Model of Students' Understanding on Thermodynamic Concepts in Learning with Virtual Labs

Gunawan, Ahmad Harjono, Hairunisyah Sahidu and Ni Made Yeni Suranti
Departmen of Physics Education, Universitas Mataram, Jln. Majapahit No 62 Mataram 83125, Indonesia
gunawan@unram.ac.id , harjonofkip@unram.ac.id , hairunisyahsahidu@gmail.com , surantiyeni@gmail.com

Lovy Herayanti
Physics Education Study Program, IKIP Mataram, Jln. Pemuda No 59A Mataram 83125, Indonesia
lovyherayanti@ikipmataram.ac.id

Abdul Talib Bon
Department of Production and Operations, University Tun Hussein Onn Malaysia, Malaysia
talibon@gmail.com

Abstract
Virtual experiments have been developed on the concept of thermodynamics. This study was intended to analyze the level of understanding of students' thermodynamic concepts after learning with virtual labs. Model testing used the pretest-posttest control group design. The research subjects were fifty-four students divided into two groups, experimental and control groups. An essay test was given to test the level of conceptual understanding of students. Data was processed to examine differences in improvement in both groups. The results showed an increase in mastery of students' thermodynamic concepts in both groups. The increase in mastery of the thermodynamic concept in the experimental group was higher than the control group. However, statistical analysis showed that the differences between the two groups were not significantly different. The concept of temperature and expansion is the concept with the highest increase.

Keywords
Thermodynamic Concepts, Thermodynamic Learning, Virtual Labs, Virtual Experiments, Experimental Group

1. Introduction
Experimental activity is an essential component of physics learning. Through experiment, students can develop their thinking skills and creativity. Many skills can be developed through the activities of physics experiment. Students can practice observing, measuring, assembling tools, communicating, and teaming up to solve problems. Physical experimental activities are also important for training students' process skills. Sinaradi (1998) stated that students need to be trained to acquire various skills such as observing, measuring, classifying, interpreting data, experimenting, and communicating, which can be adjusted to the material being studied and the level of thinking of students. One of the factors that influence the success of physics experiment is the availability of resources that includes materials and equipment, space and furniture, laboratory staff, and technicians. Sufficient resources will support the implementation of experimental activities, on the contrary, the limitations of tools and materials are the reasons for educators not to conduct experimental activity. Thermodynamics is a part of physics, which consists of several abstract concepts. This leads to low of students' mastery of physics concepts. In its study, physics has several principles, laws, and abstract theoretical concepts that need to be proved through a series of experiments. Some of the materials in physics, the proof of principle and law cannotbe done with ordinary experiments that require simple materials. It requires some equipment with sophisticated technology. This then led to the emergence of innovations in physics learning, such as the use of virtual labs in the form of computer simulations. The development of virtual labs presents innovations in learning and physics experiment. Physical experiment using computer technology is called virtual labs. Finkelstein (2005) stated that the computercould be used to support the physics teaching in collecting, presenting, and processing

data. The computer can also be used to modify experiment and display complete experiment in virtual form. As stated earlier, that experiments could affect creativity and high order thinking skills, this also applies to virtual laboratory applications. Research by Adawiyah et al. (2019) and Gunawan et al.(2018) shows that students' creative thinking skills increase after the application of virtual laboratories. Better creativity will support better understanding of concepts. This is mainly because students will find aneasier method in the process of understanding physics concepts. If their creative thinking skills are better then they will easily find a way in understanding the concept.One of the high-level thinking skills is critical thinking skills, which are very influential in the process of understanding physics concepts. Students who have good critical thinking skills will be easier to avoid understanding the wrong concept. Understanding the wrong concept is very much avoided in physics learning. Apparently, the application of virtual labs also supports developing critical thinking skills, as evidenced by the research of Mashami & Gunawan (2018) which concluded that virtual labs were able to provide a positive influence in improving critical thinking skills. The application of virtual labs has been proven to elevate several factors that support the process of understanding better physics concepts, such as creativity and critical thinking skills. It can be understood that the application of virtual labs has enormous potential to deliver students to a far better comprehension of physics concepts. However, the problem that arises is whether all that applies to all physics concepts. As in the thermodynamic concept which has so many complex and abstract concepts that attract the attention of many researchers.The application of virtual experiment in physics teaching is believed can easily help students understand abstract physics concepts that can not be explained by simple experiments. Virtual laboratory generally contains a virtual simulation that fits the learning purposes. In the context of education, computer simulation can help instructors simplify complex system operation and output methods, and help students to present simulation results that match their cognitive ability levels (Sun et al. 2013).Actual simulations with student learning environments can be developed through comprehensive virtual experiments. Computer simulations must enable teachers to adjust to the curriculum, and allow students to identify problems, plan, and apply their ideas (Shyr 2010). According to Wolf (2010), a virtual laboratory has been proposed for savings and ease in maintaining laboratory facilities.Nance et al.(2009) suggested that a virtual research environment helps saving resources and financial investment. Tetouret al.(2011) revealed other advantages besides the cost efficiency of the implementation of virtual experiments areaccurate measurement and the simplification of observation. Chenet al.(2013)revealed that a visualizedcomputerize learning environment can help students improve their misconception related to abstract physics concept.Amendola & Miceli (2016) revealed that the virtual lab media provided a new tool for learning the laws and experimental science phenomena. Virtual experiments allow students to observe phenomena by collecting, extracting, and interpreting experimental data. The aim is to train students to understand how real physics experiments are carried out. Students' understanding of thermodynamic concepts needs to be improved, one of which is through the development of computer simulations as virtual labs of thermodynamic concepts. The purpose of this study was to examine the effectiveness of using virtual labs to improve students' comprehension of thermodynamic concepts.

