THE IMPROVEMENT OF STUDENTS' CONCEPTUAL COMPREHENSION ON HEAT TRANSFER THROUGH THE USE OF FEMLAB-BASED INTERACTIVE MULTIMEDIA

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ABSTRACT

The purpose of this research is to study the effect of using a Finite Element Method Laboratory (FEMLAB)-based multimedia on students' conceptual comprehension on heat transfer material. The research used a pre-experimental design method and the intervention includes interactive media which contains conceptual information on conduction, convection, and radiation. The participants were students in the 3^{rd} semester from the mechanical engineering department in the Indonesian University of Education. Through series of data analysis, high category of N-gain score (0.72) is obtained with the highest comprehension score being in the concept of radiation (<g> = 0.86) compared to other two concepts; convection and conduction. Moreover, under the discussion of comprehension skills, a high <g> score is also obtained at the level of 0.86 which belongs to the translation skills compared to the interpretation and extrapolation skill. Having such a result, it can be seen that <g> score of conceptual comprehension on heat transfer subject is in the high-g level, so it can be concluded that the use of FEMLAB-based multimedia has effectively improves the students' conceptual comprehension. Beside that, the students give positive response toward the use of FEMLAB-based multimedia which can create a more fun learning experience in heat transfer material and can facilitate the students to independently master the related concepts.

Keywords: *conceptual comprehension, response, FEMLAB, heat transfer*

1. Introduction

Physics is one of the background sciences for other type of studies. There are many scientists who develop their concerns based on physics study, for instances are the chemists who develop the molecule structure theories and the paleontologists who reconstruct the lives of the dinosaurs. Additionally, Physics is also one of the fundamental theories in the study of engineering and technology (Young, Freedman, Sandin and Ford, 2006). It means that there will not be any engineers who can design any of their works without comprehending the law and concepts of Physics. In order to design an airplane, for example, an engineer should be able to master Physics concepts such as boundary-layer, laminar-turbulent flow, and viscosity.

The application aspect of Physics' concepts and laws in engineering and technology studies makes Physics mastery becomes a pre-requisite for the engineering students so that once they are on fields they are equipped by sufficient ability. However, most of the students still find it hard to fulfill the pre-requisite. One of the difficulties is due to the lack of student ability in understanding and analyzing mathematical equations describing the concepts or laws of Physics (Hamidah, Mulyanti and Purnawan, 2008). As a matter of example is the student's misunderstanding in valuing div (∇) operator in electric field concept as a scalar. The other difficulty is the student incapability in imagining the pattern of Physics just like the pattern of electric field, the draft pattern along vehicles, or the heat transfer pattern from high to low temperature in an entity.

In order to overcome the students' difficulties in understanding and analyzing the Physics' mathematical equations, the use of multimedia in teaching learning process can be one of alternative solution as it is suggested by Kim, Park and Lee (2005), Buchanan, Carter, Cowgill, Hurley, Lewis, Macleod, Melton, Moore, Pessah, Robertson, Smith and Vandenplas (2005), Ginns (2005), and Fisher, Schumaker, Culbertson and Desher (2010). Additionally, those 20 scientists use animated multimedia and simulation in their teaching-learning process as supporting tools in explaining the scientific concepts to their students.

In contrast with the four scientists, the designing process as well as the development of FEMLAB based multimedia and its implementation have been performed in this research with heat transfer as the main teaching material. The selection of FEMLAB as the basis of the animation making and the Physics' concept simulation is due to FEMLAB features as the basic considerations as it is cited in the book of FEMLAB (2000). They are as follow:

(a) FEMLAB can model virtually any physical phenomena, so that an engineer or scientist can describe with partial differential equations (PDEs) including heat transfer, fluid flow, electromagnetics and structural mechanics. They can create these models in 1-D, 2-D and even 3-D, complete with animation

(b) FEMLAB makes its considerable computational power available through an intuitive graphical user interface that allows users to solve complex problem by describing these problems with drawings rather than entering many lines of involve equations.

(c) Anyone who is an expert in PDEs and knows how to set up simulations using PDEs can extend those system by explicitly modeling in terms of these types of equations. FEMLAB is unique with respect to these modeling capabilities. Most systems for physical modeling use hard-coded PDEs targeted to a certain application area. In FEMLAB users can model virtually any physical phenomenon in terms of the equations themselves, using the laws of science.

(d) Users can extend FEMLAB's standard capabilities through simple script programming. While a model is running, users can pause the process at any point, evaluate its progress and methodology, and proceed either with the standard method or branch off into a new approach.

