Validity assessment of a multimedia based on cognitive load theory for undergraduate plane geometry learning

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Abstract. This paper discusses in particular how to assess the validity an android-based learning multimedia developed based on the Cognitive Load Theory (CLT) for a multimedia for learning plane geometry. The validation assessment uses two kinds of validation sheet. The first is for assessing the content of the learning material that includes three aspects: (1) The feasibility of content/material, (2) The feasibility of presentation, and (3) The compatibility with CLT in which the three of these aspects are divided into eleven indicators. These concern with how the multimedia manage intrinsic, extraneous and germane cognitive load. The second is for assessing the multimedia construction by android-based media experts, which also includes three aspects, namely (1) The feasibility of visual/display, (2) The feasibility of programming, and (3) The compatibility with CLT, these three aspects are divided into thirteen indicators for assessing the cognitive load factors. The validation was conducted by lecturers in the area of geometry and multimedia. The quantitative data acquired from the experts (validators) assessment results then converted into qualitative data by referencing to the value conversion table. The test results of the developed learning multimedia validity are: the average total score by the material expert is 4.07 with “Very Good” validity criteria. The average total score by a media expert is 3.66 with “Good” validity criteria.

1. Introduction
The learning development that accommodate the multimedia device at the present era is more likely to be fulfilled, considering the technology advantage that has been developing rapidly. The development of technology allows the education practitioners to use visualization strategy of mathematics learning material, thus, the images, animations, text (audiovisual as well) can be arranged in combination through one media. Multimedia provides the opportunity for students for not only learn from the lesson source such as educator, but also provides the opportunity for the students to develop their cognitive in more advance, creative, and innovative manners \[1\].

In the general terms, multimedia is the use of several media to present information. Combinations may include text, graphics, animation, pictures, video, and sound \[2\]. The important point of that statement is that according to its name, multimedia is a learning facility in which its contents are the combination, collaboration, and integration of more than one media for a particular reason/interest such as learning activity. Multimedia is defined as the “presentation of material by using words/texts and images” \[3\]. Discussing in further, the “texts” are described as the material presented in verbal form, for
example by using the printed or oral texts. While, “images” are the material presented in pictorial form. This form can be realized in statistical graphics (including illustration, graphic, photo, and map) or in dynamical graphics (including animation and video).

In the development of learning multimedia, there are at least seven principles of learning multimedia design that can be applied in learning activities, namely (1) Multimedia Principle, (2) Spatial Contiguity Principle, (3) Temporal Contiguity Principle, (4) Coherence Principle, (5) Modality Principle, (6) Redundancy Principle, and (7) Individual Differences Principle [4]. The implementation/application of multimedia designs in the development of learning multimedia will be able to enhance students’ comprehension in learning and also improves the display quality of the multimedia itself.

Multimedia in this research is developed in the form of application/software that can be operated through gadget with android operation system. The selection of android-based smartphone as the development basis is considering several aspects, namely the expanded utilization of smartphone towards students, and the trend of choosing android as the operation system that mostly used by smartphone users [5].

One of the theories that discuss and learn regarding cognitive load is Cognitive Load Theory (mentioned as CLT in further). CLT has been frequently used to describe the capacity/load of human cognitive system when an assignment is conducted [6]. The exploration of capacity composition exists in this human cognitive system then become the reference to analyze, evaluate, and create the proper learning model for learning participant. In the past decades, CLT has become a very successful instructional theory and has been able to identify numbers of strategy to facilitate the learning activities. This theory is based on the findings/research regarding memory, especially cognitive process that occurs during the interaction between working memory and long-term memory [7]. CLT is a part of cognitive theory group exists at present era, CLT itself is included in the big group of theories that explain the capacity/load of cognitive performance of someone which is limited, and influenced by the factor that dynamic in its nature [8].

As the instructional theory, CLT describes the implication of instructional characteristic of human cognitive architecture. The main components of this architecture is long-term memory and working memory [9]. The interaction process then will be explained in further in the section of a person cognitive system. The thing that becomes a concern of CLT is at a condition where attention and a person working memory capacity has reached its limit, thus, the performance is decreased. In that order, this condition will resulted in the ability of someone in constructing new knowledge in learning process [10].

