EFFECTIVENESS OF PHYSICS LEARNING MATERIAL THROUGH GUIDED INQUIRY MODEL TO IMPROVE STUDENT'S PROBLEM SOLVING SKILLS BASED ON MULTIPLE REPRESENTATION

Binar Kurnia Prahani [1)]
Iqbal Limatahu [2)]
Soegimin W. W. [3)]
Leny Yuanita [3)]
Mohamad Nur [3)]
[1)] Sunan Ampel State Islamic University of Surabaya, Surabaya, Indonesia
[2)] Khairun University, Ternate, Indonesia
[3)] State University of Surabaya, Surabaya, Indonesia

Abstract: The purpose of this research was produced the physics learning material through guided inquiry model that effective to improve student's problem solving skills based on multiple representation in senior high school. The development of learning material used the Kemp model and was implemented in class X1, X2, and X3 (93 students) of State Senior High School of 19 Surabaya in academic year 2013/2014 with one group pretest posttest design. The data collection used pretest and posttest. The data analysis techniques used descriptive analysis of statistic inferential, non-parametric. The results of this research are the physics learning material through guided inquiry model effectiveness in terms of improving student's problem solving skills based on multiple representation by getting the n-gain score with high category and the analysis results of statistic non parametric are: 1) nothing different of student's problem solving skills based on multiple representation at each class, 2) different student's problem solving skills based on multiple representation after implementation of physics learning material through guided inquiry model, and 3) nothing different of improving student's problem solving skills based on multiple representation at each class. It's conclusion that the learning material through guided inquiry model are effective to improve student's problem solving skills based on multiple representation in senior high school.

Key words: *Guided inquiry, learning material, multiple representation, problem solving.*

*,[1]) Corresponding author: Binar Kurnia Prahani. Lecturer, Researcher, Sunan Ampel State Islamic University of Surabaya, Jalan Ahmad Yani, Surabaya, Indonesia (60237). Phone: 085749476994
E-mail: binarprahani@gmail.com

[2)] Iqbal Limatahu. Lecturer, Researcher, Khairun University, Ternate, Indonesia, Jalan Pertamina, Ternate, Indonesia (97719). E-mail: ilimatahu@gmail.com

[3)] Soegimin W. W. Professor, Researcher, State University of Surabaya, Jalan Ketintang, Surabaya, Indonesia (60231).

[3)] Leny Yuanita. Professor, Researcher, State University of Surabaya, Jalan Ketintang, Surabaya, Indonesia (60231). E-mail: yuanita@sby.dnet.net.id

[3)] Mohamad Nur. Professor, Researcher, State University of Surabaya, Jalan Ketintang, Surabaya, Indonesia (60231). E-mail: psmsunesa@yahoo.co.id

1. INTRODUCTION

Physics was core of the development of information technology and communication has changed the fundamental operates human life. Student's competences were formed when students engage active on activities of mental, physical, and social. Based on standard competence in Indonesia, physics lesson must be student centered learning-based activities scientific. Students need appreciation of attitude, knowledge, and skills that they can be then adjust against of learning experiences them through multiple representation. Learners will learn more effective and the process is efficient when they are active for the review process the information with multiple

representation (Nieminen, Savinainen, & Viiri, 2013; Mahardika, Agus, & Dadi, 2012; Abdurrahman, Liliasari, Rusli, & Bruce, 2011).

