

INTERACTIVE MULTIMEDIA THERMODYNAMICS TO IMPROVE CREATIVE THINKING SKILL OF PHYSICS PROSPECTIVE TEACHERS

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Received: 24 August 2016. Accepted: 29 September 2016. Published: January 2017

ABSTRACT

This study aims to improve the creative thinking skills of prospective physics teacher as the impact of the application of interactive thermodynamics multimedia (ITMM). The research method used is quasi experiment with control group pretest-posttest design. The subjects consisted of 34 students in the experimental group and 33 students in the control group. Participant students are physics physics semester fourth, in one of the state universities in East Kalimantan. The research instrument consists of multiple choice test items charged with creative thinking skills. Data were analyzed by using difference test of two averages. The normalized gain score $\langle g \rangle$ of creative thinking skill aspect on the experimental group is 0.60 and the control group is 0.31. This indicates that the creative thinking skills of the prospective physics teacher increase significantly after they experience thermodynamic learning with interactive multimedia. Thus it can be concluded that the use of interactive multimedia improve the creative thinking skills of prospective physics teachers.

ABSTRAK

Penelitian ini bertujuan untuk meningkatkan keterampilan berpikir kreatif mahasiswa calon guru fisika sebagai dampak penerapan multimedia interaktif termodinamika (MMIT). Metode penelitian yang digunakan adalah kuasi eksperimen dengan *control group pretest-posttest design*. Subjek penelitian terdiri atas 34 mahasiswa pada kelompok eksperimen dan 33 mahasiswa pada kelompok kontrol. Mahasiswa partisipan adalah mahasiswa pendidikan fisika semester ke empat, di salah satu perguruan tinggi negeri di Kalimantan Timur. Instrumen penelitian terdiri dari butir tes pilihan ganda bermuatan keterampilan berpikir kreatif. Data dianalisis dengan uji perbedaan dua rerata. Rerata skor gain yang dinormalisasi $\langle g \rangle$ pada aspek keterampilan berpikir kreatif kelompok eksperimen adalah sebesar 0,60 dan kelompok kontrol sebesar 0,31. Hal ini mengindikasikan bahwa keterampilan berpikir kreatif mahasiswa calon guru fisika meningkatkan cukup signifikan setelah mereka mengalami pembelajaran termodinamika dengan multimedia interaktif. Dengan demikian dapat disimpulkan bahwa penggunaan multimedia interaktif meningkatkan keterampilan berpikir kreatif mahasiswa calon guru fisika.

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Keywords: interactive multimedia; thermodynamics; creative thinking skills; physics prospective teachers

INTRODUCTION

In an ever-changing societal situation and increasingly severe challenges, an educator should look far ahead and think about what will be facing by learners in a future. In a histo-

rical perspective, the 21st century learning developed in the United States in 2007 supported by other developed countries including Australia which was pioneered by The Partnership for 21st Century Skill has important purposes. They resulted formulation that students should be facilitated in order to have skills of communication, creative thinking, collaboration, critical thinking, and problem solving (Pacific Policy

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Research Center [PPRC], 2010). The knowledge and ability obtained can be made provision of life in a community that has both local and global character and can be accounted personally and socially. The ability to think creatively will effectively facilitate students in solving the challenges associated with events in everyday life. Therefore, the ability of creative thinking is very important to be developed and owned by students in the learning process and after the learning process.

Thermodynamics has a dynamic character and requires creativity in solving the problem. This material can be used as a vehicle for developing creative thinking skills. However, the obstacles faced are the content of material given by textbooks still tend to be mathematical, many formulas, many contain abstract concepts, based on principles, and state the processes and cycles that all this less support the development of creative thinking. These have been investigated and reported by Lewis, et al. (1993) which state that students are not able to integrate thermodynamic concepts in complex phenomena. Huang and Gramoll (2004) find out from the results of their research that students have difficulty in visualizing abstract concepts. In Carnot cycle material, students still have difficulty how to apply p-V diagram to solve the problem (Kulkarni & Tambade, 2013). Christensen, et al. (2009) found that students experienced misinterpretation in understanding the laws of the ideal gas. The constraints found by the researches turn out to affect the ability of students in understanding the material, causing frustration in building mental models, tend to be boring, so that adversely affect their learning outcomes. Based on these findings, it is deemed necessary to provide visualization of abstract concepts that students are difficult to understand in the form of animations, simulations, and virtual labs. However, dynamic visualization can not be obtained through printed books, so it takes computer technology to develop dynamic visualizations that can be used in the learning process. The resulting visualization can be interactive multimedia courseware or learning software. Through animation, simulation, and virtual laboratory students will be facilitated to be able to build knowledge and develop the ability to think creatively.

