 Padang. Giving questionnaires to educators was carried out to determine the learning models and teaching materials used. From the results of giving the questionnaire, it is known that the learning process is still conventional. In conventional learning, educators tend only to explain the material, write formulas, examples of questions and give assignments to students (Yulianti, Zhafirah, & Hidayat, 2021). This results in a lack of student activity in the learning process. In essence, in the 2013 curriculum, learning is student-centred Learning, meaning that students are required to be active in learning while educators are only facilitators. Meanwhile, the teaching materials used in schools have not fully used the model following the demands of the 2013 Curriculum.

Based on the results of the distribution of concept tests that have been given to students in class XI MIPA 3 at SMAN 13 Padang for the 2019/2020 school year, the results of students' conceptual understanding were obtained that almost some students did not understand the concept (43.3%) and there were still many students who experienced misconceptions on the questions being tested (37.5%).

Understanding concepts is an absolute requirement in achieving success in learning physics (Sari et al., 2018). Physics lessons are not memorization lessons, but more demanding students understand the concept and apply these concepts. There are still many students who do not understand the concept of physics, especially at the high school level.

Misconceptions are defined as misunderstandings that may be during or as a result of the teaching given, contrary to scientific conceptions that have been carried or developed for a long time (A. Hidayat, Zainuddin, & Misbah, 2020; Maulana, 2010). Several things that can be done to overcome misconceptions, including 1) studying misconceptions that often occur in students and analyzing the work done by students in learning, 2) realizing misconceptions in students, 3) determining priorities and preparing remedial and demonstrations for students on material that is considered very basic and prerequisite for other material, 4) trying to do a demonstration whose results do not match intuition, 5) in a discussion of physical phenomena and trying to stimulate students.

Misconceptions that occur can be remediated by using a learning model that follows the approach. Remediation is an activity to reduce or minimize misconceptions in students. The key to fixing misconceptions is to interact directly with students. One effective way to involve students in the learning process is to use teaching materials to enable students to interact and be active in the learning process. One way is to use cognitive conflict-based teaching materials.

The cognitive conflict-based learning model can be interpreted as one of the learning activities carried out to overcome the mismatch between the initial knowledge obtained from the environment and the real science (F Mufit & Fauzan, 2019). The cognitive conflict learning model effectively overcame misconceptions in students and improved students' conceptual understanding. The cognitive conflict-based learning (CCBL) model consists of 4 syntax or stages (F Mufit & Fauzan, 2019), namely: 1) activation of preconceptions and misconceptions, 2) presentation of cognitive conflict, 3) discovery of concepts and equations, and 4) reflection. Cognitive conflict learning allows students to realize their misunderstandings and provides opportunities to correct them through experimental activities (Fatni Mufit, Asrizal, & Puspitasari, 2020). In the third stage, namely the discovery of concepts and equations. The process of finding concepts and equations can be done through experimental activities and discussions. Experiments can be conducted using a virtual laboratory (Luthfi, Mufit, Rosiana, & Putri, 2020).

In learning physics, in addition to studying theory in the classroom, students need to do experiments to support the theory being studied. However, this has not been fully implemented. This is due to inadequate facilities to conduct experiments directly, especially sound and lightwave matter. To overcome this, it can be supported by virtual laboratory experiments through PhET simulations. PhET simulation is an interactive media based on the discovery that can improve students' conceptual understanding (R. Hidayat, Hakim, & Lia, 2019; Mahtari, Wati, Hartini, Misbah, & Dewantara, 2020; Maulani, Wati, Misbah, Dewantara, & Mahtari, 2018). Thus, using a cognitive conflict-based learning model that integrates a virtual laboratory through a PhET simulation can help students understand the concept of physics.

Based on the description of these problems, researchers are interested in designing cognitive conflict-based teaching materials integrating virtual laboratories to improve understanding of physics concepts in sound and light waves in class XI SMA. The purpose of this study was to determine the validity of cognitive conflict-based teaching materials integrating virtual laboratories to improve understanding of physics concepts.