(e) Other FEMLAB feature enables its users to visually draw various Physics phenomena through its' Graphical User Interface (GUI). Using GUI, FEMLAB users can solve complicated Physics problems by drawing them.

Moreover, GUI is a form of graphic interface which is composed by some elements such as icons, text boxes, sliders, menu, and pointing devices. Applications which use GUI are mostly more user-friendly for it is not obliging the users to fully understand what and how the program commands work (Sugiharto, 2006).

In order to see the effectiveness of the implementation of FEMLAB based multimedia, a question is proposed in this research: "*How do the students conceptual comprehension increase after the use of FEMLAB based multimedia*?"

2. Research Method

The research is conducted using pre-experiment method (shown in Table 1) in order to obtain the data of students' conceptual comprehension in heat transfer (Sugiono, 2008). Pre-experiment method was chosen based on the consideration that the increase of students' conceptual comprehension can be evaluated from the difference between the post-test and pre-test value, which are expressed in a normalized gain value as will be expalined later. In addition, the availability of students as the study sample is only one class of 30, so the use of control groups in this study can not be done. All of the students were used as a research sample. Moreover, this research also uses descriptive method to figure out students' response toward the use of FEMLAB-based multimedia in heat transfer class.

Class	Pre-Test	Treatment	Post-Test
Experiment	O	X	O

Symbol meaning:

X : Teaching-learning process on heat transfer using FEMLAB-based multimedia
O : Pre-Test and Post-Test

In addition, the research instrument to obtain data regarding to the improvement of students' comprehension is multiple choice, whereas questionnaire is used to derive the students' response. Multiple choice was chosen as an instrument of students' comprehension because of the simplicity of data processing. To avoid guessing factor in choosing the answer, it is given the score of 1 for true answer, score of -1 for false answer, and score of 0 for the null answer. The obtained data from both of the instruments are then processed using two standard data analysis techniques, the N-gain value (<g>) as it is issued by Hake, (1999) for assessing the students' comprehension improvement, and approval percentage (Sugiono, 2008) to analyze students' response toward the use of FEMLAB-based multimedia. Both of the analysis techniques are drawn in equation (1) and (2), respectively.

$$<g> = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}} \quad (1)$$

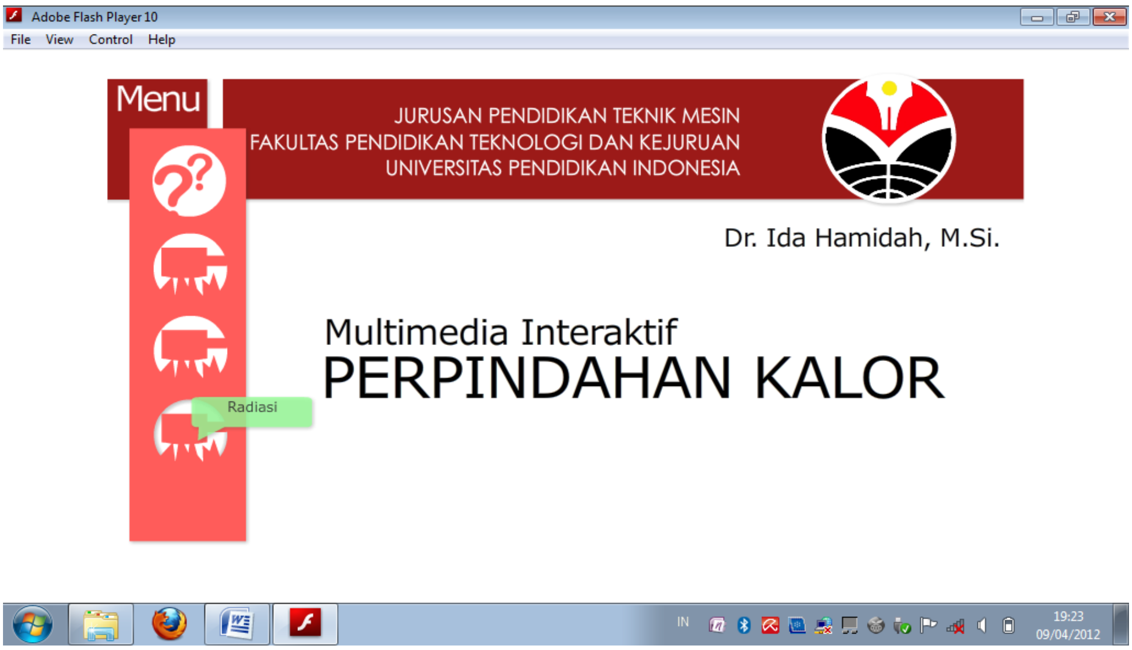
Learning is said to be effective if it can improve the conceptual comprehension of <g> between 0.3 and 0.7 (medium-g level) or <g> more than 0.7 (high-g level)

$$\%\ approval = \frac{total\ score\ in\ each\ item}{total\ ideal\ score\ of\ all\ items}\ x\ 100\% \tag{2}$$

3. Result and Discussion

3.1. Multimedia Development

The development of interactive multimedia in heat transfer concept has successfully been done. It conveys the concepts of conduction, convection, and radiation. The three concepts are further explained in other several sub-concepts in line with the material exposed in the heat transfer lectures. In the end part of each concept, exercising questions are also provided in order to assist students in improving their comprehension about heat transfer concepts.