Several studies related to the use of interactive multimedia in learning have been able to help and facilitate the improvement of concepts mastery and students' creative thinking skills. The integration of computer animation

in effective learning helps students to improve their understanding in various concepts of physics (Kohnle, et al., 2012; Dega, et al., 2013). Interactive multimedia can visualize and simplify abstract thermodynamic concepts such as enthalpy and entropy. This is expressed by Liu (2006) which states that abstract concepts such as the gas laws are more easily understood by using multimedia. Junglas (2006) suggests that the use of interactive simulations will improve students' mental models. McKagan, et al. (2008) stated that interactive software helps students to understand abstract concepts on quantum mechanical. Doyan and Sukmantara (2014) reported that learning with an effective web intranet enhances the mastery of concepts such as work, energy, and power. The research results of Siswanto, et al. (2016) also showed that the use of E-Lab effectively enhances the understanding of physics concepts. It can be concluded that to be able to enhance the students' ability to integrate thermodynamic concepts in complex phenomena and enhance understanding, the use of interactive multimedia using simulations, movies, diagrams, graphics, animations, and sounds plays a vital role to help visualize and simplify abstract concepts that students can not comprehend. In addition, the power of interactive multimedia is to give students the opportunity to study the material at any time, respond quickly, accustom to creative thinking, and encourage students' curiosity to conduct investigations. It is corroborated by Podolefsky, et al. (2010) who stated that learning by using simulations can develop students' ability to investigate, establish relationships between representation, and analogy to understand scientific ideas.

Recently, experts have been researching, designing, and developing lessons by using information and communication technology. Results of overview Mulop, et al. (2012) from 1993 to 2009 in several journals related to the utilization of information and communication technology in thermodynamic lectures states that the tendency of research in thermodynamic learning can be grouped into three groups namely; (1) the use of multimedia to assist students in problem solving (Baher, 1998; Ngo & Lai, 2003; Liu, 2009); (2) use of simulation and multimedia programs to improve student interactivity (Baher, 1998; Kumpaty, 2002; Ngo, 2003; Anderson, Taraban, & Sharma, 2005; Hassan & Mat, 2005; Junglas, 2006; Bullen & Russell, 2007; Chaturvedi, Abdel-Salam, & Kasinadhuni, 2007; Weston, 2008; Liu,

2009); (3) the use of interactive multimedia and simulations to enhance the ability of reflection and application of scientific ideas (Ngo, 2003; Jonnasen, et al., 2009). Based on these results, no one has developed and implemented a comprehensive interactive multimedia that includes animation, simulation, virtual labs, and interactive exercises aimed at improving the creative thinking skills of prospective teachers in thermodynamic learning. Therefore, it is necessary to implement interactive multimedia thermodynamics that other researchers have developed to enhance creative thinking skills with different nuances or designs with existing interactive multimedia as in Figure 1.

Interactive thermodynamic multimedia is structured using four main components: theory, animation, virtual labs, and practice. The purpose of each component is; (1) theory, contains important concepts and is a supplementary textbook owned by students and in this section there is an animated link related to the concept learned; (2) animation, used to help students understand a process and thermodynamic cycle, diagram form each process or cycle, and assist students in developing creative thinking skills, and each animation is equipped with a brief explanation; (3) virtual labs, used as a component to perform student's main activities

in developing creative thinking skills. Virtual experiments along with student-oriented student inquiry sheets are designed to allow students to experiment virtually, to formulate hypotheses, collect, analyze data, and draw conclusions; (4) exercises, used by students at the end of learning after learning thermodynamic concepts and conducting experimental activities in order to test students' understanding. This exercise is also designed by giving feedback to users to check their answers.