METHOD

The type of research used was Design/Development research. The development model used in designing teaching materials was Plomp’s model (Plomp, 2013). The advantage of the Plomp model is that it is more flexible and can be adapted to the needs and characteristics of the research (F Mufit & Fauzan, 2019).

The development of the Plomp model (2013) consists of three stages. (1) Preliminary research, namely conducting a needs analysis, reviewing literature and planning concepts; (2) the development or prototyping phase is the stage of designing a solution from solving the problems put forward in the preliminary research, which consists of prototype design and formative evaluation and prototype revision; (3) The assessment phase is a solution developed that must be tested and evaluated in practice. Evaluation is carried out so that the product developed is feasible and gets substantial value from problem-solving. Evaluation at this stage refers to the Tessmer diagram in Figure 1.

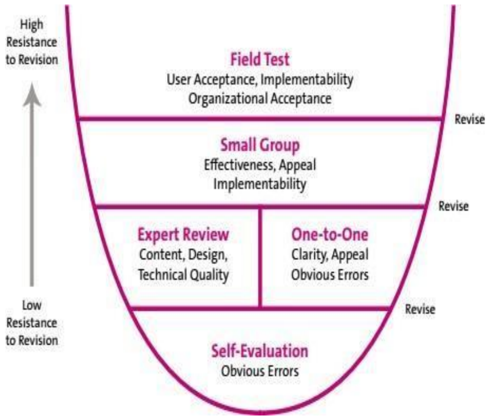


Figure 1 Tessmer Diagram

The preliminary research stage consists of two stages: analysis of needs and context and literature review. At the needs and context stage, the researcher analyzed teachers and students by providing questionnaires and giving conceptual understanding test questions to students. This aimed to determine the fundamental problems that occur in learning physics. Meanwhile, a literature review was carried out to examine teaching materials with the right model to improve students conceptual understanding.

The development or prototyping phase consists of a prototype design and formative evaluation, and prototype revision. The prototype stage aimed to design several prototypes, evaluate them, and revise them, which was done literally or repeatedly to produce good results. The product designed in this study was a teaching material using a cognitive conflict model syntax. While the formative evaluation stage and prototype revision were carried out to test the validity of the teaching materials designed in the previous stage. The first formative evaluation was carried out by the researcher himself (self-evaluation) of the incompleteness and errors of the initial prototype. At this stage, the researcher examined the completeness of teaching materials according to the structure of teaching materials according to the 2008 Ministry of National Education and the suitability of the syntax of the CCBL model. After the product was complete, three experts tested for validity. This aimed to get a valid product as desired.

The data collection instruments at the preliminary stage were questionnaires and concept tests. At the development stage, a product validation questionnaire sheet was used for experts. Expert validation sheets were prepared based on the indicators specified for teaching materials, including content feasibility, presentation feasibility, language feasibility, and graphic feasibility.

Data analysis techniques were carried out after data from all respondents or other data sources had been collected. The data analysis was carried out in two stages, and the first was by the researchers themselves (self-evaluation). The assessment test was carried out using the instrument sheet for self-evaluation. The weighting of the self-evaluation sheet uses a Likert scale. The Likert scale was usually used to measure a person's attitudes, opinions, and perceptions or group of social events or symptoms (Riduwan, 2012).

The self-evaluation data and product validity analysis was obtained from the self-evaluation checklist datasheet, and the validity was arranged using a Likert scale. The interpretation of the results of the validity analysis that has been carried out can be seen in the following Table 1

Table 1 Interpretation of The Self Evaluation Results

Total Score	Criteria
0 - 20	No Good
21 - 40	Less Good
41 - 60	Sufficiently Good
61 - 80	Good
81- 100	Very Good

The validity test conducted by Aiken's V formula to calculate the content validity coefficient based on the results of the expert's review. The formula for Aiken's V formula for calculating product validation is based on the results of expert judgment on each validation assessment indicator. The interpretation of Aiken's V formula results is 0 to 1. The Aiken validity index can be seen in the following Table 2.