The cognitive capacity/load experienced by a person (especially for the learning participant) in the cognitive structure is caused by three sources, namely 1) Extraneous cognitive load; 2) Intrinsic cognitive load; and 3) Germane cognitive load [3, 11]. Extraneous cognitive load is a cognitive capacity/load that depends on how the instructional messages are designed - in which on how the materials are arranged and presented [12]. When the messages are not arranged properly, a person has to face the cognitive processing which irrelevant or inefficient [13]. If the messages are designed properly, the extraneous cognitive load - will be very low. The intrinsic cognitive load is a burden constructed due to the high complexity of lecturing material [12]. This cognitive load is depending on the difficulty level of the material - the capacity of elements exist and how they interact reciprocally. If there are many elements in the material and those elements are correlated in complex manner, thus, the intrinsic cognitive load - is high and so the opposite [11].

Therefore, according to CLT, the effective and efficient designing of instructional/learning will create a learning condition where working memory of learning participant to be not overloaded [11]. This condition can be achieved by reducing the unimportant cognitive activity of learning participants which defined as extraneous cognitive load (irrelevant cognitive load). This cognitive load/memory is caused by the instructional procedure/format that contain unimportant information . On the other side, this theory also aimed to manage important learning essence, which later mentioned as intrinsic cognitive load determined by the important elements of learning information to reach a specific learning purpose [7].
Android-based learning multimedia that being developed by referencing to CLT theory, at least has to fulfill and/or accommodate the basic assumptions of CLT theory. The developed learning multimedia should be designed and constructed by minimizing the extraneous load emerges due to multimedia contents that related to how material is presented, as well as organizing the intrinsic load of learning participant that emerges due to the material complexity. In more specific manner, there are several types that in general become the sources of extraneous load experienced by learning participant during the learning activity, two of them are (1) Split-attention situations, and (2) Redundancy situations [14].

Split-attention situations occurs when the learning participant acquires textual and graphical elements (in the form of images, animations or others) in separate condition or presented in the different area or time [11]. This process can be significantly increases the extraneous load. The explanation regarding the difference illustration between the example of lecturing material that contains split-attention and does not contain split-attention can be observed in Figure 1 and Figure 2 [15].

Task: in the diagram above, find the value of angle BFE when line AB is parallel to line DC
Angle BCD = 110°
Angle BEF = 50°
Solution:
Angle FBE = 180° – 110° = 70° (co-interior angles between two parallel lines to 180°)
Angle BFE = 180° – 50° – 70° (Angles in a triangle sum to 180°) = 60°

Figure 1. An example of Split-Attention in example and the geometric solution.

The development of android-based multimedia in this research allows split attention to be minimized. Considering that android-based multimedia on the smartphone allows the explanation for the images that become the learning contents to be able to include in one screen slide or can be combined in a link between integrated slides and relatively fast when used in multitasking mode.
Redundancy situations are occurred when two or more information sources which should be comprehended independently without the requirement for integration or the combination of both sources are in fact delivered through an excessive media or modality [11]. On the other words, redundancy can be minimized if the information is delivered with fewer media presentation without reducing its essence. The multimedia developed in this research is trying to implement the idea expressed by Mayer [3] in the illustration of a multimedia which for example considered sufficient with two modalities, such as animation and text (writing), thus, it will not require the utilization of another modality such as narration (voice).

In order to determine whether a learning multimedia is feasible or not, either in the context of data collection of a research or for a learning purpose, thus, the assessment of validity of the multimedia becomes an essential matter. This paper is discussing in specific about the procedure and the results of validity test of the developed android-based learning multimedia of plane geometry with the reference to CLT.