2. Methodology

This study has successfully developed a model of virtual labs for learning the concept of thermodynamics. Development of the model begins with initial analysis and draft design. The expert further validated the draft model. Testing the effectiveness of virtual labs model on improving student concept mastery using experimental method with pretest-posttest control group design. Instruments used in the form of mastery test of thermodynamic concepts. The subjects of this study were students who follow fundamental physics courses that were divided into two groups (the experimental group and the control group). The improvement of students' mastery of concepts could be known from the magnitude of a normalized gain (N-gain). This is intended to avoid mistakes in interpreting the improvement of the score of each student. The average of N-gain score is categorized into three category, namely low ($g<0.3$), medium ($0.3 \leq g \leq 0.7$) and high ($g > 0.7$) The analysis of research data began with statistical test in the form of normality test and homogeneity test. Furthermore, hypothesis testing was done to examine the level of significance of differences in mastery of thermodynamic concepts in both classes.

3. Results and Discussion

This research has successfully developed several virtual experiments for learning the concept of thermodynamics. The developed virtual experiments have been validated by experts on aspects of physics content, learning, and the technology used. This article discussed the results of empirical testing that has been implemented. In learning the concept of thermodynamics in both classes, related data were obtained from the initial test, final test, and N-gain. The following describes the measurement results after the learning of thermodynamic concepts. Before testing the hypothesis, the normality and homogeneity test on the mastery of thermodynamic concepts was firstly done in both classes. Table 1 shows the results of normality tests that have been done on the mastery of the concept of thermodynamic data.

Table 1. Normality Test of Conceptual Understanding of Thermodynamics in Both classes

Kolmogorov-Smirnov test	Value of Sig.	Interpretation
Experimental Class		
Pre-test	.200(*)	Normally Distributed
Post-test	.126	
N-gain	.200(*)	
Control Class		
Pre-test	.200(*)	Normally Distributed
Post-test	.200(*)	
N-gain	.042	*Non*-Normally Distributed

Table 1 shows that there were normally distributed data except the N-gain value which was not normally distributed. This implied the type of statistical test used. Meanwhile, the homogeneity test results showed that the test data in both classes came from a homogeneous population.After the prerequisite test data analysis, the hypothesis testing then being performed. The result of normality test indicated that there was distribution of data that was not normally distributed. The solution of the non-normally distributed data, in this case, is using Mann-Whitney test. The tests were performed on thermodynamic concept mastery data covering pre-test, post-test, and N-gain tests. Table 2 shows the results of the hypothesis test data mastery of the concept.

Table 2. Hypothesis Test Results

Mann-Whitney Test	Pre-test	Post-test	N-gain
Value of Sig.	.882	.159	.075
Interpretation	There is no difference between the two sample groups		

Table 2 shows that there was no statistically significant difference in the mastery of concepts in both classes before and after treatment. However, the improvement of mastery of the thermodynamic concept in the experimental group was higher than the control group.

Besides described in general, this study also analyzed each sub thermodynamic concepts namely the concept of temperature and expansion, the law on the ideal gas, gas kinetic theory, thermal energy transfer, and thermodynamic law. Improvement in each sub concept was analyzed to determine the level of understanding of students. Data shows that understanding thermodynamic concepts in both classes has increased after treatment. Comparison of the increase in mastery of concepts in both classes in each sub-concept can be seen in Figure 1.