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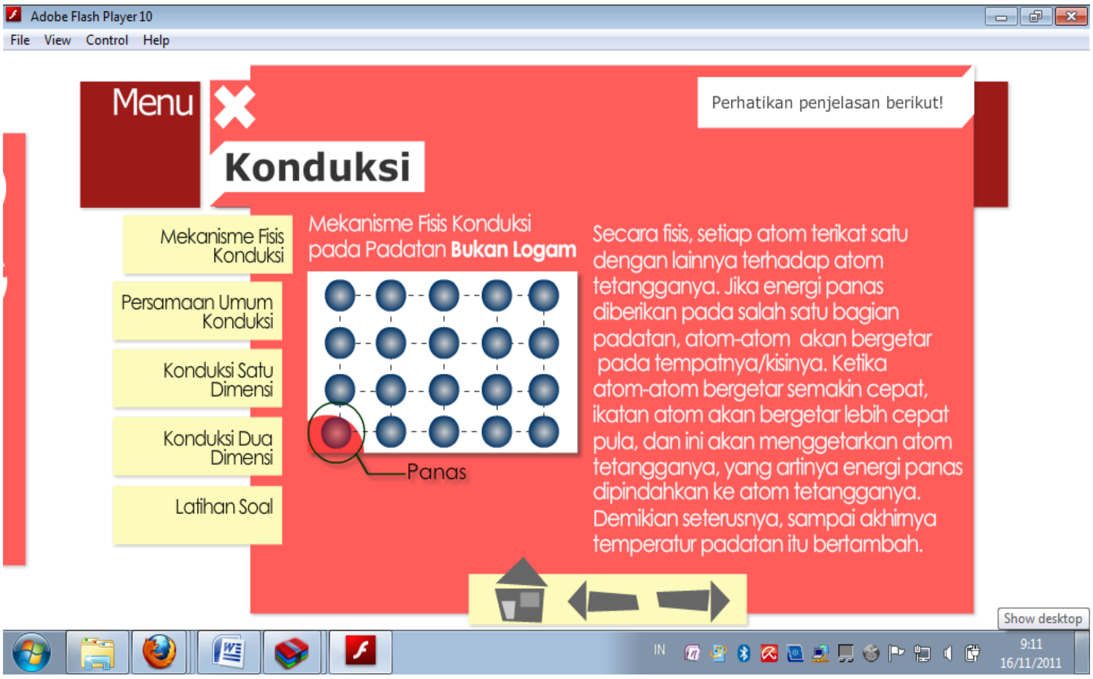
The multimedia development is started by creating the over-all storyboard followed by designing the desired visualization as well as the sound effect. After being created, the multimedia is then evaluated by the experts of multimedia and heat transfer, to get the opinion from them about the heat transfer material and feature quality of multimedia. Additionally, the pictures of opening page and one of the heat transfer concepts displayed in the multimedia are provided in figure 1 and figure 2, respectively.

Figure 1 shows the opening page of FEMLAB-based interactive media for heat transfer and it consists of material information about heat transfer. If students click the Menu button, sub-menus like *Definisi* (definition), *Konduksi* (conduction), *Konveksi* (convection), and *Radiasi* (radiation) will be displayed. Using this Menu system, students are allowed to choose any lecturing material match to their comprehension level.



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Otherwise, in the Conduction Sub-Menu (as shown in Figure 2) other sub-icons like *Mekanisme Fisis Konduksi* (conduction physics mechanism), *Persamaan Umum Konduksi* (general equations of conduction), *Konduksi Satu Dimensi* (one dimension conduction), *Konduksi Dua Dimensi* (two dimension conduction), and *Latihan Soal* (exercises) are also provided. The almost alike sub-Menus are also available in both the sub-Menus of convection and radiation which are in line with the lecturing material given in the classroom. The lecturing materials in the Covection sub-Menu are general equations of convection, natural convection, forced convection, and exercises. In the other hand, the lecturing materials in the Radiation sub-Menu are general equations of convection, nature of radiation, thermal radiation, emissivity, shape factor radiation, radiation from gases, solar radiation, and exercises.

