THE DEVELOPMENT AND VALIDATION OF CONCEPTUAL KNOWLEDGE TEST TO EVALUATE CONCEPTUAL KNOWLEDGE OF PHYSICS PROSPECTIVE TEACHER ON ELECTRICITY AND MAGNETISM TOPIC

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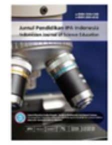

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ABSTRACT

The conceptual knowledge test is an efficient way to measure the conceptual knowledge of physics prospective teachers in the electrical and magnetism topic. The characteristic of this instrument is physical questions in the form of multiple-choice options. A methodology for developing the conceptual knowledge tests are described. The process of developing and validating the conceptual knowledge test consist of 5 steps: (1) content analysis; (2) construction of multiple choice items; (3) readability test and expert validation; (4) limited tryout; and (5) larger application. The process of validating test instruments through trials was conducted in order to obtain data related to difficulty index, discriminating power, distractor functionality, and reliability coefficient value that was analyzed using ITEMAN version 3.0 program. The participants was 215 physics prospective teachers of University in Makassar city. The instrument validation resulted in 40 items that consisted of 26 items for electricity and 14 items for magnetism. Therefore, the instrument is called as Conceptual Knowledge Test-Electricity and Magnetism (CKT-EM). The value of the reliability coefficient (α) (Alpha Cronbach) of 0.87 indicates that the instrument of conception test on electrical and magnetism topics is valid and sufficient to measure student conception on electrical and magnetism topics.

Keywords: conceptual knowledge-test; electricity and magnetism; readability test; validity; reliability.

INTRODUCTION

Studies of educational research that related to the development of students' conceptual knowledge in the world of science education (physics) has been done more last decades (Fang et al., 2016; Gomez-Granell & Cervera-March, 1993; Hammer, 1994). Conceptual knowledge have been a primary review in physics (Hammer, 1994; Hegarty Hazel & Prosser, 1991; Tolmie & Mackenzie, 1992). Conceptual knowledge is the important element to solve problems (Gomez-Granell & Cervera-March, 1993; Hegarty-Hazel & Prosser, 1991; Streveler, Litzinger, Miller, & Steif, 2008).There are more previous studies about conceptual knowledge related to subject-matter or content in physics, like electricity and magnetism (Anderson et al., 2000; Finkelstein, 2005; Gok, 2012; Planinic, 2006; Stelzer, Brookes, Gladding, & Mestre, 2010). Furthermore, conceptual knowledge is often approached from the viewpoint of semantic networks, because all retrieval and inference is based on traversing such networks (Koponen & Nousiainen, 2018). Electricity and magnetism contents are the important concepts that have to be learned to our student because electric and magnetism interactions play a central role in determining the structure of the natural word and are the foundation of most current and emergent technology (Chabay & Sherwood, 2006). Therefore, it is important to explore student conceptual knowledge on electricity and magnetism topics.

A variety of tests have been developed to measure students' conceptual knowledge on electricity and magnetism. Unfortunately, an extensive review of the literature on electricity and magnetism conceptual knowledge research also indicated that there are very few valid and reliable instrument that can be used to measure students' conceptual knowledge on electricity and magnetism. Some examples of instruments that have been widely used in a number of previous studies to measure student conceptual knowledge on electricity and magnetism topics focused on static electric for electricity topic. One of them is Conceptual Survey of Electricity and Magnetism (CSEM) that have been developed by Maloney, et.al (2001). This instrument has been used to measure students' difficulties of some conceptual areas from electricity and magnetism in a number of previous studies (Gok, 2012; D. P. Maloney, O'Kuma, Hieggelke, & Heuvelen, 2001; Planinic, 2006b). The Conceptual Survey of Electricity and Magnetism (CSEM) is multiple-choice test that consists of 32-question. This instrument consists of eleven categorizations of the questions about conductor and insulators, Coulomb's law, force and field superposition, force, work, and electric potential, magnetic force, Faraday's law, and Newton's third law. Based on the description about the characteristics of the CSEM instrument, this instrument tests electrical content that focuses on static electricity. In the CSEM instrument, no items were found which tested dynamic electrical content that was needed in this study. Therefore, this study focuses on developing instruments on dynamic electricity and magnetism topics.