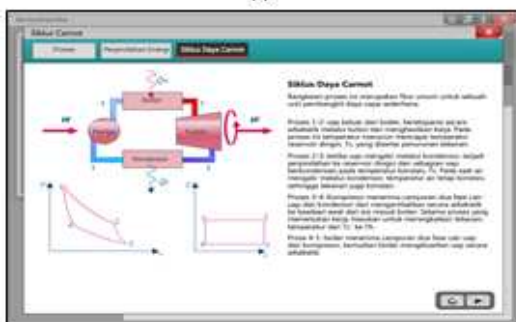
The thermodynamic materials which are the focus of this study are the basic concepts of thermodynamics, energy and the first law of thermodynamics, the properties of pure substances, the ideal gas, the second law of thermodynamics, as well as the Carnot cycle. This developed interactive multimedia not only serves as a development of mastery of thermodynamic concepts, but also can develop indicators of creative thinking skills. These indicators include fluency, flexibility, elaboration, and originality. Therefore, the purpose of applying interactive multimedia-based Thermodynamic learning in this research is to improve the creative thinking skill of physics teacher candidate. Stages of interactive multimedia-based Thermodynamics learning can be described in Table 1.



(a)



(b)



(c)



(d)

Figure 1. Example of Interactive Multimedia Interface Thermodynamics: (a) front page; (b) material; (c) animation; (d) virtual laboratory.

Table 1. Learning Stage of Interactive Thermodynamics Multimedia (ITMM)

Stages	Students Activities	AbilitiesnTrained
Orientation	Recognize thermodynamic materials and concepts, objectives and problems to be solved. Studying thermodynamic concepts through ITMM to gain knowledge as a basis for problem solving.	Understanding Thermodynamics concepts
Exploration	Students discuss in groups (3-4 persons) to infer the intent and design their problem solving through virtual experiments or steps to be performed. Students conduct virtual experiments on a virtual lab menu: - Presenting divergent questions - Formulate hypotheses - Designing virtual experiments - Conduct virtual experiment - Collect and analyze data - Make a conclusion	Fluency Flexibility Originality Elaboration Flexibility
Presentation	Communicate the results of the investigation through group presentations	Fluency
Evaluation	Doing the exercises through ITMM, Writing a summary, Record individual and group assignments.	Elaboration

METHOD

The method used in this research is quasi experiment with control group pretest-posttest design (Fraenkel, 2007). In this design there are two groups, namely experimental group ($n = 34$) and control group ($n = 33$). The experimental group received learning using interactive multimedia thermodynamics and the control group gained traditional learning. The two groups performed pretest and posttest creative thinking skills in the form of multiple choices consisting of 40 questions. The result of qualitative question validity analysis by three experts shows that the question of creative thinking in the thermodynamic context is valid to be used and the result of quantitative validity (product moment) shows a significant result (valid). The reliability of the question using the Cronbach alpha value criterion is 0.79. These results show that the creative thinking skills developed have high internal consistency. The data of the two groups were analyzed using the mean difference test (T test or Mann-Whitney) and normalized gain scores $\langle g \rangle$. Normalized gain scores by the formula (Hake, 1998):

$$\langle g \rangle = \frac{\% \langle S_f \rangle - \% \langle S_i \rangle}{100 - \% \langle S_i \rangle} \quad (1)$$

where, S_f = posttest scores, S_i = pretest scores by categories yaitu: low ($\langle g \rangle < 0,3$), moderate ($0,3 \leq \langle g \rangle \leq 0,7$), and high ($\langle g \rangle \geq 0,7$).