3.2. The Improvement of Comprehension on Heat Transfer Concepts

The data of students' conceptual comprehension is obtain by providing a 20 item multiple choice test (ideal score = 20) which consists of seven questions about conduction, six on convection, and the other six items about radiation. The average score of pre-test, post-test and N-gain value (<g>) of students' conceptual comprehension is provided in the table 2. Based on the <g> score average, it can be concluded that the use of interactive multimedia in the heat transfer class can effectively improve students' conceptual comprehension to the point of 0.72 or can be categorized as a high-g level.

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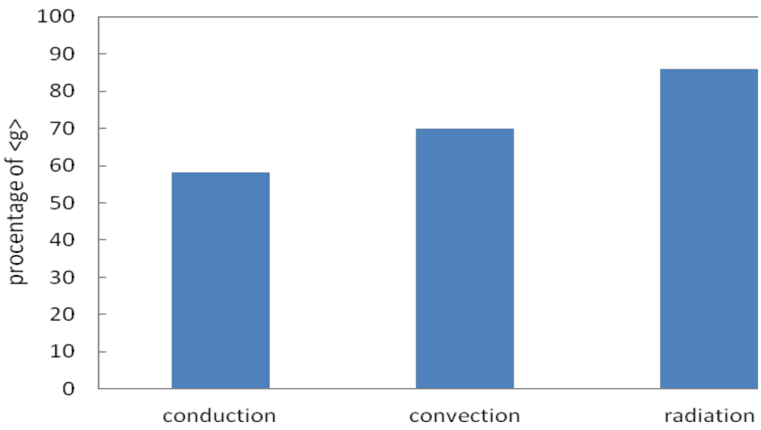
	Pre-Test	Post-Test	<g>
Average Score	0,26	0,79	0,72

In order to provide a better perspective, the same average mechanism is also conducted in the other sub-materials (conduction, convection, and radiation) as it is shown in Figure 3. Figure 3 describes that the highest <g> average score is obtained in the comprehension on radiation concept (0.86) while <g> average score of comprehension on conduction concept with 0.59 point is the lowest.



Besides conceptual comprehension on sub-materials (conduction, convection, and radiation), data analysis is also conducted on each skill type of conceptual comprehension. They are translation skill, interpretation skill, and extrapolation skill (Anderson and Krathwohl, 2001). The <g> score for each skill is shown in Figure 4. Figure 4 shows the average <g> score for each skill type of conceptual comprehension. It can be seen that translation skill has the highest score compare to interpretation and extrapolation skill, since extrapolation skill has the lowest score compared to other comprehension skills. Furthermore, extrapolation skill obtains the lowest score improvement due to the skill characteristic that requires the highest level of conceptual comprehension skill compared to other two.

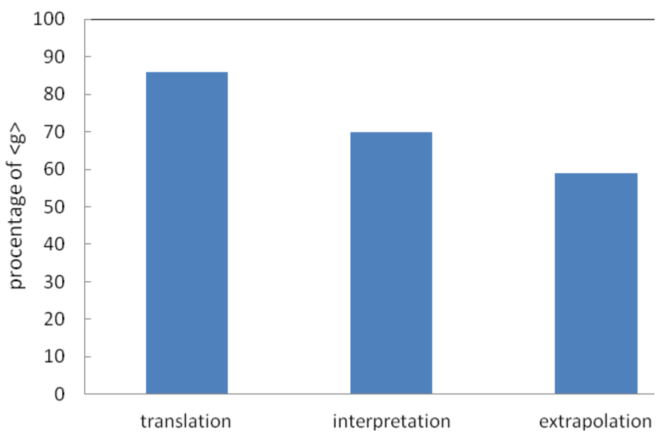


Figure 4. Procentage of <g> score of conceptual comprehension on each skill type: translation, interpretation, and extrapolation

In general, using the <g> score average, where the <g> score of conceptual comprehension of 0.72 and based on the condition of <g> score as is explained in the equation (1), it can be concluded that the use of FEMLAB-based interactive learning media can effectively improve students' conceptual comprehension on heat transfer subject.

3.3. Students' Response toward The Use of FEMLAB-Based Multimedia

The data of students' response toward the use of FEMLAB-based multimedia is obtained through distributing questionnaires filled by the students. Questionnaire given to students after learning using FEMLAB-based multimedia, and conducted under the supervision of lecturers. The summary of the data is depicted in table 3. From the table, it can be seen that the students give positive response toward the use of FEMLAB-based multimedia with 4.05 average score in the scale of 5.