Table 2. Aiken's V Index

Index Validity	Criteria
V <0.4	Less Valid
0.4 <V <0.8	Valid
V> 0.8	Very Valid

RESULT AND DISCUSSION

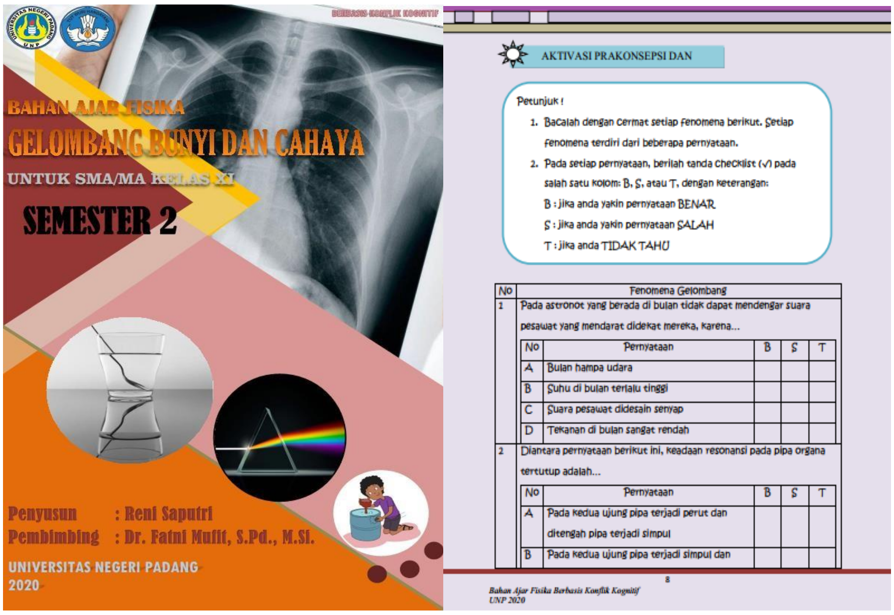
The results of the preliminary research stage, namely giving a questionnaire to the teacher, found that the learning model used by the teacher had not fully implemented the learning model following the demands of the 2013 curriculum. The learning model used was still conventional. Teachers still predominantly use the lecture method, namely teacher-centred learning.

The teacher-centred learning process caused students to understand less about concepts and be only interested in memorizing formulas. Efforts made by teachers to improve conceptual understanding and overcome misconceptions were only by providing practice questions, and the solutions were discussed in front of the class without being involved in the concept discovery process (F. Mufit, Asrizal, Hanum, & Fadhilah, 2020). While the 2013 curriculum requires students to be active in the learning process so that learning is student-centred (student centre learning). The teaching materials also have not used a specific model following the demands of the 2013 Curriculum. On the other hand, existing ICT (Information and Communication Technology) facilities in schools have not been utilized optimally.

The results of the second preliminary research were obtained from giving concept test questions to students, which showed that students' conceptual understanding was still low even though they had studied the material previously. Only a small proportion of students (19.2%) understood the concept, most students did not understand the concept (43.3%), and quite several students experienced misconceptions on the questions tested (37.5%).