Based on tests the problem solving skills based on multiple representation in State Senior High School of 19 Surabaya on a sample of 32 students of class X are completed correctly the problems of physics sub subject of heat only 12.50%. The results of observations through interviews and questionnaires to students and teachers found some cause has not been done the maximum effort to practice the problem solving skills based on multiple representation in learning physics, namely: (1) The limited time teacher of physics to be able to provide a learning tool in the training of students' ability to multiple representation; (2) Students have difficulty using a multiple representation of physics; and (3) Master's field of study of physics difficulty dealing with students with low ability can be activated and motivated to learn physics. Physics teacher should ideally conceptual understanding of physics and deep, able to perform qualitative and quantitative reasoning, understand and be able to develop multiple representation, and have skills in scientific inquiry, and able to anticipate the conceptual difficulties experienced by students. On learning of physics students need to be trained to develop the problem solving skills based on multiple representation. Multiple representation is one good method and is expanding to cultivate an understanding of concepts, problem solving physics and difficulties due to the many engagement picture (David, Christophe, & Norma, 2013; Nieminen, Savinainen, & Viiri, 2013).

The result of research (Heuvelen & Zou, 2001; Meltzer, 2005, Kohl & Finkelstein, 2008) suggested the shape of a multiple representation physics is the ability to resolve issues in physics with the representation of the various ways mathematically, verbal (written or oral), and visual (notation, images, and graphics). The main function of multiple representation in learning for students, namely: as a complement to cognitive processes, limiting interpretation between representation and builders of understanding (Ainsworth, 2006; 1999). Issues concerning lack of ability to multiple representation of students completing the physical problem can be solved by providing exciting new experiences for students (Putri, Mahardika, & Ketut, 2012). Challenges in the formation of multiple representation capabilities can be achieved by using the inquiry model (Mahardika, Agus, & Dadi, 2012).

Based on the curriculum in Indonesia on the material of heat required to plan and carry out experiments to investigate the thermal characteristics of a material, especially the heat capacity. Students need the ability to perform multiple representation of scientific activities and develop science (Waldrip, Prain, & Carolan, 2010). One of the learning activities in the investigation of the heat learning material is inquiry learning model. Guided inquiry learning model as an alternative needs to be developed to achieve basic competency topic of heat and improve problem solving skills based on multiple representation of students through inquiry and guidance. Learning ability can improve problem solving skills based on multiple representation is an inquiry and guidance. Each step in the inquiry model requires the ability representation when the student is able to use the problem solving skills based on multiple representation maximally expected to make it easier to solve the problems on the material of heat. Learning model of guided inquiry consists of six stages, namely: (a) planning, (b) information, (c) process information, (d) making information, (e) communicate information, and (f) evaluate (Branch & Oberg, 2004). Guided inquiry learning allows students to build knowledge in a multiple representation and help students develop an understanding of concepts.

The ability of mathematical representations and verbal is required in the inquiry, among other things: abstracting from the data analysis to draft the necessary proportionality math’s, solving problems is required count math is right, to understand the definition, during the discussion, make sentences, communicate, interpret, formulate and communicate the conclusions (Maliyah, 2012). The use of guided inquiry model is expected to improve problem solving skills based on multiple

representation, especially in each phase of guided inquiry model. At this stage of communicating information students are required to use all the knowledge represented in the various representations that the results can be presented inquiry process valid. After students conduct an investigation, in evaluating the students were given about the test's ability to view multiple representation of physical mastery of the ability to multiple representation of physics students. The results of the study (Kohl & Finkelstein, 2008; Kohl & Finkelstein, 2007) stating that the student has not been experts still need guiandce when solving problems using multiple representation in building the description of verbal, visual and mathematical activities inquiry.

Students must gain an understanding of the concept and requires a learning activity that can present their concept as a whole with multiple representation (Nieminen, Savinainen, Nurkka, & Viiri, 2011; Cook, 2006). The results of the study (Putri, Mahardika, & Ketut, 2012) concluded through inquiry can overcome the lack of ability to multiple representation of students in solving physics problems. The results of the study (Maliyah, 2012) concluded that guided inquiry learning on material temperature and heat affect the ability of representation and student achievement in high school. The results of the study (Mahardika, Agus, and Dadi, 2012) concluded inquiry model can improve the ability of multiple representation and physics of high school students learning outcomes. The ability to multiple representation of physics have been studied in other countries (Heuvelen & Xueli, 2001; Meltzer; 2005; Kohl & Finkelstein, 2008; Kohl & Finkelstein, 2007; Kohl & Finkelstein, 2006; Kohl & Finkelstein, 2005; Nieminen, Savinainen, & Viiri, 2013; Nieminen, Savinainen, Nurkka, & Viiri, 2011; Waldrip, Prain, & Carolan, 2010; Waldrip, Prain, & Carolan, 2006).