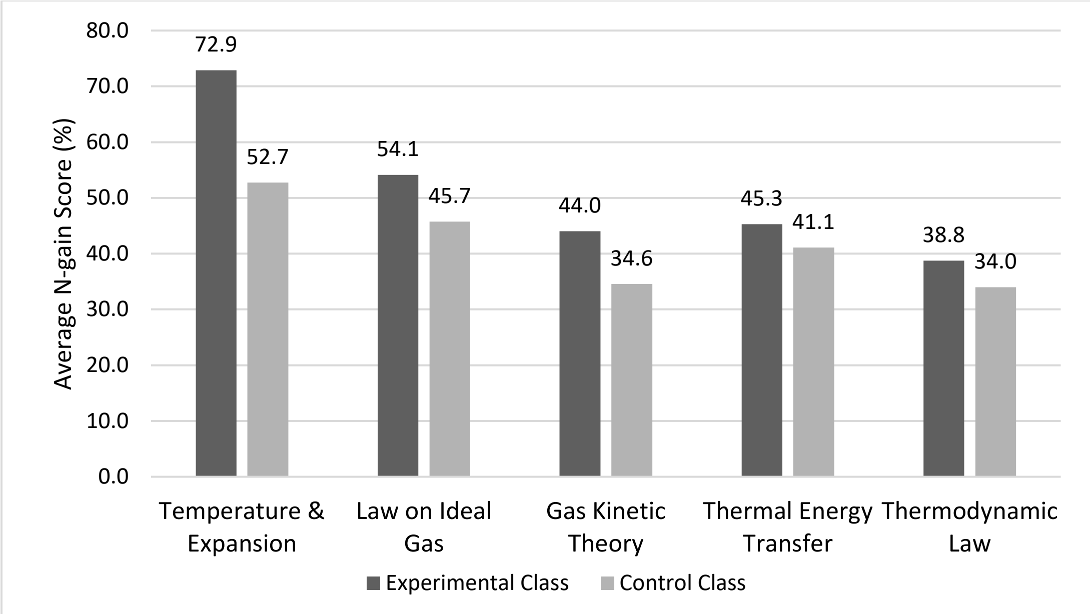

Figure 1. Comparison of N-gain Score on Thermodynamic Concepts in Both Classes

Figure 1 shows that the improvement in the experimental group was higher than the control group in all sub-concepts. The highest increase occurred in the concept of temperature and expansion. It was also the concept with the largest difference increase compared to other sub-concepts. This was understandable because the concept was much studied in high school, making it easier for most of the students. It also proved the effectiveness of developed interactive simulations in helping students recall the material of the previous study. The results of this study are supported by the results of research conducted by Zacharias & Constantinou (2008).The studywas conducted by comparing the results of direct and virtual treatment in physics experiments, especially on temperature and heat materials. The research found that the virtual experimental model was also succeeded in increasing students' comprehension of the concepts of temperature and heat.Other research also revealed similar results. Gunawan et al. (2018) and Hermansyah et al. (2019) revealed that the application of virtual labs in physics learning could improve student conceptual understanding significantly. The learning process using this virtual laboratory helps students work independently by exploring features freely based on the worksheet provided.Users can change a variable and directly see the effect on other variables. Features and menus provided in virtual labs give participants the freedom to use their imagination. Students were allowed to make plans and stages that they find easier to understand a concept. This virtual laboratory was provided with student worksheet that contains some open questions which encourage students' respond to possible answers to a problem. Computer simulation is one of the essential tools for understanding thermodynamics and statistical mechanics. The results of Tsai & Landau (2004) showed that the use of computer simulations proved to be more efficient in calculating the values of physical variables, including in larger systems, with more accurate results. The use of simulations was quite successful because it is more efficient and accurate. A new approach to the simulation was obtained by modifying some estimates and circumstances at each phase of the physical process. There are some difficulties commonly encountered by students in learning thermodynamics concepts such as interpret the graph, equations, and physical process, understanding the concept of thermodynamics and its application in everyday life. There is an assumption that thermodynamic concepts seem to separate from real life. The conventional learning that only emphasizes the aspect of common mathematical equations done by lecturers makes students difficult to understand the concept of thermodynamics. Students are assisted in learning abstract thermodynamic concepts. Students' difficulties in aspects of graphics can be overcome by appropriate visualization, for example visualization of isochoric, isobaric, isothermic, and adiabatic processes.Experiments in the form of interactive simulations in this model provide learning opportunities for students to make estimates and prove the truth of their expectations independently.This is following the results of research conducted by McIntyre et al.(2008), which stated that computer couldbe used for visualization, animation, calculation, reasoning in order to help students learn physics. Analysis of content and pedagogy were easier to do, thus the resulting curriculum as what is expected. The virtual laboratory for some students was also considered as a fun game. They can try and learn to make predictions that are further proved by themselves. In short, this helps to reduce the difficulty and tension in physics learning that is generally felt by some students while studying physics. Nevertheless, learning on this concept still needs to be optimized since there were still many students who have not to reach maximal achievement in both experiment and control class. The results of the statistical analysis also showed that there was no significant difference between the students' comprehension of the concept in both classes. It was also influenced by the type of problem used in this concept, which was quite a lot of matter in the form of a mathematical problem. In the case of a mathematical calculation, the ability of the two classes is not significantly different. In