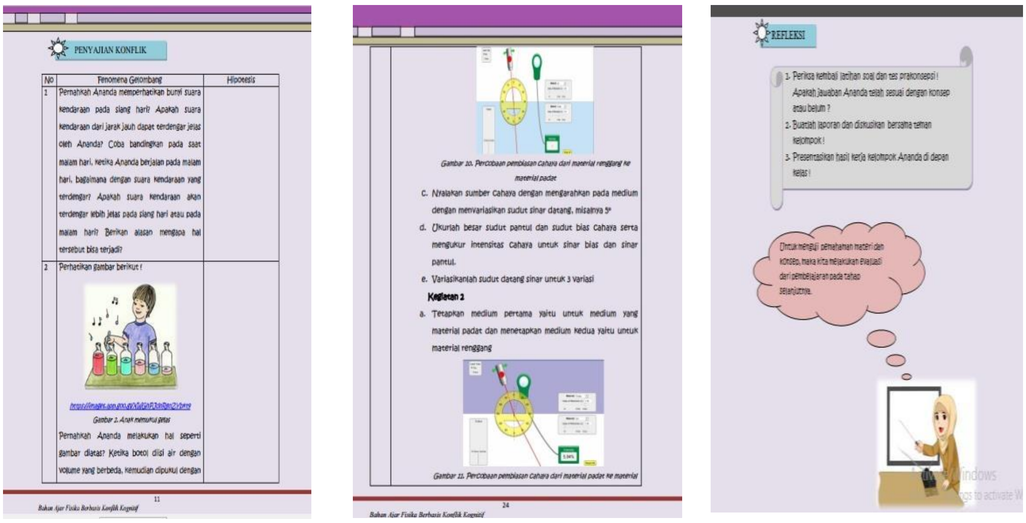
The development/prototyping stage began with designing a prototype of teaching materials to solve problems in preliminary research. Teaching materials were prepared based on 4 syntaxes of cognitive conflict-based learning models (CCBL models), namely 1) activation of preconceptions and misconceptions, 2) presentation of cognitive conflict, 3) discovery of concepts and equations, and 4) reflection. In the third syntax, a virtual laboratory was integrated. Teaching materials were also arranged according to the structure of the 2008 Ministry of National Education. The following is a design drawing of conflict-based cognitive teaching materials that integrate virtual laboratories to improve understanding of physics concepts.

The following is a display of design cover of teaching materials and activation of preconception and misconception syntax as shown in Figure 2. The following is a display of cognitive conflict syntax, the discovery of concept and equations syntax, and the syntax for the reflection section as shown in Figure 3.



(a) (b)

Figure 2 (a) Design Cover of Teaching Materials and (b) Activation of Preconception and Misconception Syntax



(a) (b) (c)

Figure 3 (a) Presentation of Cognitive Conflict Syntax, (b) Discovery of Concept and Equations Syntax, and (c) Reflection Syntax

After the teaching material was designed, a self-evaluation was carried out to check the completeness of the material teaching components and for apparent errors. The results of self-evaluation of the five components of teaching materials based on cognitive conflict can be seen in Figure 4. In the teaching material structure component, 1) it was following the 2008 Ministry of National Education, 2) the teaching materials were also complete, consisting of four CCBL syntax models, 3) teaching materials have been integrated with a virtual laboratory on the syntax. Third, check the 4) language and 5) graphics.

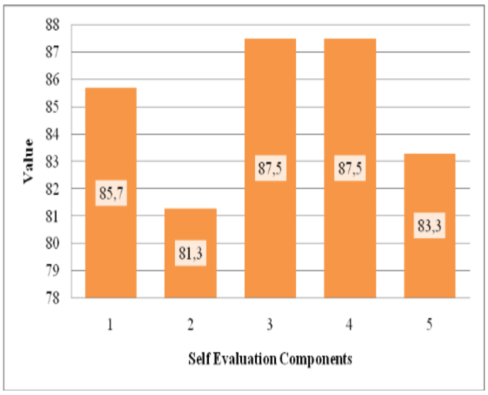


Figure 4 Self Evaluation Test Results

Based on Figure 4, the values for each indicator range from 81.3 to 87.5. Out of all the indicators provided, the self-evaluation assessment was in the very good category. The excellent category ranges from 81-100. The average score obtained from self-evaluation was 85. From this score, self-evaluation was in the very good category.

In the review of the validation stage by three physics lecturers, the validation results of teaching materials were in the very valid category. Teaching materials have been valid in four components of assessment, namely 1) content validity, 2) construct validity, 3) language validity and 4) face validity.

First, the content validity consists of 12 indicators, namely 1) description of indicators in teaching materials following core competencies and basic competencies 3.10 & 4.10, 2) learning objectives in teaching materials according to indicators, 3) material on teaching materials by learning objectives, 4) physics symbols used appropriately, 5) physics equations used appropriately, 6) physics terms used appropriately, 7) material presented does not cause multiple interpretations, 8) physics phenomena presented following the material, 9) pictures used by the material, 10) images quoted from other people's work include references/sources, 11) cognitive conflict-based teaching materials contain cognitive conflict syntax, and 12) the teaching materials made have integrated the virtual laboratory correctly. The plot results of the content feasibility component indicator can be seen in the following Table 3.

