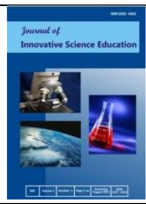
JISE 8 (3) 2019 : 332 - 343

Journal of Innovative Science Education

http://journal.unnes.ac.id/sju/index.php/jise



Development of Inquiry Materials Based on Chemical Representation to Improve Students' Critical Thinking Ability

Lia Lindawati [1]✉, **Sri Wardani** [2], **Sri Susilogati Sumarti** [2]

[1] SMA Islam Teladan Al Irsyad Al Islamiyyah Purwokerto, Indonesia
[2] Universitas Negeri Semarang, Indonesia

Article Info

Article History:
Received March 2019
Accepted June 2019
Published December 2019

Keywords:
Inquiry, chemical representation, critical thingking

Abstract

Twenty first century learning directs teachers and students to develop learning to promote critical thinking skills. The learning model accommodating critical thinking skills is inquiry. Chemistry learning modules that have not used a chemical representation approach. This study aims to produce chemical representation based equilibrium modules with a decent and quality inquiry approach. This research is a development research from Thiagarajan modified 4D model. Four stages of development are Define (design), Design (Develop), Develop (development), and Disseminate (spread), with disseminate not done. Evaluation of module feasibility is seen from the validity and effectiveness of the module. The effectiveness of the module is seen from the increase in learning outcomes and improvement of students' critical thinking skills. Based on the results of the analysis obtained a validity value of 3.41 (85.25%) with a very good category. In a large-scale trial obtained an increase in learning outcomes through the N-Gain test obtained an average value of 0.72 with a high category, while the aspect of critical thinking was assessed based on observations on the observations and explanations of students in answering questions. Critical thinking ability of students at a score of 3.35 with a good predicate. While the response of students who agreed to use the chemical module was 96%. The average score of posttest using critical thinking questions is 81.39. Based on the results of the evaluation of inquiry-based chemical equilibrium material modules and the chemical representation approach it is said to be feasible and effective for learning.

✉ Alamat korespondensi:
Jl. Prof. Dr. Suharso, Arcawinangun, Kec. Purwokerto Tim., Kabupaten Banyumas, Jawa Tengah 53113, Indonesia
E-mail: lia.lindawati@gmail.com

p-ISSN 2252-6412
e-ISSN 2502-4523

INTRODUCTION

Chemistry is one branch of science that studies matter and energy that accompany material changes. (Effendy, 2007; Aliyah et al., 2018). Chemistry is very close to human life, but studying chemistry as a subject is still considered difficult by most students, due to the nature of complex concepts and abstract phenomena (Wang, 2007). Difficulties in studying chemistry are also caused by the complexity of the calculations involved, languages that are rarely used in everyday life, and differences in levels of representation used by chemists in explaining chemical phenomena (Gabel, 1993; Sheppard, 2006).

Experts describe chemistry using levels of representation that include macroscopic, sub-microscopic, and symbolic representations (Johnstone, 1982; Nyachwaya & Wood, 2014). Understanding chemistry requires the ability to think using three different but interconnected levels of representation that are macroscopic, submicroscopic, and symbolic (Johnstone, 2000; Chandrasegaran, 2007; Chittleborough & David, 2007). The concept of chemical learning using multiple representations is a form of representation that combines text, real images, or graphics, and symbols (Herawati et al, 2013). Learning activity using representations can bridge the process of students' understanding of the chemical concepts: Development of chemical representations based on the sequence of phenomena seen, reaction equations, atomic and molecular models, and symbols (Sunyono, 2011; Herawati et al., 2013; Sunyono et al., 2015).

Chemical phenomena are described and explained by chemists in three levels of representation. Macroscopic representation is a concrete level, in this level students observe phenomena that occur, either through experiments conducted or phenomena that occur in everyday life. Sub-microscopic representation is an abstract level that explains macroscopic phenomena. This representation provides an explanation at the particle level where matter is described as an arrangement of atoms, molecules and ions, while symbolic representations are used to represent macroscopic phenomena using chemical equations, mathematical equations, graphs, reaction mechanisms, and analogies (Johnstone, 1982; Sunyono, 2011; Nyachwaya & Wood, 2014; Sunyono et al., 2015).