Further research, especially to heat the material at high school students based on the curriculum in Indonesia, which refers to guided inquiry model to improve student's problem solving skills based on multiple representation was very need to be implemented. Based on the above, the selected models of guided inquiry model to improve student's problem solving skills based on multiple representation on the material of heat. In general, the purpose of this research is to produce a physics learning material through guided inquiry model was effective to improve student's problem solving skills based on multiple representation of senior high school.

2. METHODOLOGY OF RESEARCH

The research subject of the implementation of the results of the development of guided inquiry model learning device on the material of heat in the implementation is class X1, X2 and X3 in State Senior School of 19 Surabaya in the academic year 2013/2014 a total of 93 students. The design of the test is used to investigate the effectiveness development of the learning material physics model of guided inquiry. This research include in a pre-experimental research (Creswell, 2014; Fraenkel, Wallen, & Hyun, 2012), one-group pretest-posttest design. When the student reaches a minimum value of 75 each to improve student's problem solving skills based on multiple representation (mathematical, visual, and mathematical), then the student has reached the stated to improve student's problem solving skills based on multiple representation (Mahardika, Agus, & Dadi, 2012). The analysis of the effectiveness of physics learning material through guided inquiry model to improve student's problem solving skills based on multiple representation, the result of the pre-test, post-test, n-gain that had been collected were analysed by using the parametric statistical. N-gain (g) showed increased student's problem solving skills based on multiple representation before and after treatment. Normalized Gain $< g > =$ (score post-test – score pre-test) / (100 – score pre-test) (Hake, 1998).

Table 1 Normalized gain

N-Gain	*Criteria*
$0.70 < N\text{-}Gain$	High
$0.30 \leq N\text{-}Gain \leq 0.70$	Moderate
$N\text{-}Gain < 0.30$	Low

3. RESULTS OF RESEARCH

The result of the development of the physics learning material through guided inquiry model valid for use in teaching physics to improve student's problem solving skills based on multiple representation. The effectiveness of physics learning material through guided inquiry model were the implementation of devices with three of replication in class X1, X2, X3 views of the application physics learning material through guided inquiry model can improve student's problem solving skills based on multiple representation. The improving of the student's problem solving skills based on multiple representation can be seen from n-gain of the third class of replication derived n-average gain of class X1, X2, and X3 is equal to 0.78, 0.75, and 0.78 with the high category.

Based on the results of non-parametric statistical analysis, namely: 1) In the class X1 and X2; class X1 and X3; class X2 and X3 there are differences in the ability to multi earliest student's problem solving skills based on multiple representation in one class to another class; 2) In the class X1, X2, and X3 there is an increased student's problem solving skills based on multiple representation; and 3) In class X1 and X2, and X3 class X1, X2 and X3 class there is no difference upgrading of student's problem solving skills based on multiple representation in one class to another class. Based on the above results it can be concluded that physics learning material through guided inquiry model that have been developed effective to improve student's problem solving skills based on multiple representation of senior high school.