Another similar instrument that can be used to measure students' conceptual knowledge on electricity and magnetism topics is Brief Electricity and Magnetism Assessment (BEMA). BEMA was developed by Ding, et.al. (2006). This instrument is a 30-item multiple-choice test which covers the main topics discussed in both the traditional calculus-based E&M physics curriculum and the matter and interactions curriculum (*Matter & Interactions II: Electric and Magnetic Interactions*). It was reevaluated through Rash Analysis (Ding, 2014).This instrument is specifically designed to students' knowledge on electrical and magnetic concepts who have completed electrical and magnetic courses. Electrical and magnetic content tested in BEMA has a more complex level of difficulty than CSEM instruments. All items of the BEMA instrument were taken from the curriculum and the electrical course material given in the fourth or fifth semester in college. Unlike the CSEM instrument, all items of this instrument are basic electrical and magnetic content which are part of basic physics subject matter. Nevertheless, the BEMA instrument was not in accordance with the needs of this study because the content provided focused on more complex electrical and magnetic materials and there were no items that tested dynamic electrical materials in the instrument.

McColgan, et.al. (2017) has developed an instrument to assess students' conceptual knowledge on the topics of electricity and magnetism. This instrument was named Electricity and Magnetism Conceptual Assessment (EMCA). It includes 30 multiple-choice questions with a completion time of 30–40 minutes. Topic covered in this instrument include electrostatics, electric fields, circuits, magnetism, and induction. The motive of writing this instrument based on CSEM and BEMA but this instrument focused to assess content about electricity and magnetism in introductory physics courses. This instrument is in accordance with the content that will be tested in this study. However, the weakness in this instrument is that the electrical content tested is more dominant about static electricity than dynamic electricity. Whereas, the structure of the basic physics course curriculum in the second semester discusses more dynamic electrical content. Based on the weakness of previous studies about development of several types of conceptual knowledge tests on the content of electricity and magnetism, we designed a form of test that can assess the conceptual knowledge of physics pre-service teachers on electricity and magnetism topic with the distribution of sub concepts based on the results of the initial survey conducted through a questionnaire administered to a number of physics prospective teachers.

Electricity and magnetism review in Basic Physics courses were generally given in the first year. The scope of electricity and magnetism material was wide enough. So, there were some physics prospective teachers had difficulty to master the material of this course even though they have passed it. The results of initial survey conducted on physics pre-service teacher who have contracted Basic Physics course showed that they have difficulties in some electrical concepts, especially in dynamic electrical and magnetism sub topic (Rahmawati, et.al., 2017). This finding was then followed up by conducting a survey of prospective teachers' conceptual knowledge related to electricity (dynamic electricity) and magnetism materials to support the findings of the initial survey. Therefore, an instrument that measures physics prospective teachers' conceptual knowledge on electricity and magnetism topic was required in particular content areas.

An instrument was named to be good if it had three characteristic. They were valid, reliable, and usable (Groundlund, N.E & Linn, 1990; Secolsky & Denison, 2012). There were several approaches that can be used to perform instrument validity, namely content validity, construct validity, and criterion validity (Groundlund, N.E & Linn, 1990).

The purpose of this study is to describe the results of the development and validation of the conceptual knowledge test to measure the conception of physics prospective teacher on electricity and magnetism topic, certainly in sub-topic areas based on the results of the distribution of questionnaires related to the subject matter of Basic Physics subject which was perceived difficult by physics prospective teachers. The design of conceptual knowledge on electricity and magnetism topic not only assessed physics prospective teachers' conceptual knowledge but also detects their difficulty level about electricity and magnetism.

METHOD

The research method that used in this research is developing and validation multiple choice. Haladyna (2004) explained that the step of developing and validating test items consist of five steps, including content concern, style format concerns, writing the stem, and writing the choice. Furthermore, Erdogan, *et. al* (2009)reveals that the development and validation an instrument or tests requires eight steps. They are review of literature, development of item pool, validation of item pool, constructing initial draft, taking expert opinion, pilot testing, administration of the instrument, and calculation of validity and reliability. Therefore, the research method used in this research is development research because in accordance with the purpose of research is to describe the development and validation of conceptual knowledge test on electricity and magnetism topic. The location of this test was conducted in one of the universities in Makassar. A number of 105 physics prospective teacher consist of 62 woman and 43 men. They are second year physics prospective teachers who have contracted Basic Physics courses.