Conceptual understanding in chemistry involves the ability to represent and translate chemical problems into the form of macroscopic, sub-microscopic, and symbolic representations (Bowen & Bunce, 1997). Chemistry learning generally tends to limit at the macroscopic level and symbolic level only, sub-microscopic representations tend to be ignored. Chemical learning that emphasizes symbolic level and problem solving causes students to have difficulty developing conceptual understanding in chemistry (Gabel, 1993).

Teaching materials are all forms of material or set of materials arranged systematically and used to help teachers and students in carrying out learning activities (Hamdani, 2010). Appropriate teaching materials will support the achievement of learning objectives (Lestari et al., 2018). Teaching materials made with a chemical representation approach and integrated material presentation using a learning model will help students understand the material. Learning using a module-assisted inquiry model can improve the understanding of the concept of hydrolysis (Septiani et al., 2014). The inquiry learning model can train students to develop curiosity, scientific thinking skills, and critical thinking skills (Oguz-Unver & Arabacioglu, 2011; Corlu & Corlu, 2012). Inquiry is a method related to student activities in developing science (Oguz-Unver & Arabacioglu, 2011).

Wahyudin et al. (2010), Ngertini et al. (2014), and Wibowo et al. (2015) suggested that the inquiry model is teaching requires students to process messages so that they gain knowledge, skills, and values. Inquiry learning is applied so students are free developing the concepts they learn is not only limited to the material just recorded then memorized (Yulianingsih et al., 2013; Trisanti et al., 2013; Choerunnisa & Wardani, 2017; Wardani & Sumarti, 2017; Ika et al., 2017).

Based on the standard content of high school chemistry subjects, one of the subjects studied is chemical equilibrium. Chemical equilibrium is a condition when the reaction rate is forward and vice versa the same in the reversible process. Chemical and physical processes in dynamic equilibrium Petrucci et al. (2011). Driel & Graber (2002) and Demircioglu et al. (2013) say that one of the chemical concepts that is difficult for students to understand is chemical equilibrium material. Chemical equilibrium topics related to chemical reactions, stoichiometry and micro kinetics are abstract topics for students. In this material representation is needed which can help students in understanding the concept of chemical equilibrium (Wu et al., 2000).

The instrument used to assess critical thinking skills and problem solving should be guided by basic knowledge. In solving problems the process of thinking is more important than the knowledge possessed. Instruments of critical thinking skills pay attention to the strengthening of the basic concepts of student material (Carson, 2007; Redhana & Liliasari, 2008; Amalia & Endang, 2014).

Understanding the concept of equilibrium through chemical representation will improve students' critical thinking skills Facione (1990). The practice of critical thinking is to think seriously, actively, and accurately in analyzing all information that has been received with a rational reason, able to explain the reasons for problem solving, so as to produce a formula or conclusion that can be applied in daily life (Snyder & Snyder, 2008; Liberna, 2011; Thomas, 2011; Villalba, 2011).

Understanding of chemical concepts through a chemical representation approach will improve the ability of students to interpret, analyze, conclude, and provide explanations, so the creation of inquiry-based equilibrium teaching materials with inquiry approaches is expected to improve students' critical thinking and ability. The use of teaching materials that combine the incuri model with chemical representation is expected to be able to construct concepts through the relationship of observed macroscopic levels with concepts at the sub-microscopic and symbolic level so that students can fully understand the concept of chemistry.