Based on the results of the implementation physics learning material through guided inquiry model can improve student's problem solving skills based on multiple representation with n-average gain of class X1, X2, and X3 is equal to 0.78, 0.75, and 0.78 with the high category (Hake, 1998). Based on the average completeness multipurpose learning student's problem solving skills based on multiple representation on implementation in class X1, X2, and X3 for 93.55%, 77.25%, and 95.93%. Aspects of the student's problem solving skills based on multiple representation is highest for the problem solving skills of mathematical representation and the lowest on verbal representations. Normality data test of pretest and posttest student's problem solving skills based on multiple representation using Shapiro-Wilk test with significance level $\alpha = 0{:}05$ (two-tailed). Normality test results pretest and posttest data obtained in class X1, X2, and X3 sig. <0:05, this means pretest and posttest data is not normally distributed. Normality test results obtained from the data n-gain in class X1 and X2 sig. <0:05, it means the data is n-gain in class X1 and X2 distribution is not normal. In the X3 class sig. > 0.05, this means that the data on the class of n-gain X3 normal distribution.

The results of analysed by using the parametric statistical of student's problem solving skills based on multiple representation.

A. Difference of student's problem solving skills based on multiple representation before implementation physics learning material through guided inquiry model

Test the difference of the earliest representations of multi pretest students using the data capabilities of multiple representation using Mann-Whitney U test with significance level $\alpha = 0{:}05$ (two-tailed). Table 2 show the result of u Mann-Whitney test on pretest of student's problem solving skills based on multiple representation before implementation physics learning material through guided inquiry model in one class to another class. In class X1 and X2; class X1

and X3; and class X2 and X3 sig. > 0.05, this means that there is no difference of student's problem solving skills based on multiple representation before implementation physics learning material through guided inquiry model in one class to another class.

Table 2 Result of U Mann-Whitney Test on pretest

Sampel	***Mean***	***Asymp. Sig. (2-tailed)***
Pretest X1 and X2	6.646 1.507	.185
Pretest X1 and X3	7.181 1.983	.264
Pretest X2 and X3	6.678 2.483	.281

B. Improving of student's problem solving skills based on multiple representation after implementation physics learning material through guided inquiry model

Test of improving student's problem solving skills based on multiple representation using the data pretest and posttest of each class using the Wilcoxon test with significance level α = 0:05 (two-tailed). Table 3 shows that in class X1, X2, and X3 value sig. <0.05, this means there is an increased student's problem solving skills based on multiple representation after implementation physics learning material through guided inquiry model in class X1, X2, and X3.

Table 3 Results of Wilcoxon on the data pretest and posttest

Data Pretest-Posttest	***Mean***	***Asymp. Sig. (2-tailed)***
X1	4.5161 84.5161	.000
X2	2.1875 79.0625	.000
X3	1.0000 82.6667	.000

C. Difference of improvement the student's problem solving skills based on multiple representation

Test the difference increased student's problem solving skills based on multiple representation using the n-gain of each class, Mann-Whitney U test with significance level α = 0:05 (two-tailed). Table 4 shows that in class X1 and X2; class X1 and X3; class X2 and X3 have sig. > 0.05, this means that there is no difference improvement of student's problem solving skills based on multiple representation in one class to another class.

Table 4 Results of Mann-Whitney U test on n-gain

Sampel	***Mean***	***Asymp. Sig. (2-tailed)***
N-gain X1 and X2	.7656 1.51	.579
N-gain X1 and X3	.7821 1.98	.766
N-gain X2 and X3	.7668 2.48	.273

4. DISCUSSION

Based on previous research (Kohl & Finkelstein, 2008; Kohl & Finkelstein, 2007; Kohl & Finkelstein, 2006; Kohl & Finkelstein, 2005; Meltzer, 2005; Heuvelen & Zou, 2001) states the form of a problem solving based on multiple representation in physics is the ability to resolve issues in physics with the representation of the various ways mathematically, verbal (written or oral) and visual (symbols / notation, images, and graphics). The student's problem solving skills based on multiple representation gained from multi ability tests on the material representation of the physics of heat consisting of nine indicators that were translated into 18 essay using Bloom's taxonomy new (revised by Anderson, & Krathwohl, 2001) of C4 (analyzing) to C6 (creating).