2. Method
Discovering the results of expert validation towards the developed android-based learning multimedia of plane geometry in accordance with CLT, thus, it will be feasible to be used as learning supplement on the plane geometry subject/course. The implementation method of validity assessment of the developed media in this research is a part of development research. After the development product of learning multimedia application of plane geometry is developed, the validity assessment or test is performed by experts. This stage is conducted by involving two experts, the first is the material expert who own competency in plane geometry who also a geometry lecturer and the second is the media expert who own competency in computer and programming field, as well as the lecturer of computer science. The material expert assesses the validity in the aspects of material and learning on the learning multimedia application, while the media expert assesses the validity in media aspect; specifically on the feasibility of display, programming, and the compatibility of the application with the theory used. The procedures of validity assessment performed in this research can be explained as follows:

2.1. Determining the type of data collection instrument and the formulation procedure
The instrument used to collect the validation data from material and media experts is questionnaire. In more specific manner, the questionnaire used is a close-type questionnaire presented with the statements associated with multimedia that have been provided by the researcher, and also equipped with judgment/assessment columns with Likert Scale (1-5 value range). The assessment/judgment columns for the validators can be filled by giving a check mark on the value range selected. On each statement of the questionnaire, there are columns that can be filled by validators (material and media experts) with improvement suggestion or response towards statement associated with the feasibility of developed media.

There are several procedures that have to be conducted before formulating the questionnaire, including:
   a. Formulating the aims to be achieved with questionnaire.
   b. Identifying the variable that will be determined as questionnaire target. The variable is feasibility level or the validity of learning media.
   c. Describing each variable that becomes more specific and independent sub-variable (indicator or sub-indicator).
   d. Determining the type of data to be collected, as well as determining the analysis technique. The type of data collected to be analyzed is quantitative data.

2.2. Formulation the notions of validation form questionnaire
The questionnaire notions (validation form) are formulated by considering the aspects and criteria regarding material content contained with competency standard, basic competency, and indicator in plane geometry learning, presentation aspects as well as the aspects mentioned in the theory used as
development reference (CLT). Similar condition also applies for questionnaire notions (validation form) for media expert.

Table 1. The notions of validation form of material expert.

| Aspect                           | Indicator                                                                 | Total Item |
|---------------------------------|---------------------------------------------------------------------------|------------|
| Feasibility of Content          | A. Suitability of content with competency standard, basic competency, and indicator | 3          |
|                                 | B. Correctness of content                                                 | 9          |
|                                 | C. Support of content                                                     | 2          |
| Feasibility of Presentation     | A. Technique of Presentation                                              | 2          |
|                                 | B. Support of Presentation                                                | 2          |
| Compatibility with Cognitive Load Theory | A. Managing Intrinsic Cognitive Load on material presentation             | 3          |
|                                 | B. Improving the Germane Cognitive Load                                   | 3          |
|                                 | C. Minimizing the Extraneous Cognitive Load on material presentation      | 2          |
|                                 | D. Using worked example to support students constructing knowledge         | 4          |
|                                 | E. Minimizing the Split Attention Effect on image presentation            | 3          |
|                                 | F. Minimizing the redundancy effect in product utilization                | 2          |

Table 2. The notions of validation form of media expert.

| Aspect                           | Indicator                                                                 | Total Item |
|---------------------------------|---------------------------------------------------------------------------|------------|
| The Feasibility of Visual/Display | A. Proper layout                                                          | 3          |
|                                 | B. Proportional design                                                    | 2          |
|                                 | C. Decent program typography                                              | 3          |
|                                 | D. Proper use of image                                                    | 2          |
|                                 | E. Attractive cover                                                       | 3          |
| The Feasibility of Programming  | A. The ease and flexibility of navigation                                 | 2          |
|                                 | B. The creativity and innovation of product                               | 2          |
|                                 | C. The possibility for further development                                 | 1          |
| Compatibility with Cognitive Load Theory | A. Managing Intrinsic Cognitive Load on material presentation             | 3          |
|                                 | B. Improving the Germane Cognitive Load                                   | 3          |
|                                 | C. Minimizing the Extraneous Cognitive Load on material presentation      | 2          |
|                                 | D. Minimizing the Split Attention Effect on image presentation            | 3          |
|                                 | E. Minimizing the Redundancy Effect in product utilization                | 2          |