The CKT-EM instrument consists of 45 items before being validated. After validation, the number of items became 40 consisting of 26 items about electricity and 14 items about magnetism. Form of CKT-EM instrument is a multiple choice with five choices of answers that provided along with the reasons. Electrical material distributions that was developed included electric current, electric potential difference, electromotive force, resistance, energy and electrical power, dc circuit, and Kirchhoff I & II law. Meanwhile, the magnetic material distribution included forces in electric charge moving in magnetic fields, magnetic fields caused by straight wires, and coils. Readability validation was measured by consideration of 5 physics prospective teachers who have passed Basic Physics course from one of university in Bandung by using questioner. Furthermore, content validation was performed by three expert judgment who are expert with using assessment rubric. The empirical validation was done through tryout using physics prospective teachers' response which then was analyzed through ITEMAN Version 3.0 program.

The instruments used in this study were questionnaires, readability assessment sheet, and validation sheet for expert judgment. First, the questionnaires were used to identify the material topics of Basic Physics course that were perceived as difficult by physics prospective teachers. Second, readability assessment sheet was used to get response of 5 students about the degree of instrument readability. Generally, readability validation of test was examined from 3 main components namely: (1) the use of words and sentences, (2) the use of Language; and (3) the clarity of instrument guidance (Brookhart, 2010). Scaling was method used to assess each aspect. Scale analysis used was Likert. In Likert, subject read every statement in the questionnaire and evaluate the question based on the categorized answer (Haladyna et al., 2010; Svetina & Levy, 2014; Tarrant, et.al., 2009). There are 5 answer that can be chosen by subject and it has its own score. The range of score is from 1 to 5 score with its' categorize. The score 1 indicates very bad, score 2 is bad, score 3 for enough, score 4 is good, and 5 is excellent. Data analysis techniques that was used was quantitative and qualitative descriptive. In this case, the average score of the subjects' answer for each item. Furthermore, the results of quantitative data analysis were converted into qualitative form. The categorization of scoring were shown in Table 1.

Table 1 Conversion of Average Score Interval

The average score interval	Categorize
$X \geq \bar{X} + 1.SBx$	Very good
$\bar{X} + 1.SBx > X \geq \bar{X}$	Good
$\bar{X} > X \geq \bar{X} - 1.SBx$	Bad
$X < \bar{X} - 1.SBx$	Very Bad

Based on Table 1 above, the interpretation of the average score to readability test after being converted into the rating scale is shown on Table 2.

Table 2 Score Average Interpretation of Instrument Readability Test

Score average interval	Categorizing readability test	Judgment
≥ 4	Very clear	Without revision
$4 > X \geq 3$	Clear	Few revision
$3 > X \geq 2$	Enough	Full revision
$X < 2$	Not Clear	Rejected

Third, the validation sheet was used to validate the contents of the test through expert judgment by 3 expert persons. There were 3 elements which should be assessed by experts: a) accuracy of content; b) the accuracy of construction problems; and c) language aspect. Assessment techniques use a rating scale system in which validators provide score on the validation sheet. The result of validation from all validators was analyzed to prove instrument content validation. To assess each aspect of the statement, it was used Likert scale analysis. For the favorable statement, very bad has 1 score, 2 score is not good, 3 score is enough, then 4 score is good, and 5 score is very good. Data analysis technique of content validation result uses quantitative analysis in the form of validators' agreement level using inter-rater method. To find out this agreement, we can use the validity index proposed by (Aiken, 1988). The content validity index of each item is calculated using Aiken's Formula Index as follows.

$$V = \frac{\Sigma s}{n(c-1)} \ldots \quad (1)$$

Notes:

V = rater agreement index about content validity;
s = score total
n = number of validator
c = number of categorize which can be chosen by validators

To determine the value of s, it can be calculated using the formula s = r - 10, where r = category selection scores rater and 10 is the lowest score in the scoring category. Index V values ranged from 0-1. Criteria for determining whether valid or not is categorized by the coefficient of the content validity index of V(Aiken, 1988). The categorization of the content validity index (V) is shown on Table 3.