Response Indicator	Average Score	Percentage (%)	Criteria
Motivation Improvement	3,82	76	Good
Conceptual Comprehension Assistance	4,15	83	Very Good
Free-Time Studying Access	4,21	84	Very Good
Innovation Assistance	4,09	81	Very Good
Wide Chance of Trial	3,97	79	Good
Over-All Average	**4,05**	**81**	**Very Good**

Criteria category: 0%≤poorly bad≤20%; 20%≤poor≤40%; 40%≤fairly good≤60%; 60%≤good≤80%; 80%≤very good≤100%

Moreover, using the approval percentage equation as it was given in the equation (2), it can be seen that students' response to the use of FEMLAB-based multimedia is in the level of 80% which is categorized as 'Very Good'. Additionally, 70% of approval percentage on students' motivation indicates that the students, using the multimedia, are motivated to learn and comprehend learning material more seriously. The other multimedia function which is as the helping tool to improve conceptual comprehension obtained students' approval percentage at the level of 83%. It means that the existence of simulation and animation in the interactive multimedia can help students to draw the relation between physical scales related in certain phenomena and can ease students to recall the forgotten concepts. Moreover, the multimedia function as a media to provide free-time learning chance, help innovating new ideas, and give wide chance to have a try are in the level of 84%, 81%, and 79% of students approval. These positive responses indicate that the use of FEMLAB-based multimedia can be conducted in Physics class or in other studies which need visualized concept. In the other word, the use FEMLAB-based multimedia can be one of the ways to improve student's conceptual comprehension and students' motivation.

4. Result Discussion

In the Fig 3, it can be seen that the highest <g> score is obtained in the radiation concept. Concerning the difficulty level, in fact radiation concept uses less mathematical equations compared to conduction and convection concepts. The simple mathematical equation in radiation concept lightens the students' learning burden and as consequence they give more attention in comprehending the concept which helps them to get high <g> score.

Compare to the <g> score in conceptual comprehension, the average <g> score in comprehension skills are more varied as it is shown in Fig 4. In terms of definition, translation skill is related with students' ability in comprehending abstract concept. Moreover, the students are asked to state the concept in a simple and concrete form. On the other hand, interpretation skill is the ability to recognize and comprehend the main idea of a communication practice, for instance in giving supporting examples in forms of charts or tables. Meanwhile, the extrapolation skill has higher requirement which needs higher intellectual capability. The extrapolation skills requires students to be able to predict the tendency of similar data depicted in different form.

The improvement of conceptual comprehension as it shown by the high obtained number of <g> score indicates the effectiveness of the use of FEMLAB-based multimedia in heat transfer class. The improvement is due to the condition where students learn the concept not only through verbal lecturing, but also through the visual explanation provided in FEMLAB simulation.

It is in line with the notion proposed by Sagala (2005) which states that teaching-learning process that use teaching media not only ease down the students to understand, comprehend, and experience the concept, but also trigger strong learning motivation compared to learning merely from media providing abstract words. Similar support of the use of proper teaching media is also proposed by Ginns (2005) in his research which concludes that getting-back the students focus and attention will be easier to do if the material is conveyed supported by pictures rather than non stop talking explanation. Furthermore, as it is suggested by Buchanan et al. (2005), the use of animation is considered more effective in helping students to remember, comprehend, and draw the concept compared to conventional teaching aids like handouts and text books. It is due to the three-dimension teaching tools that optimally help students to learn. The conceptual comprehension improvement using FEMLAB-based multimedia is also in line with the research conducted by Fisher, et.al (2010) which states that the use of multimedia which comes from the computerized professional development (PD), could improve teachers' performance about the routine and planning for concept teaching, as did student performance on tests of concept knowlwedge.

The high N-gain score in heat transfer material is also in line with the students' response toward the use of FEMLAB-based multimedia which allows students to do independent learning. The concept obtained through independent learning will last longer than that the one obtained through classical method like memorizing. FEMLAB-based multimedia can help students to recognize, do self-inquiry, comprehend, and master the concept of the material. It is due to the condition where students are not merely listening to the lecturing but more actively involved in enriching and discovering their own comprehension so that they can have better concept mastery.

5. Conclusion

Based on the research result and data analysis, it can be concluded that:

a. The <g> score of conceptual comprehension on heat transfer subject is in the high-g level, so it can be concluded that the use of FEMLAB-based multimedia has effectively improves the students' conceptual comprehension.
b. The students give positive response toward the use of FEMLAB-based multimedia which can create a more fun learning experience in heat transfer material and can facilitate the students to independently master the related concepts.

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