Thermodynamics interactive multimedia to improve physics prospective teacher’s generic science skills

A Hakim*, L Liliasari², A Setiawan² and M Amir³

1 Program Studi Pendidikan Fisika, Universitas Mulawarman, Jl. Muara Pahu, Samarinda 75119, Indonesia
2 Sekolah Pasca Sarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
3 Program Studi Pendidikan Kimia, Universitas Mulawarman, Jl. Muara Pahu, Samarinda 75119, Indonesia

*abdul.hakim@fkip.unmul.ac.id

Abstract. This study aimed to determine the increase of generic science skills (GSS) as result of the implementation of the interactive multimedia thermodynamics. Research method used a quasi experiment with control group pretest-posttest design. The research subject was 34 students as experimental group and 33 students as control group of physics prospective teachers of the fourth semester, in one of the state university in East Kalimantan. The research instrument used multiple choice test embedded GSS. Data analyzed with the differences of two averages. The result showed that after the implementation of interactive multimedia increased of GSS of physics prospective teachers quite effectively. The highest of normalized gain of GSS indicator of mathematical modeling (0.67), and the lowest for causality (0.53). These results indicated that the interactive multimedia increase the GSS of physics prospective teachers.

1. Introduction

Physics is a part of science that always attempts to investigate natural facts through either direct or indirect observation. The application of the fields such as information and communication technology, medicine, genetic engineering, marine, and agriculture cannot be separated from physics. Various countries, including Indonesia, make physics as a compulsory subject for their citizens in the curricula of their primary level up to higher education.

One of the reasons to teach physics at the university level is to give birth to physicist in addition, physics is considered to be able to grow a number of generic skills beneficial for the future career in various occupations with a broader scope. Generic skills are basic skills which are general in nature and can be transferred across different jobs [1]. Generic skills are employability skills used to apply knowledge [2]. In the context of science learning the generic skills that can be developed, specifically in learning are generic science skills (GSS). They are necessary to pursue careers in the field of physics or other fields [3]. Liliasari stated that GSS are thinking and action skills based on the science knowledge of individual obtained through learning science [4]. Generic skills are very useful for an individual in continuing his or her education and for the success of his/her career [5]. Based on several arguments above, it is clear that GSS are skills to pursue careers in various fields of work. Therefore,
teaching and learning should be designed to give opportunities to students to sharpen and develop their generic skills.

Thermodynamics is a part of physics can be made a medium to develop GSS. However, the problem lies in the non-mathematical matter or concepts of thermodynamics, such as the large number of formulas, abstract concepts that it is based on principles, states processes, and cycles. These aspects affect to students’ ability in understanding the materials. Sometimes these cause frustration in building their mental model, trigger boredom, and eventually negatively impact their learning outcomes. A number of research results in relation to the difficulties experienced by students in understanding thermodynamic concepts are, among others, as follows. Lewis, Stern, & Linn reported that students were not able to integrate thermodynamics concepts into complex phenomena [6]. Huang and Gramoll found that students experienced difficulties in visualizing abstract concepts [7]. Students also had difficulties in applying P-V diagram to solve problems [8]. In addition, Christensen, Meltzer, & Ogilvie [9] discovered that students misinterpreted the laws of ideal gases. Hence, efforts of improving the teaching and learning process should be made by actively involving students in building their knowledge and understanding. It used information technology as instructional media in the form of thermodynamics interactive media (TIMM). In this case students GSS can be developed.

Various pieces of research pertaining to the use of interactive multimedia in teaching and learning, show that interactive multimedia is considered to be beneficial in facilitating improvement in college students’ concept mastery and GSS. Integration of computer animation into teaching and learning was proven to be effective in helping students increase their understanding of various physics concepts [10]. Interactive multimedia can visualize and simplify the abstract concepts of thermodynamics, such as enthalpy and entropy. Liu reported that abstract concepts such as laws of gases are more easily understood when taught using multimedia [11]. Junglas revealed that the use of interactive simulation would improve students’ mental model [12]. On the same note, McKagan et al. said that interactive software assisted students in understanding abstract concepts in the concept of quantum mechanics [13]. Doyan and Sukmantara reported that teaching and learning with intranet web was effective to improve the mastery of concepts of work, energy, and power [14].