Tests performed twice, the initial test (pretest) and final test (posttest). Pretest value is used to determine the student's problem solving skills based on multiple representation before beginning student learning using the physics learning material through guided inquiry model. Values obtained posttest students describe mastery of the student's problem solving skills based on multiple representation after participating in guided inquiry learning models can be known about whether there is an increase of the physics learning material through guided inquiry model is implementation to heat the material. The improvement of the student's problem solving skills based on multiple representation can be seen from n-gain of the third class. The n-gain average of class X1, X2, and X3 is equal to 0.78, 0.75, and 0.78 with the high category (Hake, 1998).

The incensement shown by the results of analysis using n-gain shows on the implementation of physics learning material through guided inquiry model was effective in improving the student's problem solving skills based on multiple representation mastery of physics in the material of heat. The implementation in there of class shows that the consistency of the physics learning material through guided inquiry model was developed to improve student's problem solving skills based on multiple representation. Learning based on guided inquiry model allow students to build knowledge in a multiple representation and help students develop conceptual understanding (Pandey, Nanda, & Ranjan, 2011; Lee, Linn, Varma, & Liu, 2010; Minner, Levy, & Century, 2010; Wilson, Taylor, Kowalski, & Carlson, 2010). Furthermore the students really need concepts to define and connect between each representation which is a constituent element of a multiple representation (Cheng & Gilbert, 2007; Chittleborough & Treagust, 2008; Cook, 2006; Meij & Jong, 2006). The research was also found there are still some students who have not completed a multiple representation. This is consistent with the results (Cook, 2006; Larkin & Simon, 1987; Meij & Jong (2006), which concludes the student should obtain an understanding of concepts and requires a learning activity that can present their concept as a whole with multiple representation of mathematical, visual, and verbal (multiple representation) so successful in achieving the desired competence. This is consistent with their responses cited difficulty working and less confident when doing multiple representation. In reality test item difficulties they experienced during the learning because they do not perform activities relevant to learning scenarios that have been developed by researchers. They are not active and more dominant in activities that are not relevant, other than that they find it very difficult to represent abstract concepts. In the learning objectives of incomplete given remedial solutions to the accompaniment of learning to be able to visualize and represent verbally in the process of understanding the concepts in meaningful learning. Students are able to represent to visualize abstract concepts easier to understand the concept of heat from the students who are still not experts (Meltzer, 2004; Loverude, Kautz, & Heron, 2002).

Possible solutions to be applied in order to achieve mastery indicators for students who are weak in the student's problem solving skills based on multiple representation is giving us more about relating, students gain an understanding of physics concepts in context through multiple representation, and the guidance of a teacher for learning should be more intensive for students have the speed of learning is still low. The results of the study (Kohl & Finkelstein, 2008) concluded that

students are not expert guidance they need to use a special representation in building multi verbal and visual description of a problem to be converted into a mathematical representation.

The response of students who stand out and recorded during the learning is that students feel very need the guidance of teachers in teaching when they experience difficulties, especially on new material and abstract. It became real evidence and guided inquiry reinforces that the model is able to teach the student's problem solving skills based on multiple representation through guidance to students who are not expert. The use of multiple representation play an important role in helping students build an understanding with easier and better, because the concept is complex and wide can be presented more simply and holistic (Ainsworth, 2006; Ainsworth & Labeka, 2004; Ainsworth & Loizou, 2003; Ainsworth, Bibby, & Wood, 2002; and Ainsworth, 1999).