2.3. Arranging/formulating the questionnaire (validation form)
The questionnaire is formulated in accordance with the notions arranged in prior, each indicator is represented as the obvious and concise statement item. Thus, it can be interpreted by validators into assessment score in Likert Scale (1 to 5).
2.4. The type of data of validation result
The result of validation form filling by validators resulted in two types of data which consist of:

1. Assessment score, consists of the accumulation of empirical data from the score in Likert Scale. This data is a quantitative data which later converted into qualitative data in the form of the interpretation of validity quality with the scale such as “Very Good”, “Good”, “Decent”, “Deficient/Lacking”, and “Very Deficient”.

2. The response and improvement suggestion provided by validators towards the developed media. This data is qualitative data used as the reference for improvement or revision of the developed media.

2.5. Determining the data analysis technique
The quantitative data acquired from the experts (validators) assessment results then converted into qualitative data by referencing to the value conversion table as presented in Table 3 [16].

| Quantitative Data | Scale/Range                          | Qualitative Data |
|-------------------|--------------------------------------|------------------|
| 5                 | X > Xi + 1,50 SBi                    | Very Good        |
| 4                 | Xi + 0,50 SBi < X ≤ Xi + 1,50 SBi    | Good             |
| 3                 | Xi - 0,50 SBi < X ≤ Xi + 0,50 SBi    | Decent           |
| 2                 | Xi - 1,50 SBi < X ≤ Xi - 0,50 SBi    | Deficient        |
| 1                 | X ≤ Xi - 1,50 SBi                    | Very Deficient   |

Note:
Xi = Ideal Average
= ½ (highest score + lowest score)
SBi = Ideal standard deviation
= 1/6 (highest score + lowest score)
X = Assessment score from experts

According to the formulation above, by referring to the highest score on the scale, 5 is the highest and 1 is the lowest, thus, in order to acquire the score used as the reference of the interpretation of validity assessment; the classification table is arranged as follows:

| Average Score Range/Scale | Classification |
|---------------------------|----------------|
| x > 4,01                  | Very Good      |
| 3,34 < x ≤ 4,01           | Good           |
| 2,66 < x ≤ 3,34           | Decent         |
| 1,99 < x ≤ 2,66           | Deficient      |
| x ≤ 1,99                  | Very Deficient |

Note: x= Average Score

In this research, the feasibility and validity of the developed product at least have to fulfill the classification of “Good”. It means that, if the assessment result for the entire aspect is at least in “Good” category, then the product from the development result is determined as feasible to be used.

3. Result and Discussion
In the validation process, the media expert gives 4.3 average assessment score (very good) with several improvement suggestions for the material content in the multimedia. The media expert gives 3.8 average assessment score (good), and several improvement suggestion on the display and programming section.
These results show that the developed learning multimedia has fulfilled the “valid” criteria and feasible to be used and/or tested in the next process.

3.1. Validation of Material Expert
The validation of the material experts is conducted by a lecturer of geometry at the Mathematics Education Department of Yogyakarta State University. The Material expert validation uses questionnaire instrument with 47 statement items. Based on the result of the average calculation, the average scores of material expert are: (1) the content feasibility aspect is 4.22; (2) the feasibility aspect of presentation is 4; (3) The compatibility aspect with CLT is 4. The total average score is 4.07 with criteria of “Very Good.”

The improvement suggestion from the material expert is specified into two things, namely:
- The improvement of punctuation mark which is less appropriate in material script
- The editorial improvement for several definitions, postulates and theorems which are less/not yet appropriate.