Table 3 Value of Content Validity

No	Assessment Components	Value of Validity Instruments	Category
1.	Suitability of indicators with core competencies & basic competencies 3.10 & 4.10.	0.89	Very Valid
2.	Conformity of learning objectives with indicators.	0.56	Valid
3.	Suitability of material with teaching materials	0.67	Valid
4.	Physics symbol accuracy	0.67	Valid
5.	The accuracy of the physical equations	0.67	Valid
6.	The accuracy of physics terms	0.89	Very Valid
7.	The presentation of the material does not cause multiple interpretations	0.78	Valid
8.	Conformity of physical phenomena with matter	0.89	Very Valid
9.	The suitability of the image to the material	0.67	Valid
10.	Images quoted from other people's work include references/sources	0.78	Valid
11	Cognitive conflict-based teaching materials contain cognitive conflict syntax, namely	0.89	Very Valid

No	Assessment Components	Value of Validity Instruments	Category
	presentation of preconceptions and misconceptions, presentation of cognitive conflict, the discovery of concepts and equations, and reflection		
12	The teaching materials made have been integrated the virtual laboratory correctly	0.67	Valid
Average		0.75	Valid

Based on Table 3, it can be explained that the value for each indicator of the content validity ranges from 0.56 to 0.89. Out of the twelve indicators, two categories were valid and very valid. The very valid category ranged from 0.89, while the valid category ranged from 0.56 to 0.78. The average value obtained for the content eligibility component was 0.75. Thus the content validity was at the validity level of valid. Second, the construct validity contains seven indicators, namely 1) the presentation of the preconception and misconceptions activation stage in teaching materials can reveal students' initial knowledge, 2) the presentation of the cognitive conflict in teaching materials can trigger students to think deeply, 3) the discovery of the concept and equations in teaching materials lead students to find concepts & equations, 4) the reflection stage on teaching materials can reveal the progress of students' understanding, 5) numbering images are presented in sequence, 6) naming images are presented appropriately, and 7) presentation of teaching materials which is made allows the interaction between teachers and students. The results of the indicator value for the construct validity can be seen in the Table 4.

Table 4 Value of Construct Validity

Num	Assessment Components	Value of Validity Instruments	Info
1.	The presentation of the preconception and misconceptions activation stage in teaching materials can reveal students' initial knowledge	0.78	Valid
2.	The presentation of the cognitive conflict presentation stage in teaching materials can trigger students to think deeply	0.67	Valid
3.	The presentation of the concept discovery stage and equations in teaching materials lead students to find concepts & equations	0.56	Valid
4.	presentation of the reflection stage on teaching materials can reveal the progress of students' understanding	0.89	Very Valid
5.	Image numbering suitability	0.89	Very Valid
6.	Image naming accuracy	0.78	Valid

Num	Assessment Components	Value of Validity Instruments	Info
7	Presentation of teaching materials which is made allows the interaction between teachers and students	0.67	Valid
Average		0.75	Valid

Based on Table 4, it can be explained that the value on each indicator of the construct validity ranges from 0.56 to 0.89. Out of the seven indicators, there were two categories included as valid and very valid. The very valid category ranged from 0.89, while the valid category ranged from 0.56 to 0.78. The average value obtained for the construct validity was 0.75. Thus the construct validity was in the valid category.

Third, the language validity uses seven indicators, namely 1) the language used is following the level of thinking of students, 2) the language used in teaching materials has a politeness (ethical) value, 3) the language used is communicative and informative so that the message conveyed is easy to understand (educational), 4) the language used does not mean double, 5) the terms used are following the agreed technical terms of science, 6) the language used is following the rules of good and correct Indonesian grammar, and 7) the spelling used refers to Indonesian language guidelines. The plot results of each language validity indicator can be seen in Table 5.