Level of significance of two-averaging test used effect size calculation (d). According to Morgen, et al. (2004) results of significant differences do not provide information about the quality of the differences between the two data groups. Therefore, Cohen (Morgen, et al., 2004) recommends a significant difference with five categories: very small ($d < 0.2$), small ($0.2 \leq d \leq 0.5$), moderate ($0.5 < d \leq 0.8$), high ($0.8 \leq d < 1.0$), and very high ($d \geq 1.0$). By the formula:

$$d = (M_E - M_C) / \sqrt{(SD_E^2 + SD_C^2) / 2} \quad (2)$$

where, M_E = average scores of experimental group, M_C = average scores of control group, SD_E = deviation standard of experimental group, SD_C = deviation standard of control group.

RESULTS AND DISCUSSION

The indicator of creative thinking skill developed in this research consists of four indicators namely fluency, flexibility, elaboration, and originality. To determine the achievement of interactive multimedia-based thermodynamic learning related to the creative thinking

Table 2. Pretest, posttest, and normalized gain scores <g> of each indicator of creative thinking skills in the experimental and control groups

Creative Thinking Indicators	Experimental Group (n=34)		<g> (%)	Control Group (n=33)		<g> (%)
	pretest	posttest		Pretest	posttest	
Fluency	34.22	71.12	56	36.36	59.05	36
Flexibility	44.22	85.09	72	40.96	58.33	29
Elaboration	34.33	76.52	60	35.37	53.76	28
Originality	36.47	70.27	49	35.45	54.85	31

ability of prospective physics teachers, normalized gain scores <g> were analyzed in the experimental and control groups. The average pretest, posttest, and normalized gain scores <g> of each indicator of creative thinking in the experimental and control groups is presented in Table 2.

Normalized gain scores <g> of the fluency indicators in the experimental and control groups showed a moderate increase (Table 2). This suggests that interactive multimedia-based thermodynamic learning can improve the ability of creative thinking in fluency indicators. The flexibility indicator score shows a moderate increase in the experimental group and a low increase in the control group. This shows that interactive multimedia-based thermodynamic learning can improve the ability of creative thinking in flexibility indicator. The elaboration indicator score was a moderate increase in the experimental group and the low increase in the control group. This shows that interactive multimedia-based thermodynamic learning can improve the ability of creative thinking in elaboration indicator. Normalized gain scores <g> indicator of originality in the experimental group and control group shows a moderate increase in the experimental group and control group. The improvement of the four indicators of creative thinking can not be separated from the learning process with ITMM that has been done experimental group. By using the learning of ITMM the lecturer's dominance is reduced, but his role as a facilitator persists.

Students appear to be increasing fluency ability when students trigger many ideas or hypotheses to solve problems with the help of ITMM. In addition, through the presentation of experimental results of trained students foster fluency skills. The flexibility capability is grown at least in two ways through ITMM and when asking divergent questions to solve problems collaboratively. For example, in thermocouple

experiments, students ask the question such as: How the sensitivity of various metal wires as temperature sensors? How big is the seebeck coefficient generated by the junction between the wires for different types of thermocouples ? Elaboration skills are grown when students conduct experiments, collect and analyze data. For example, it presents data in the form of tables, graphs, and mathematical equations. Originality skills are grown as students plan experiments and create unusual combinations. For example, setting up and assembling tools virtually. The results of the interactive thermodynamics multimedia-based learning and the indicators of creative thinking abilities are presented in Table 3.

Table 3 shows that the improvement of creative thinking ability in each indicator between the experimental group and the control group are significantly different. Normalized gain scores <g> of experimental group and control group are in moderate category. The results of difference test of two averages at $\alpha = 0.05$ shows a significant difference of improvement of creative thinking skills between experiment group and control group. Effect size (d) of each indicator of creative thinking skills are in very high category. This shows that the learning of thermodynamics using interactive multimedia is quite effective in improving the creative thinking skills of prospective physics teacher rather than learning without interactive multimedia thermodynamics in regular learning.