contrast to procedural and conceptual issues, the students' mastery of the experimental class was higher than the control class. It means learning that has been done with virtual labs gave students a better understanding of the concepts and related procedures. Finkelstein (2005), found that conceptual mastery can be improved through the use of computer simulations. Computer technology can also help the process of gathering data analysis, experimental modification,and presentation in virtual form. McKagan et al. (2008) found that students' mental intuitions and models can be improved with the help of visualization of concepts, abstract processes, and microscopic processes that can not be observed. Zacharia (2003) stated that students' positive attitudes toward physics also increased after learning by using simulations. Interactive simulation helps students to visualize the problem and follow up the solution. The use of a virtual lab is effective in improving students' generic science skills, especially on logical inference indicators and concept-building capabilities (Gunawan et al. 2013). Finkelstein et al. (2005)argue that the application of computer simulation on direct current electric circuit learning could help students master concepts, complete tasks, assemble real circuit, and explain how it works. The recent researches have emphasized that the use of the simulations bea benefit in the teaching process of Science concepts (Gorghiu et al. 2009). Donnelly et al. (2013) have found that the implementation of virtual chemistry laboratory could overcome the difficulties of discovery learning that teachers typically encounter in working in the laboratory. Virtual laboratories can be used as a risk-free environment for education and training. Virtual laboratory utilization is proven to help achieve the stated goals (Noor & Wasfy 2008). Theory and practice can be combined through the use of virtual laboratories. Students are able to improve problem solving skills (Gunawan et al. 2017) as well as their creativity in learning (Gunawan et al 2017). This pattern enables the development of interactive experiments, sharing experiments, data management, semantic integration, and support for web-based graphical user interfaces (Ciepela et al. 2010).In their study, Zacharia & Constantinou (2008) compared the effects of experiments performed physically and virtually. Gunawan et al. (2018) stated that virtual simulations help students to be creative, especially for aspects of elaboration and fluency. The results show that the experimental mode is equally effective in increasing students' understanding of the concepts of temperature and heat.

4. Conclusion

This research has successfully developed several virtual experiments to improve students' mastery of thermodynamic concepts. The implementation of virtual laboratory was proven to make it easier for students to understand the concept of thermodynamics better than the control group who study conventionally. Improved mastery of the concept of experimental group was higher than the control group on all sub-concepts of thermodynamics. The concept of temperature and expansion is a sub-concept with the highest increase, which is equal to 72.9% in the high category.Although there was a substantial increase, the differences in mastery of the thermodynamic concepts in the two groups did not differ significantly.

Acknowledgments

Special thanks to the Directorate of Research and Community ServiceMinistry of Research, Technology and Higher Education who has funded this research from 2015 to 2017.

References

Adawiyah, R., Harjono, A., Gunawan, G., and Hermansyah, H., Interactive e-book of physics to increase students' creative thinking skills on rotational dynamics concept. In *Journal of Physics: Conference Series IOP Publishing,* vol. 1153, no. 1, pp. 012-117, 2019

Amendola, D.,andMiceli.C., Online Physics Laboratory for University Courses, Journal of e-Learning and Knowledge Society, vol.12, no. 3, pp. 75-85,2016

Chen, Y. L.,Pan, P.R., SungY. T., andChang.K. E.,Correcting Misconceptions on Electronics: Effects of A Simulation-Based Learning Environment Backed by A Conceptual Change Model,Journal of Educational Technology & Society,vol. 16, no. 2, pp. 212-227, 2013

Cheng,K. K.,Thacker, B. A., Cardenas, R. L.,Crouch, C., Cheng, K. K., Thacker, A., and Cardenas, R. L. Using An Online Homework System Enhances Students' Learning of Physics Concepts in An Introductory Physics Course, American Journal of Physics,vol. 72, no. 11, pp. 1447,2004.