Table 5 Value of Language Validity

No	Assessment Components	Value of Validity Instruments	Info
1.	The suitability of language with the level of thinking of students.	0.89	Very Valid
2.	The political (ethical) language used	0.78	Valid
3.	The language used is communicative and informative so that the message conveyed is easy to understand (educational)	0.89	Very Valid
4.	The language used does not mean double	0.78	Valid
5.	The conformity of the terms with the agreed technical terms of science	0.89	Very Valid
6.	Suitability of the language with good and correct Indonesian grammar rules	0.67	Valid
7.	The spelling used refers to General Guidelines for Indonesian Spelling (PEUBI)	0.89	Very Valid
Average		0.83	Very Valid

Based on Table 5, it can be explained that the value on each indicator of the content eligibility component ranges from 0.67 to 0.89. Out of the seven indicators, there were two categories of valid and very valid. The very valid category ranged from 0.89, while the valid category ranged from 0.67 to 0.78. The average value obtained in the language validity was 0.83. Thus the language validity was a very valid category and could be used in learning.

Fourth, the face validity uses six indicators, namely 1) the arrangement of the cover of the teaching material is shown to be attractive, 2) the font used is correct, 3) the font size can be read clearly, 4) the size of the title of the teaching material is more proportional to the size of the material content. teaching, 5) the arrangement of the cover colour and design is correct, and 6) the cover illustration describes the contents of the teaching material. The results of the plot of the value of each face validity indicator can be seen in Table 6.

Table 6 Value of the face validity Component

No	Assessment Components	Value of Validity Instruments	Info
1.	The attractiveness of the cover of teaching materials	0.78	Valid
2.	Font accuracy	0.89	Very Valid
3.	Clarity of font size	1.00	Very Valid
4.	Proportionality of the size of the title letter to the size of the content of the teaching material.	1.00	Very Valid
5.	Accuracy of cover colour with design	0.89	Very Valid
6.	The cover illustration describes the contents of the teaching material	0.89	Very Valid
Average		0.91	Very Valid

Based on Table 6, it can be explained that the value on each indicator of the content eligibility component ranges from 0.78 to 1. Out of the six indicators, there were two categories, namely valid and very valid. The very valid category ranged from 0.89 to 1, while the valid category was at a value of 0.78. The average value obtained for the face validity was 0.91. Thus the face validity was in a very valid category.

The average value of each component of the assessment of teaching materials can be determined from the average value of the four components of the assessment of teaching materials. In this teaching material, four components have been analyzed. The four components include 1) content validity, 2) construct validity, 3) language validity, and 4) face validity. The validity value of teaching materials for each assessment component can be seen in Figure 5.

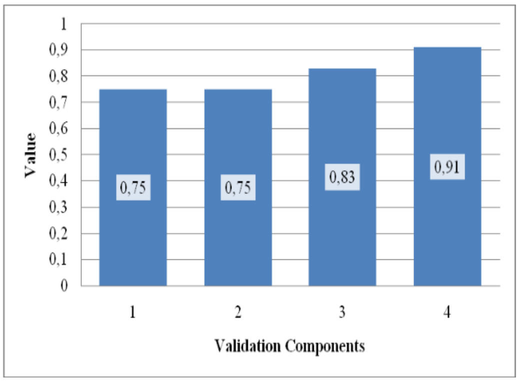


Figure 5 Value of Validation Components

Based on Figure 5, the average value for each component of the validation assessment on teaching materials varies, ranging from 0.75 to 0.91, with an average value of all components of 0.81. From this value, it can be concluded that the overall components of teaching materials were in a very valid category. Thus, cognitive conflict-based teaching materials integrating virtual laboratory had a very valid level of validity. The results of the validation of teaching materials were obtained from suggestions from experts for revision.

At the development stage (prototype phase), there were two stages of research. First, the results sheet of the self-evaluation instrument on physics teaching materials was in the very good category. The design of teaching materials was said to be very good because it indicated that the components related to teaching materials were by the Ministry of National Education (2008). Teaching materials were also in accordance with the CCBL model syntax sequence, which could improve conceptual understanding and remediate misconceptions. In addition, the teaching materials have integrated a virtual laboratory, the rules of language and graphics in the teaching materials are appropriate.