Table 3 Expert Validity Categorize

Value of validity index (V)	Categorize
$V_{account} \leq 0.40$	Low
$0.40 < V_{account} \leq 0.80$	Moderate
$V_{account} > 0.80$	High

3. RESULTS AND DISCUSSION

The result and discussion of this study is divided into three parts: (1) The development of Conceptual Knowledge Test, (2) The validity of Conceptual Knowledge Test, and The reliability of Conceptual Knowledge Test.

3.1 The Development of Conceptual Knowledge Test

The instrument of knowledge of electrical concept and magnetism was developed from several sources (Cavaliere, et.al, 1985; Maloney et al., 2001; (Nugroho & Setiawan, 2009; Thohir, Wasis, & Sugimin, 2013; Werdhiana & Rustaman, 2008). The number of items about the test instrument is initially as many as 45 numbers in the form of multiple choice with the reason of the number of electrical matter and magnetism is 1: 2. Material distribution and item number are shown in Table 4. Table 4 was used to construct items. Furthermore, all of the items on the CKT-EM test were validated. Instrument validation results eliminate 5 items. Some of the items are item number 8,16,21,30 and 33. The final design of this CKT-EM test produced 40 item numbers.

Table 4 Blue Print of CKT-EM

	Materials	Indicators (Learning goals)	Number of Items
1.	Electric current	Applying electric current concept in circuit	1, 2
		Applying electric charge conservation (electric current conservation) in circuit	3, 4, 5
2.	Potential difference	Applying potential difference in circuit	6, 7, 8, 9
3.	Electromotive Force	Applying electromotive force in direct current circuit	10, 11
		Defining battery's potential difference when it is connected to lamp and other load	12, 13
4.	Resistance	Defining wire's size and temperature affects to its resistance	14, 15, 16
5.	Energy dan power of electric	Applying the electric power concept in circuit	17, 18
		Applying electrical energy conservation and loop rules in direct current circuit	19, 20, 21
6.	Direct current circuit	Applying short circuit current	22, 23, 24
		Interpreting series, parallel, and combination both series and parallel circuit	25, 26
		Applying resistance concept in series and parallel circuit	27, 28
7.	Kirchhoff's Rules	Applying Kirchhoff's rule in direct current circuit formulation	29, 30
8.	Force of charge particles moving in a magnetic field	Interpreting state of electrical charge around the magnetic field	31, 32, 33, 34, 35
		Applying magnetic field concept of charge particle which is around magnetic field area	36, 37
9.	Magnetic force acting on a current-carrying	Determining magnetic field direction which is influenced by steady-curries wire	38, 39, 40, 41
		Determining magnetic field magnitude caused by electric	42

	conductor	current of Solenoid	
10.	Coil carried a steady current	Determining magnetic field direction of current loop in the coil arrangement	43, 44, 45

3.2 The Validation of CKT-EM

The process of validating test consisted of 3 stages: (1) the readability of instrument, (2) the expert validation, and (3) the validity of instrument

3.2.1 The readability of instrument

Readability test is conducted by five second-grade physics prospective teacher who have passed Basic Physics Course. There are 3 elements developed into 9 assessment aspects (Brookhart, 2010; Groundlund, N.E & Linn, 1990). The nine criteria are: 1) the use of the word question or command of a matter of brief, clear, and assertive; 2) a series of sentence questions and answer choices is a necessary statement only; 3) choice of logical answers in terms of material and in accordance with the command questions; 4) the length of choice of answers is relatively the same; 5) the use of language in accordance with Indonesian rules; 6) words are easily understood (not ambiguous); 7) the use of sentences/ communicative statements; 8) suitability of illustrations (in the form of tables, graphics, drawings, diagrams etc.) and; 9) illustrations of tables, graphs, drawings, diagrams or others clearly and legibly. The results of readability test showed that the average score for all items about the test was in the range of 3.2 to 4.8 with a score of at least 1 and maximum score 5. According to Table 2 related to the average interpretation of the test instrument assessment score, the result of readability test was in the category "very clearly" and “clearly". The summary outline of item classification based on their readability categories which can be seen in Table 5.