The results of inferential statistical analysis was conducted to determine the student's problem solving skills based on multiple representation after physics learning material through guided inquiry model which has been developed by researchers. Based on a review of data for normality test showed that the data are not normally distributed, so the statistical analysis used in the form of non-parametric inferential statistical analysis (Mann-Whitney U test and Wilcoxon). The student's problem solving skills based on multiple representation of the data analyzed pretest student's problem solving skills based on multiple representation on the Mann-Whitney U test with significance level $\alpha = 0{:}05$ (two-tailed). In class X1 and X2; class X2 and X3; class X1 and X3 have sig. > 0.05, this means that there is no difference in the ability to multi earliest student's problem solving skills based on multiple representation in one class to another class. It shows that students have the student's problem solving skills based on multiple representation was same on early learning. Improving the student's problem solving skills based on multiple representation of the data were analyzed student pretest and posttest ability to multiple representation of each class (X1, X2, and X3) using Wilcoxon test with a significance level $\alpha = 0{:}05$ (two-tailed). In class X1, Class X2 and X3 class sig. <0:05, this means an increased student's problem solving skills based on multiple representation significantly heat the material for each class after using the physics learning material through guided inquiry model. The result of differences in improvement student's problem solving skills based on multiple representation using the n-gain the student's problem solving skills based on multiple representation of each class using Mann-Whitney U test with significance level $\alpha = 0{:}05$ (two-tailed). In class X1 and X2; class X1 and X3; class X2 and X3 have sig. > 0.05, this means that there is no difference student's improvement problem solving skills based on multiple representation one class to another class.

The results of Mann-Whitney U test is used to determine whether there is a significant difference from the increased student's problem solving skills based on multiple representation of senior high school in class X1, X2, and X3. The results showed that no significant difference in the increase in the student's problem solving skills based on multiple representation of senior high school in class X1, X2, and X3. This may occur possible because teachers have implemented physics learning material through guided inquiry model to the fullest. No differences increase the student's problem solving skills based on multiple representation due to the role of teachers in designing learning and student activity is maximal learning (Axford, Harders, & Wise, 2009)

Based on the results of learning indicators completeness, n-gain, non-parametric statistical analysis, student activities and student responses indicate on the implementation physics learning material through guided inquiry model to be effective in improving the student's problem solving skills based on multiple representation of on the material of heat. Model of guided inquiry was defined as one inquiry learning model that is presenting problems, questions and supporting material or material determined by the teacher. Guidance in the form of problems, questions, and this analogy that encourages students conduct an investigation to determine the answer (Acevedo, Dooren, Clarebout, Elen, and Verschaffel 2010; Bao, et al., 2009). Vygostky states that children

develop concepts in a more systematic, logical, and rational which is the result of a dialogue with skilled mentors. The physics learning process using physics learning material through guided inquiry model focused on exploratory activities with social interaction, exercises and tasks regarding the ability of problem solving skills based on multiple representation of physics in the material of heat, and the guidance of teachers through questions and analogies. This is consistent with the theory of constructivism by Vygotsky, which has three major implications in learning, namely: 1) Through social interaction students become aware of mental function and is able to use it basically for growth; 2) The teacher gives the tasks within the reach of students (zone of proximal development); and 3) Provide learning by scaffolding (Arends, 2012). The improvement of student's problem solving skills based on multiple representation at every stage of inquiry model (Maliyah, 2012). On the guided inquiry learning models developed by the researchers also used questions and analogies as guidance when experimentation and investigation activities to improve student's problem solving skills based on multiple representation. Analogies and the question will be guidance for students not yet proficient to practice expected competencies. The student's problem solving skills based on multiple representation is very important because students can improve their understanding of the concepts of physics when students can present with multiple representation of concepts of physics that have (Rosengrant, Van Heuvelen, & Etkina, 2008). Guided inquiry learning can to improve student's problem solving skills based on multiple representation. Results of the study is strengthened by the result of research (Putri, Mahardika, & Ketut, 2012; Mahardika, Agus, & Dadi, 2012) which concluded inquiry model can improve the student's multiple representation in physics of senior high school. Guided inquiry learning on the material of heat using experimental methods and demonstrations discussion requires the ability to multiple representation that affect the learning achievement (Maliyah, 2012).

Based on of the results of this research that physics learning can be improve the student's problem solving skills based on multiple representation in Indonesia. Therefore, teachers can use the physics learning material through guided inquiry model to support implementation the curriculum in Indonesia of a holistic manner so that the learning can touch the basic elements of each component of the subjects that will be discussed in physics learning.