The research results of Siswanto, Saefan, Suparmi, & Cari also demonstrated that the use of e-Lab was effective in improving physics conceptual understanding [15]. The use of computer aided instruction of for physics provides wide-range of alternatives to students such as visualization of abstract concept, graphical representation through animation and simulation [8]. Furthermore, the advantage of interactive media lies in the opportunities given to students to study the materials anytime, give responses quickly, get accustomed to think creatively, and it encourages their curiosity to investigate. Podolefsky, Perkins, & Adam argued that teaching and learning using simulations could develop students’ ability in conducting investigation, making relationship between representations, and making analogies to understand scientific ideas [16].

2. Method
The TIMM was implemented in the course of thermodynamics in a state institute of teacher training and education in East Kalimantan with a quasi-experimental method and the control group pretest-posttest design [17], consisting of the experimental group (n=34) and control group (n=33). The experimental group was taught with the TIMM, and the control group was given instruction with power point media. The instrument was a test on GSS integrated with thermodynamics in 40 multiple choice questions. The results of qualitative analysis of item validity by three experts showed that the items on science generic skills in the context of thermodynamics were valid, and the quantitative validity analysis (product moment) indicated a significant result (valid). The score of items’ reliability, tested using the criteria of Cronbach’s alpha, was 0.79. This score indicated that the items of GSS had high internal consistency. Data of the normalized gain of two groups were tested using mean difference (t-test or Mann-Whitney U-test).
3. Result and Discussion

There are four indicators of GSS developed in the implementation test, namely mathematical modeling, logical self-consistency, causality, and symbolic language. To determine the success of thermodynamics teaching and learning based on interactive multimedia on students’ GSS, the normalized gains of the experimental and control classes were analyzed. The mean of pretest, posttest scores and normalized gains for each indicator of GSS of the experimental class and control class are presented in Table 1.

Table 1. The mean pretest, posttest scores and normalized gains <g> for each indicator of GSS of the experimental class and control class.

| Indicators of GSS         | Experimental Class | Control Class |
|---------------------------|--------------------|---------------|
|                           | Pretest | Posttest | <g>% | Pretest | Posttest | <g>% |
| Mathematical Modeling     | 37.87   | 79.78   | 67   | 36.74   | 60.98   | 38   |
| Logical Self-Consistency  | 37.74   | 76.60   | 62   | 41.44   | 62.71   | 36   |
| Causality                 | 35.64   | 72.07   | 53   | 29.18   | 45.97   | 23   |
| Symbolic Language         | 34.96   | 73.85   | 56   | 34.79   | 52.40   | 27   |

The normalized gain for the indicator of mathematical modeling in both experimental class and control class showed medium improvement (Table 1). The score indicates that the teaching and learning of thermodynamics based on interactive multimedia could improve the skill of mathematical modelling. For the indicator of logical self-consistency, there was medium improvement in both the experimental and control classes. This shows that the teaching and learning of thermodynamics based on interactive multimedia could improve logical self-consistency skill. For the indicator of causality, medium improvement was also observed in both the experimental and control classes. This proves that the teaching and learning of thermodynamics based on interactive multimedia could improve causality skill.

Finally, medium improvement was observed in the indicator of symbolic language for the experimental class and low improvement for the control class. This indicates that the teaching and learning of thermodynamics based on interactive multimedia could improve symbolic language skill.

The mean difference of the normalized gains show differences in the level of difficulties experienced by the physics in understanding each of the thermodynamics concepts. The results of analysis (sig. > 0.05, p < 0.05) of the effects of the teaching and learning of thermodynamics based on interactive multimedia on the indicators of GSS are presented in Table 2.