Some of the examples are as follows:

| The revision of editorial content of Axiom Menu |  |
|-----------------------------------------------|  |
| **Before Revision** | **After Revision** |
| *Line, symbolized by AB.* Conceive a length but has no width and thickness. | *Line, symbolized by AB*. Conceive unlimited length, perfect straightness, has no width and thickness |

The Revision on Congruent Triangle Menu

| **Before Revision** | **After Revision** |
|---------------------|--------------------|
| **Postulate 5.1**  | **Postulate 5.1**  |
| “Two triangles are congruent if the sides and angles that located at the sides are equal on both triangles” | “Two triangles are congruent if both triangles are having sides with equal length and the angles located at the sides are having equal size in pairs.” |

3.2. Validation of Media Expert
The validation of the material experts is conducted by a lecturer of computing at the Mathematics Education Department of Yogyakarta State University. The media expert validation uses questionnaire instrument with 26 statement items. Based on the result of the average calculation, the average scores of media expert are: (1) the display/visual feasibility aspect is 3.83; (2) the feasibility aspect of programming is 3.83; (3) The compatibility aspect with CLT is 3.32. The total average score is 3.66 with criteria of “Good”.

Several examples of improvement suggestion from media expert are as follows:
1. Main menu improvement
2. The improvement of the colors of letter and image which are less sharp/contrast
3. The improvement of image size.
4. The improvement of User Guide icon
5. The improvement of sub-menu navigation on the main menu of Axiom as well as in Line and Angle.
6. Removing the unnecessary navigation button on sub-menu of definition and postulate,
7. The improvement of navigation location of sub-menu of a Special Parallelogram.
8. Additional revision, editorial improvement and the wrong images

4. Conclusion
This research is motivated by the need for learning supplements other than books/modules in the course/lesson of plane geometry that able to accommodate the cognitive load management of learning participant, thus, the learning objectives can be achieved maximally. This paper specifically discusses the validation procedures and feasibility test results through expert validation process. The test results of the developed learning multimedia validity are: the average total score by the material expert is 4.07 with “Very Good” validity criteria. The average total score by a media expert is 3.66 with “Good” validity criteria. According to these results, the developed learning multimedia can be utilized in the learning process because it has fulfilled the validity element proved by those interpretations.

References
[1] Sagala S 2006 Konsep dan Makna Pembelajaran: Untuk Membantu Memecahkan Problematika Belajar dan Mengajar (Bandung: Alfabeta)
[2] Ivers K S and Barron A E 2010 Multimedia Project in Education Designing, Producing and Assessing (Santa Barbara, CA: Libraries Unlimited)
[3] Mayer R E 2009 Multimedia Learning: Prinsip-prinsip dan aplikasi, T W Utomo, Trans (New York: Cambridge University Press).
[4] Mayer R E 2001 Multimedia Learning (New York: Cambridge University Press)
[5] Gartner Says Tablet Sales Continue to Be Slow in. (2015, 5th January). Retrieved from http://www.gartner.com/newsroom/id/2954317#
[6] Chandler P and Sweller J 1991 Cogn. Instr. 8 293
[7] Sweller J, Van Merrienboer J J G and Paas F G W C1998 Educ. Psychol. Rev. 10 251
[8] Sweller J, Ayres P, and Kalyuga S 2011 Cognitive Load Theory (New York: Springer)
[9] Kalyuga S 2011 Educ. Psychol. Rev. 23 1
[10] Zhang J 2013 J. Educ. Stud. 6 134
[11] Clark R C, Nguyen, F and Sweller J 2006 Efficiency in Learning: Evidence-based Guidelines to Manage Cognitive Load (San Francisco, CA: Pfeiffer)
[12] Fraser K L, Ayres P and Sweller J 2015 Simulation in Healthcare: J. of the Soc. for Simulation in Healthcare. 10 295
[13] Miwa K, Kazuaki K, Terai H and Mizuno Y 2016 The 8th Int. Conf. on Advanced Cogn. Tech. Appl., IARIA (Rome, Italy) p 38
[14] Kalyuga S 2009 Managing Cognitive Load in Adaptive Multimedia Learning (Harsey, PA: Information Science Reference)
[15] Ayres P and Sweller J 2005 The Split-attention Principle in Multimedia Learning, in The Cambridge Handbook of Multimedia Learning, R. E. Mayer, Editor (New York: Cambridge University Press)
[16] Sudijono A 2012 Pengantar Evaluasi Pendidikan (Jakarta: PT. Raja Grafindo Persada)