Table 5 Categories of instrument readability test

Rating scale	Categories of readability test	Number of items (%)	Judgment
≥ 4	Very clearly	24 (53.33)	Without revision
$4 > X \geq 3$	Clearly	21 (46.67)	Few revision
$3 > X \geq 2$	Enough	0	Full revision
$X < 2$	Not clearly	0	Rejected

The result of students’ response to readability test instrument could be classified into three elements as Table 6.

Table 6 Students’ response of readability test

Response aspects	Number of test items	Total of test items (%)
The use of unfamiliar words	33,34,35,41,42	5 (11.11)
The use of difficult sentences or ambiguity	12,14,16,23,26, 31,32,33,36,40, 41,43	12 (26.67)
The illustration of unclear picture, symbol, table, graphic,	19,21,23,27,33, 38,40,42,44,45	10 (22.22)

Table 6 shows that there are a number of questions that need to be revised both in terms of the use of words that are more familiar with undergraduate students, the use of more communicative sentences, and the use of more complete and detailed illustrations. In addition, from this input it can also be said that there are some issues that need to be revised in the mild revision category.

3.2.2 The expert validation of instrument

Instrument' validation data from three experts was analyzed with descriptively quantitative through the determination of content validity index using Aiken's Formula. The result of determining content validity index of all items was further categorized based on their validity level by referring to Table 3. Summary of the categorization analysis of items' content validity level was presented in Table 7.

Table 7 Categories of items' content validity

Validity index (V)	Categories	Number of item (%)
$V_{hitung} \leq 0.40$	High	0
$0.40 < V_{hitung} \leq 0.80$	Moderate	42 (93.33)
$V_{hitung} > 0.80$	Low	3 (6.67)

Table 7 showed that item 16, 22 and 36 were in the low category. The low index of content validity (V) of the three items was then cross-checked with notes in the form of comments, suggestions and input validator. The results of re-checking on item 16 and 22 to the input of the three validators indicated that there were some errors in the process of composing the problem, namely: 1) the preparation or the series of sentences about less good, and less communicative; 2) the use of a few words in sentences is less precise, including at some points the answer choice; and 3) discrepancies between items and indicators to be measured. Meanwhile, the error found in item 36 is the presentation of the less obvious picture.

3.2.3 The validity of instrument

After validating the content of the test instrument, the instrument validation process of the test was followed by an instrument test to some Physics prospective teacher as the empirical validation stage through limited try out and larger application. Empirical validation results were then analyzed using ITEMAN version 3.0 to determine the discriminating power, difficulty level, and distractor functionality of test. In addition, the need to test the instrument was to determine reliability coefficient value (α) test instrument that showed the level of instrument' validity and reliability so that it was feasible to use or not.

1

a. Discriminating power of CKT-EM

The discriminating power of test is a measure of the effectiveness of the item in distinguishing between high scores and low scores of a test(Aiken, 1988). The quality of items about multiple-choice form can be determined by discriminating power coefficients. (Nitco, 1983) establishes a decision rule on a problem item that is divided into three types based on the value of the distinguishing power coefficient, which is accepted, revised, and rejected. The three types of decisions are (1) if the value of the discriminating power coefficient is greater than 0.3, then the decision on the item is accepted; (2) The decision of the item is revised when the discriminating power coefficient is between 0.10 and 0.29; and (3) the item is rejected if the value of the discriminating power coefficient is below 0.10. Interpretation of the discriminating power analysis data of the item was presented in Table 8.