Table 2. Normalized gain for each indicator of GSS in the experimental and control classes.

| Indicators of GSS         | Normality Test | Mean Difference Tests |
|---------------------------|----------------|-----------------------|
|                           | Experimental  | Control               | (Z and t) Sig. | d    |
| Mathematical Modelling    | 0.182          | 0.200                 | 6.166          | 0.000 | 1.61 |
| Logical Self-Consistency  | 0.200          | 0.180                 | 5.012          | 0.000 | 1.19 |
| Causality                 | 0.200          | 0.003                 | -4.026         | 0.000 | 1.15 |
| Symbolic Language         | 0.162          | 0.182                 | 5.835          | 0.000 | 1.19 |

Table 2 shows that the improvement in each indicator of GSS for the experimental class and control class was significantly different. The normalized gains of mathematical modelling for the experimental class and control class were normally distributed. The normalized gains were then analyzed parametrically using independent sample t-test. The results of analysis of t-test indicate that the average normalized gains of mathematical modelling for the two classes differed significantly with an effect size (d = 1.61) categorized as high. This finding means that the teaching and learning of thermodynamics with interactive multimedia could significantly improve the GSS for the indicator of mathematical modelling.

The normalized gains of logical self-consistency for the experimental class and control class were normally distributed. The normalized gains were then analyzed parametrically using independent
sample t-test. The results of analysis of t-test demonstrate that the normalized gains of both classes were significantly different, with an effect size \( (d=1.19) \) at the high category. The results demonstrate that the teaching and learning of thermodynamics with interactive multimedia could significantly improve the GSS for the indicator of logical self-consistency.

The normalized gains of causality for the experimental class and control class were not normally distributed. The normalized gains were then analyzed non-parametrically using Mann-Whitney (independent sample test). The results of analysis demonstrate that the normalized gain scores of the indicator of causality for both classes were significantly different, with an effect size \( (d=1.15) \) at the high category. The result demonstrates that the teaching and learning of thermodynamics with interactive multimedia could significantly improve the GSS for the indicator of causality.

The normalized gains of symbolic language for the experimental class and control class were normally distributed. The normalized gains were then analyzed parametrically using independent sample t-test. The results of analysis of t-test indicate that the normalized gains of symbolic language in both classes were significantly different, with an effect size \( (d=1.19) \) at the high category. The results demonstrate that the teaching and learning of thermodynamics with interactive multimedia could significantly improve the GSS for the indicator of symbolic language.

Results of data analysis show that the increased average normalized gain of the GSS of the experimental class was greater than that of the control class. The improvement in the four indicators of GSS is inseparable from the role of the TIMM used in the experimental group.

The students sharpened their symbolic language skill through the symbols of physics dimensions contained in the menus of materials and animations; for example, the symbol of P for pressure, V for volume, and T for temperature. In addition, through virtual laboratory activities, the students were trained to use symbolic language, such as using symbols to identify various variables. With these various activities, the students were trained to use symbolic language; hence, the symbolic language skill of the experimental class was greater than that of the control class.

The skills of logical framework, causality, and mathematical modelling were through animations and virtual experiments. Various animations and simulations presented systematically trained students to use logics, causality, and mathematical modelling; for example, the addition of heat to a system and the changes occurring to the system. In addition, the efforts of improving mathematical modelling skill require a series of systematic exploratory activities. The inquiry approach in the activity of virtual experiment in the interactive multimedia helped students do exploratory activities systematically. This claim is in line with the argument of Lowe that dynamic multimedia can facilitate students to think systematically in accordance with the order of events based on the regularity of phenomena or symptoms, make students understand why something happens and what effects take place. The development of symbolic language and logical self-consistency skills also affects the skills of causality and mathematical modelling [17]. Kulkarni &Tambade stated that teaching and learning aided by computer with animations and simulations in the classroom gives an alternative to students to understanding various alternatives of concepts through visualization of abstract concepts and graphic representation [8].

4. Conclusion

Based on the results of research, the application TIMM on the learning to improve the GSS, it can be conclusion as the results show that the teaching and learning with TIMM was effective with a high criterion in improving the physics prospective teachers’ GSS. The highest of normalized gain of GSS indicator of mathematical modelling (0.67), and the lowest for causality (0.53). The developed TIMM has positive implications for the improvement of the GSS of the physics prospective teachers

Acknowledgments

The researcher would like to thank to funded by the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia.
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