5. CONCLUSION

Based on the results and discussion of this research are the learning material effectiveness in terms of improving student's problem solving skills based on multiple representation by getting the n-gain score with high category and the analysis results of statistic non parametric are: 1) nothing different of student's problem solving skills based on multiple representation at each class, 2) different student's problem solving skills based on multiple representation after implementation of physics learning material through guided inquiry model, and 3) nothing different of improving student's problem solving skills based on multiple representation at each class. It's conclusion that the learning material through guided inquiry model are effective to improve student's problem solving skills based on multiple representation in senior high school. Besides, the findings of the research should be confirmed through more studies in different level and countries.

REFERENCES

Abdurrahman, Liliasari, Rusli, A., & Bruce, W. (2011). Implementasi pembelajaran berbasis multi representasi untuk peningkatan penguasaan konsep fisika kuantum, *Cakrawala Pendidikan*, *30*(1), 30-45.

Acevedo, N., A. Van Dooren, W., Clarebout, G., Elen, J., & Verschaffel, L. (2010). Representational flexibility in linear-function problems: a choice/no-choice study. In L. Verschaffel, E. De Corte, T. de Jong and J. Elen (Eds.) *Use or representations in reasoning and problem solving: Analysis and improvement*, 74-79. Milton Park, UK: Routledge.

Ainsworth, S. & Loizou, A. (2003). The effects of self-explaining when learning with text or diagrams, *Cognitive Science*, *27*(1), 669–681.

Ainsworth, S. & Van Labeke, N. (2004). Multiple forms of dynamic representation, *Learning and Instruction*, *14*(1), 241–255.

Ainsworth, S. (1999). The functions of multiple representation, *Computers and Education*, *33*(1), 131–152.

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representation, *Learning and Instruction*, *16*(3), 183-198.

Ainsworth, S., Bibby, P., & Wood, D. (2002). Examining the effects of different multiple representational systems in learning primary mathematics, *The Journal of Learning Sciences*, *11*(1), 25–61.

Anderson, L., & Krathwohl, D. A. (2001). *Taxonomy for learning, teaching and assessing: a revision of bloom's taxonomy of educational objectives.* New York: Longman.

Arends, R. (2012). *Learning to teach, 9th edition*. New York: Mc-Graw Hill.

Axford, B., Harders, P., & Wise, F. (2009). *Scaffolding literacy. An integrated and sequential approach to teaching reading, spelling and writing*. Australia: Acer Press.

Branch, J. & Oberg, D. (2004). *Focus on inquiry a teacher guide to implementing inquiry based learning*. Canada: Alberta Education, Alberta.

Cheng, M. & Gilbert, J. (2007). Towards a better utilization of diagrams, *Science Educational Research*, *11*(1), 190-203.

Cook, M. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles, *Science Education*, *90*(6), 1073-1091.

Creswell, J. W. (2014). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research.* United State America: SAGE Publication, Inc.

David, M. J. Christophe, D. J., & Norma, A. J. (2013). The effect of representations on difficulty perception and learning of the physical concept of pressure, *Themes in Science and Technology Education*, *6*(2), 91-108.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). New York: McGraw-Hill.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics test data, *American Journal of Physics*, *66*(1), 64–74.

Heuvelen, V. & Zou. X. L. (2001). Multiple representation of work-energy processes, *American Journal of Physics*. 69(2), 184.

Kohl, P. B. & Noah, D. F. (2005). Student representational competence and self-assessment when solving physics problem, *Physical Review Special Topics-Physics Education Research*, *1*(1), 1-11.

Kohl, P. B. & Noah, D. F. (2006). Effect of representational on students solving physics problem: A fine-grained characterization, *Physical Review Special Topics-Physics Education Research*, *2*(1), 1-8.