Table 8 Distribution of Items' Criterion based on Discriminating Power Index

Discriminating Power (*p value*)	Criterion	Number of Items (%)
> 0.3	Accepted	14 (30.11)

0.10 to 0.29	Revised	26 (58.78)
< 0.10	Rejected	5 (11.11)

Table 8 showed that the total number of items worthy of use as a test instrument was 90%. In other words that the large percentage of the number of items that were not feasible to use was 10% in terms of items' discriminating power coefficient.

b. The Difficulty Level of Items

The difficulty level of items is generally defined by the term percentage or proportion that responds correctly (Anastasi & Urbina, 1997). In this case, the proportion of correct answers was the comparison between a numbers of test participants who answered correctly on the items analyzed compared to the total number of test participants. The main reason for using problem-level analysis of difficulty level is to select a number of items that have the appropriate degree of difficulty level (Aiken, 1988). Category of difficulty level is determined by coefficient (p). The difficulty level of item is divided into three categories: (1) difficult category, if the value of coefficient p is greater than 0.3; (2) medium category, if coefficient p is between 0.3 and 0.7; and (3) easy category, if the p value is greater than 0.7. The result of ITEMAN version 3.0 item analysis for the difficulty level of items showed the varying p values spread into the three categories of difficulty levels. Furthermore, difficulty level category was presented in Table 9.

Table 9 Distribution Items based on Difficulty Level Index

Difficulty level (p)	Criterion	Number of Items (%)
$p < 0.3$	Difficult	24 (54)
$0.3 \leq p \leq 0.7$	Medium	19 (42)
$p > 0.7$	Easy	2 (4)

c. The Functional Distractor of CKT-EM

One of the important elements in the analysis of items' quality like the multiple choice form is the functionality distractor of item. The purpose of functional distractor analysis of items was to know whether the provided distractor makes sense or not. The distractor of the item used should be reasonable so that the distractor can be selected by at least 5% of all test takers (Chavda, Misra, & Duttaroy, 2015). Based on this statement, Mukherjee & Lahiri (2015)distinguish the effectiveness of distractor level over two types of non-functional distractors or termed Non-Functional Distractors (NFDs) and effective or Effective Distractor (ED) distractors. The distractor of a question item was categorized in the NFD if the number of distractors selected was <5% of the total number of test takers. Conversely, the distractor item was categorized as ED when selected by 5% or more by the test participants. Next, we can determine the efficiency distractor (distractor efficiency / DE) of each item based on the number of NFD items in%. If a given item contains three or more NFDs, then its DE value is 0%. Furthermore, if the item consists of two, one, or zero NDF, then DE is 33.3%, 66.6%, and 100% respectively. The distribution of item clustering based on the characteristics of the distractors was shown in Table 10.

Table 10 Classification of Items based on Functional Distractor Level

Parameter	Number of Items' NDF			
	0	1	2	≥ 3
Total (%)	27	10	5	3
	(60)	(22.22)	(11.11)	(6.67)
DE (%)	100	66.60	33.30	0

Table 10 showed that the number of questions that all the answer choices work well there were as many as 60% of the 45 items.

d. The Reliability of CKT-EM

One of the important aspect considered in a measuring instrument is the reliability of test. Test reliability refers to the consistency of scores obtained by the same test participants when retested by the same test in different situations or from one measurement to another (Anastasi & Urbina, 1997; Thorndike, 1971). Therefore, the reliability level of a test or measuring instrument is very important consideration.

The determination of the reliability coefficients of this test was analyzed using ITEMAN version 3.0 program. The result of test instrument reliability analysis showed that the coefficient value of Alpha (α) is 0.56 from 60 physics prospective teachers. The value of the test reliability coefficient of 0.56 according to Remmrers, Gage, & Rummel (1965)can be used for research purposes. The value of the reliability coefficients of this test interprets that the instrument is acceptable. Therefore, the CKT-EM test instrument is reliable to measure students' conceptual knowledge.

The CKT-EM instrument that has been revised, furthermore, was tested to 215 physics prospective teacher. The result of large application showed that the coefficient of Alpha is 0.87. This value is sufficient based on report by Fraser (1989). He reported that alpha coefficients in the range 0.58-0.81 indicated that the instrument had satisfactory reliability for scales containing five items each.

4. Conclusion

Research on the development and validation of the concept knowledge test instrument on electrical and magnetism materials has produced 40 items. Test instrument validation stages ranging from validation of instrument legibility, content validity, and test instrument testing have resulted in valid and reliable instruments with a reliability coefficient of 0.87. Based on this, it can be concluded in general that the concept of knowledge test instrument on electricity and magnetism topics is feasible to use.

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