Ciepiela, E.,Harężlak,D., Kocot,J., Bartyński,T., Kasztelnik,M., Nowakowski, P., and Bubak,M.,"Exploratory Programming in The Virtual Laboratory", in *Proceedings of the International Multiconference on Computer Science and Information Technology, IMCSIT 2010*, vol. *5*, pp. 621–628, 2010

Donnelly, D.,O'Reilly, J., and McGarr, O.,Enhancing the Student Experiment Experience: Visible Scientific Inquiry Through a Virtual Chemistry Laboratory, Research in Science Education, vol.43, no. 4, pp. 1571–1592, 2013

Finkelstein, N. D., Adams, W. K., Keller, C. J., Kohl, P.B.,Perkins,K. K., Podolefsky,N. S., andR. Lemaster.R.,When Learning About The Real World Is Better Done Virtually: A Study of Substituting Computer Simulations for Laboratory Equipment. Physical Review SpecialTopics-Physics Education Research, vol.1, no 4, pp.1–8, 2005

Gorghiu, L. M., Gorghiu,G., Alexandrescu, T.,andBorcea, L., Exploring Chemistry Using Virtual Instrumentation-Challenges and Successes. Research, Reflections and Innovations in Integrating ICT in Education1, pp. 371–375, 2009

Gunawan, G., Harjono, A., Sahidu, H., and Nisrina,N., Improving Students' Creativity Using Cooperative Learning With Virtual Media on Static Fluid Concept. *In Journal of Physics: Conference Series*, vol.1006, no. 1, pp. 012-016, 2018

Gunawan, G., Harjono, A., Sahidu,., H and Herayanti, L, Virtual Laboratory to Improve Students' Problem-Solving Skills on Electricity Concept, *Jurnal Pendidikan IPA Indonesia,*vol. 6, no. 2, pp. 257-264, 2017

Gunawan, G., Nisrina, N., Suranti, N. M. Y., Herayanti, L., and Rahmatiah, R., Virtual Laboratory to Improve Students' Conceptual Understanding in Physics Learning. In *Journal of Physics: Conference Series* IOP Publishing, vol. 1108, no. 1, pp. 012-049, 2018

Gunawan, G., Setiawan, A., andWidyantoro, D. H., Model Virtual Laboratory Fisika Modern untuk Meningkatkan Keterampilan Generik Sains Calon Guru,Jurnal Pendidikan dan Pembelajaran, vol.20, no. 1, pp. 25–32, 2013

Gunawan, G., Suranti, N. M. Y., Nisrina, N., Herayanti, L., and Rahmatiah, R., The effect of virtual lab and gender toward students' creativity of physics in senior high school. In *Journal of Physics: Conference Series* IOP Publishing, vol. 1108, no. 1, pp. 012-043, 2018

Gunawan,G., Sahid.u, H, Harjono, A.,and Suranti, N. M. Y., The Effect of Project Based Learning with Virtual Media Assistance on Student's Creativity Physics, *Cakrawala Pendidikan,* vol.36, no. 2,pp. 167-179, 2017

Hermansyah, H., Gunawan, G., Harjono, A., and Adawiyah, R., Guided inquiry model with virtual labs to improve students' understanding on heat concept. In *Journal of Physics: Conference Series* IOP Publishing, vol. 1153, no. 1, pp. 012-116, 2019.

Mashami, R. A., and Gunawan, G., The Influence of Sub-Microscopic Media Animation on Students' Critical Thinking Skills Based on Gender. In *Journal of Physics: Conference Series* IOP Publishing, vol. 1108, no. 1, pp. 012-106, 2018

McIntyre,D. H., Tate,J.and Manogue, C. A., Integrating Computational Activities into The Upper-Level Paradigms in Physics Curriculum at Oregon State University,American Journal of Physics, vol.76, no, 4, pp. 340-346, 2008

McKagan, S. B.,Perkins,K. K., Dubson,M., Malley,C., Reid, S., LeMaster,R.,andWieman,C. E., Developing and Researching Phet Simulations for Teaching Quantum Mechanics, American Journal of Physics, vol. 76, no. 4, pp. 406-417, 2008

Nance, K., Nance, K.,Hay, B.,Dodge, R.,Seazzu, A., and Burd. S., Virtual Laboratory Environments: Methodologies for Educating Cybersecurity Researchers,Methodological Innovations Online, vol.4, no. 3, pp. 3–14, 2009

Noor,A. K.,andWasfy, T. M., Simulation of Physical Experiments in Immersive Virtual Environments. Engineering Computations,vol. 18, no. 3/4, pp. 515–538, 2008

Shyr. W. J.,Enhancement ofPLC Programming Learning Based on A Virtual Laboratory,World Transactions On Engineering And Technology Education, vol.8 no. 2, pp. 196-202, 2010.