After that, the teaching material validation test was carried out by experts of 3 Physics lecturers. The results of this assessment were used to determine the validity of the teaching materials designed and as a guide in making revisions and improvements to the teaching materials that have been made. The assessment component in the validation instrument must be relevant and consistent in accordance with the theory related to teaching materials. There are four components of assessment on the validation of teaching materials. These components are components of content validity, construct validity, language validity and face validity.

The content validity on the teaching material validation sheet consists of twelve indicators. The twelve indicators are in the valid category. Teaching materials were valid because the description of indicators in teaching materials was following core competencies and basic competencies 3.10 & 4.10, and teaching materials contain CCBL model syntax. Symbols, terms, equations and physical phenomena in teaching materials were appropriate. Based on the results of the component, the researcher obtained input from the validator. Researchers made improvements to the presentation of learning objectives by improving them following the indicators to be achieved.

The construct validity on the teaching material validation sheet consists of seven indicators that were categorized as valid. Teaching materials were valid because teaching materials are following the provisions of the Ministry of National Education, namely titles, learning instructions, competencies to be achieved, supporting information, exercises, worksheets and evaluations, and teaching materials have integrated a virtual laboratory in the third syntax, namely the concept discovery stage and equation. The discovery stage of concepts and equations can be carried out through experimental activities, both actual experiments and virtual laboratories.

In the third syntax of cognitive conflict-based learning models, students conducted experiments to find concepts and equations about the relationship between these concepts(F Mufit, Festiyed, Fauzan, & Lufri, 2019). The validity of offering teaching materials was very important because the presentation developed in teaching materials could attract students 'interest in learning, increasing students' curiosity in learning physics(F. Mufit et al., 2020). Based on the validation of the construct validity results, the researcher obtained input from the validator to revise the supporting information on teaching materials. The validator asked that the supporting information be adjusted to the content of the teaching material.

The language validity was a very valid category. This was supported by the language used following students' level of thinking, the language used was communicative and informative, and the spelling used was already referring to Indonesian language guidelines. The structure of writing teaching materials was adjusted to the rules for using the correct Indonesian language so that readers can easily understand it (Delvia, Mufit, & Bustari, 2020).

The face validity was in the very valid category and got the highest average value compared to the other three components. The average value obtained for the graphic component was 0.91. This shows that the teaching materials are made easy to understand. The use of fonts, font sizes, cover colour arrangement, and cover illustrations was proportional so that the teaching materials used were interesting to read. An attractive illustration plus the right layout can make teaching materials more harmonious and exciting to study, motivate students, and attract students' attention to use teaching materials in the learning process (Fadhillah & Andromeda, 2020).

Based on the validity of the validator, the average value obtained from the teaching material assessment component was 0.81. This shows that cognitive conflict-based teaching materials integrating a virtual laboratory on sound and light waves to improve understanding of physics concepts can be used as alternative teaching material in the physics learning process, and its practicality and effectiveness can be tested.

CONCLUSION

Based on the results of research and discussion, it can be concluded that cognitive conflict-based teaching materials have been produced with the following characteristics: (1) teaching materials consist of titles, learning instructions, competencies, supporting information, work steps, and evaluation; (2) Teaching materials are prepared according to the cognitive conflict-based learning model (CCBL) which consists of 4 syntaxes, namely: a) activation of preconceptions and misconceptions, b) presentation of cognitive conflict, c) discovery of concepts and equations, and d) reflection. In the 3rd syntax, the CCBL model is integrated with a virtual laboratory. Teaching materials are designed to improve students' understanding of physics concepts. The validity of cognitive conflict-based teaching materials on sound and light waves has a validity value in the very valid category. Teaching material products have been valid from content validity, construct validity, language validity, and face validity and can be tested for practicality and effectiveness tests so that they are worthy of being used as alternative teaching materials in learning.

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