Kohl, P. B. & Noah, D. F. (2007). Strongly and weakly directed approach to teaching multiple representation use in physics, *Physical Review Special Topics-Physics Education Research*, 2(1), 1-10.

Kohl, P. B. & Noah, D. F. (2008). Pattern of multiple representation use by expert and novices during physics problem solving, *Physical Review Special Topics-Physics Education Research*, 4(1), 1-13.

Larkin, J. & Simon, H. (1987). Why a Diagram is (sometimes) worth ten thousand words, *Cognitive Science*, 11(1), 65-99.

Lee, H., Linn, M. Varma, K., & Liu, O. (2010). How do technology-enhanced inquiry science units impact classroom learning, *Journal of Research in Science Teaching, 47*(1), 71-90.

Loverude, M., Kautz, C., & Heron, P. (2002). Student understanding of the first law of thermodynamics: Relating work to the adiabatic compression of an ideal gas, *American Journal of Physics,* 70(2), 137–48.

Mahardika, K . I., Agus, S., & Dadi, R. (2012). Model inkuiri untuk meningatkan kemampuan representasi verbal dan matematis pada pembelajaran fisika di SMA, *Jurnal Pembelajaran Fisika*, *1*(2), 165-171.

Maliyah, N. (2012). Pembelajaran fisika dengan inkuiri terbimbing melalui metode eksperimen dan demontrasi diskusi ditinjau dari kemampuan matematik and kemampuan verbal siswa, *Jurnal Inkuiri*, *1*(3), 227-234.

Meij, J. & Jong, T. (2006). Supporting students' learning with multiple representation in a dynamic simulation-based learning environment, *Learning and Instruction*, *16*(3), 199-212.

Meltzer, D. E. (2004). "Investigation of students' reasoning regarding heat, work, and the first law of thermodynamics in an introductory calculus-based general physics course, *American Journal of Physics, 72*(14), 32–46.

Meltzer, D. E. (2005). Relation between students' problem-solving performance and representational format. *American Journal of Physics*, *73*(5), 463.

Minner, D., Levy, A., & Century, J. (2010). "Inquiry based science instructions-what is it and does it matter? Results from a research synthesis years 1984 to 2002, *Journal of Research in Science Teaching, 47*(2), 474-496.

Nieminen, P., Savinainen, A. & Viiri, J. (2013). *Representational consistency and the learning of forces in upper secondary school physics*. Jyväskylä: Jyväskylä University Printing House.

Nieminen, P., Savinainen, A., Nurkka, N., & Viiri, J. (2011). An intervention for using multiple representation of mechanics in upper secondary school courses, *in Proceedings of the ESERA (2011) Conference,* Lyon, 2011.

Pandey, G. K., Nanda, & Ranjan, V. (2011). Effectiveness of inquiry training model over conventional teaching method on academic achievement of science students in India, *Journal of Innovative Research in Education, 1*(1), 7-20.

Putri, M. A., Mahardika, & Ketut. (2012). Model pembelajaran *free inquiry* (inkuiri bebas) dalam pembelajaran multi representasi fisika di MAN 2 Jember. *Jurnal Pembelajaran Fisika*, *1*(3), 324-327.

Rosengrant, D., Van Heuvelen, A., & Etkina, E. (2009). Do students use and understand free-body diagrams?. *Physical Review Special Topics-Physics Education Research, 5*(1), 1-8.

Waldrip, B. Prain, V., & Carolan, J. (2006). Learning junior secondary science through multi-modal representations, *Electronic Journal of Science Education, 11*(1), 86-105.

Waldrip, B. Prain, V., & Carolan, J. (2010). Using multi-modal representations to improve learning in junior secondary science. *Res. Science Education*, *40*(1), 65-80.

Wilson, C. D. Taylor, J. A. Kowalski, S. M. & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation, *Journal of Research in Science Teaching*, *47*(5), 276 – 301.