The result of data analysis showed that the normalized gain score <g> on the flexibility indicator in the experimental group was higher than the control group, whereas the lowest normalized gain score <g> is in the originality indicator both in the experimental group and the control group. Overall improvement in creative thinking skills has not been satisfactory. Creating interactive multimedia that can lead to the

Table 3. Normalized gain scores <g> each indicator of creative thinking skills in the experimental and control groups

Creative Thinking Indicators	Normality Test		Test of Average of Differences (Z and t)		Significances	d
	Experimental	Control				
Fluency	Not Normal (Sig. 0.012)	Normal (Sig. 0.200)	Z = -4.073	Sig. 0.000	Significantly different	1.05
Flexibility	Not Normal (Sig. 0.000)	Not Normal (Sig. 0.000)	Z = -4.775	Sig. 0.000	Significantly different	1.40
Elaboration	Normal (Sig. 0.170)	Normal (Sig. 0.200)	t = 10.148	Sig. 0.000	Significantly different	0.95
Originality	Normal (Sig. 0.200)	Normal (Sig. 0.200)	t = 4.539	Sig. 0.000	Significantly different	1.05

Normality Test = Kolmogorov-Smirnov Test (normal, sig.>0.05), $p < 0,05$.

improvement of creative thinking skills of prospective physics teachers is not an easy thing. Therefore, a more rigorous and comprehensive analysis of the appropriateness between each indicator of the creative thinking skill developed with the characteristics of the material, animation, simulation, and the virtual laboratory used, the learning activities performed, and the instruments used for further improvement the creative thinking ability of physics teacher candidate students should be done.

All the indicators of creative thinking skills in the experimental and control groups experienced an increase in moderate and significantly different categories (Table 3). This shows that the learning of thermodynamics using interactive multimedia is quite effective in improving the creative thinking ability of prospective physics teacher compared with learning without interactive multimedia. These results reinforce some previous research results related to the use of information and communication technology in learning. According to Wheeler, et al. (2002), the use of ICT in learning can improve students' creative thinking ability. Similar disclosed Laisema and Wannapiroon (2014) that the use of information technology in learning is effectively support the development of creative thinking skills of the students.

Faizin (2009) has stated that interactive multimedia learning model can be used in physics teaching and learning as: (1) Virtual laboratory through modeling and presentation of phenomena and processes. (2) An expressive learning space for students to demonstrate their ideas, predict, lower the laws of physics and solve problems. The simulation of concepts and phenomena of physics through interactive multimedia simulation will be effective in teaching the students because: (1) Supporting

a strong learning space in studying the physical symptoms, (2) Easy to use and flexible, and (3) Easily accessible in the computer environment. Ivers, et al. (2002) revealed that multimedia can encourage students to learn in groups, convey their knowledge in different ways, solve problems, revise their work, and build knowledge. Computer simulations can encourage students to investigate, ask questions, make predictions, hypothesize (Tawil, 2011), observe, and interpret results (Kulkarni & Tambade, 2013), developing high-level thinking skills of students (Reshaw & Taylor, 2000). Furthermore, computer simulations can facilitate students in formulating and testing hypotheses and as a vehicle to match their ideas to what they observe in simulations (Zacharia, 2003).

The high normalized gain score <g> in the experimental group was not separated from the learning activities they experienced. In the experimental group, students have the opportunity to directly teach themselves thoroughly, construct their understanding, and train their creative thinking skills. Each material is equipped with animation, simulation, and virtual labs. Through the virtual laboratory activities students are trained to develop their creative thinking skills, such as fluency indicators, where students always think of various answers or solutions to the hypotheses that have been formulated. The flexibility indicator, reflected in the student's ability to build a systematic relationship and inductive reasoning to make conclusions. The elaboration indicators showed by the students' ability to add or itemize the object becomes more interesting through measuring, collecting, managing, and analyzing experimental data. Indicator of originality, observed from the students skills in designing experimental activities to be performed. In the

control group the students receive only a single amount of informations; they lack the opportunity to develop their creative thinking skills.

CONCLUSION

Based on the results of the research, it can be concluded that (1) interactive multimedia thermodynamics which developed in Thermodynamics learning can improve the creative thinking skill of prospective physics teacher; (2) the highest improvement of creative thinking skills occurs in the flexibility indicator and the lowest in the indicators of originality; (3) learning by using interactive multimedia thermodynamics is quite effective in improving the creative thinking skills of prospective physics teacher rather than regular learning, without interactive multimedia thermodynamics.

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