Sinaradi, F., Menguji Kualitas Barang: Suatu Alternatif Model Pengajaran Sains,Dalam Pendidikan Sains yang Humanistis (Kanisius, Yogyakarta, 1998).

Sun, C. T.,Wang,D. Y., andChangY.Y.,Effects of Thinking Style on Design Strategies: Using Bridge Construction Simulation Programs,Journal of Educational Technology & Society, vol. 16 no. 1, pp. 309-320, 2013

Tetour, Y.,Boehringer,D.,andRichter,T., "Integration of Virtual and Remote Experiments into Undergraduate Engineering Courses",in *Global Online Laboratory Consortium Remote Laboratories Workshop (GOLC), 2011 First*, 1-6. IEEE, 2011

Tsai,S. H.and Landau. D. P., Computer Simulations: A Window on The Static and Dynamic Properties of Simple Spin Models,American Journal of Physics, vol.76, no. 4, pp. 445-452, 2004

Wolf. T., Assessing Student Learning in A Virtual Laboratory Environment,IEEE Transactions on Educationvol. 53 no. 2, pp. 216-222, 2010

Zacharia, Z. C. andConstantinou, C. P.,Comparing The Influence of Physical and Virtual Manipulatives in The Context of The Physics by Inquiry Curriculum: The Case of Undergraduate Students' Conceptual Understanding of Heat and Temperature,American Journal of Physics, vol.*76*, no. 425,2008

Zacharia.Z., Beliefs, Attitudes, and Intentions of Science Teachers Regarding The Educational Use of Computer Simulations and Inquiry-Based Experiments in Physics, Journal of Research in Science Teachingvol. 40, no. 8, pp. 792-823, 2003

Biographies

Gunawan is a Senior Lecturer in Physics Education, the Faculty of Teacher Training and Education, Universitas Mataram. He completed his doctoral program in a physics education study program at the Indonesian Education University in January 2011. Currently, he is the Director of the research center for physics and technology education, Universitas Mataram. His research focus in recent years has been in the development of virtual laboratories, interactive multimedia, and learning management systems.

Ahmad Harjono is a Senior Lecturer in Physics Education, the Faculty of Teacher Training and Education, Universitas Mataram. He completed his doctoral program in an educational technology at Malang State University. Currently, he is the Chair of the Physics Education Study Program, University of Mataram. His research focus is on developing learning media, learning styles, advance organizers, and thinking skills.

Hairunnisyah Sahidu is a Associate professor in Physics Education, the Faculty of Teacher Training and Education, Universitas Mataram, Indonesia. She has expertise in learning evaluation and learning device innovation.

Lovy Herayanti is a Lecturer in Physics Education, the Faculty of Mathematic and Science Education, IKIP Mataram, Indonesia. She completed her doctoral program in a science education study program at Surabaya State University in February 2018. Currently, she is actively researching several issues related to information technology applications in science learning.

Ni Made Yeni Suranti is a member of the Science Education Research Center, Universitas Mataram. She is also currently completing a program of study at Universitas Mataram.

Abdul Talib Bon is a professor of Production and Operations Management in the Faculty of Technology Management and Business at the Universiti Tun Hussein Onn Malaysia since 1999. He has a PhD in Computer Science, which he obtained from the Universite de La Rochelle, France in the year 2008. His doctoral thesis was on topic Process Quality Improvement on Beltline Moulding Manufacturing. He studied Business Administration in the Universiti Kebangsaan Malaysia for which he was awarded the MBA in the year 1998. He's bachelor degree and diploma in Mechanical Engineering which his obtained from the Universiti Teknologi Malaysia. He received his postgraduate certificate in Mechatronics and Robotics from Carlisle, United Kingdom in 1997. He had published more 150 International Proceedings and International Journals and 8 books. He is a member of MSORSM, IIF, IEOM, IIE, INFORMS, TAM and MIM.