METHODS

This research is research and development (research and development or R & D). The development model used is a modified 4-D model as suggested by Thiagarajan, which consists of defining, designing, developing, and disseminating Trianto (2013). This study modified the 4-D model, namely simplification of four stages into three stages, namely define (definition), design (design), and develop (development). The product developed using this modified 4D model was tested for validity and its effectiveness was a chemical equilibrium material module with inquiry-based chemical representation approach. This research was conducted in class X1 of the Al-Irsyad Al Islamiyyah Exemplary High School-Islamic High School in Purwokerto. In the small class trial the subject was 20 students, while the trial of 1 (one) real class which was the subject of the study was a large class with 36 students. The focus of this research is the development of valid and effective modules. Indicators of success in this study are: 1) this device is declared valid if the average value is in the range of $3.00 \leq n \leq 4.00$; 2) this device is declared effective if: a) the cognitive average score of students ≥ 75 with 75% classical completeness; b) Critical thinking ability of students reaches an average of both with a minimum value of 2.50.

The steps in this development include define phase which consists of analysis of syllabus, material, students, assignments, and teaching materials. The design phase is to design the product with characteristics that have been analyzed at the define stage. And finally the development stage by validating modules and devices. Then the products will be tested on limited classes and large scale classes. In the large-scale trial aspects measured aspects are cognitive aspects in the form of mastery of concepts, aspects of students' critical thinking skills.

Gain calculation of normalized (N-Gain)

Calculating Gain normalized score based on the formula by Archambault (2008), namely:

Table 1. Criteria normalized Gain

Percentage	Classification
N-Gain > 70	High
30 ≤ N-Gain ≤ 70	Moderate
N – Gain < 30	Low

RESULTS AND DISCUSSION

Results of Validation of Research Instruments

The initial product development (draft I) was validated by four validators. Validation is carried out on (1) teaching materials, which consist of material assessment and readability assessment, (2) syllabus, (3) lesson plan, (4) response questionnaire, (5) cognitive test questions, (6) observation sheet assessment aspects of thinking ability critical. The recapitulation of the results of the validation of the research instruments is presented in Table 2.

Table 2. Summary of Results of Expert Validation on Learning Devices

N	Device	Value Validation	Criteria	Category
1	teaching material	3.41	Valid	Good
2	Syllabus	3.37	Valid	Good
3	Lesson plan	3.26	Valid	Good
4	Inquiry Observation Sheet	3.33	Valid	Good
5	Critical Thinking Ability Observation Sheet	3.2	Valid	Good
6	Student Response	3.33	Valid	Good

Based on the results listed in Table 1. It can be concluded that all research instruments have valid criteria. The results of the research are Muna et al. (2016) report the results of the study. They showed that there was an effect of implementing guided inquiry learning on student metacognition skills. Existence the influence of guided inquiry learning on metacognition skills is due activities carried out, student collaborative interactions, as well as the role of the teacher as facilitator. Increased metacognition skills of students are on the criteria high. While Wibowo et al. (2015) have developed chemical modules that are closely related to inkuri which thermochemical material can improve student logic.

The Effectiveness of Inquiry-Based Module Teaching Materials with a chemical representation approach

The effectiveness of the product is known based on the results of the analysis of cognitive competencies, the ability of students' critical thinking skills. The achievement of these two competencies is the goal of implementing the module in the process of teaching and learning activities.

The results of students' cognitive competencies are obtained after students carry out pretest and posttest activities. The pretest and posttest questions consist of 30 questions with 30 multiple choices. Increased cognitive ability is known through calculation of normalized gain values between the values of the pretest and posttest. The results of the pretest-posttest values can be seen in Table 3.

Tabel 3. Pretest and Posttest Data

Data	Average	Max value	Min Value	Sign	Data normality
Pretest	32,41	50	20	0,061	Normal
Posttest	81,31	93.33	60	0,120	Normal

The results of the study obtained the average value of pretest 32.41 and the average posttest value was 81.31. The results of the N gain average mastery of the concept are 0.72 in the high category. Classical learning completeness of students shows that as many as 31 of 36 students get scores minimal completeness criteria above 75 (complete). The results of the pretest-posttest values can be seen in Figure 1.

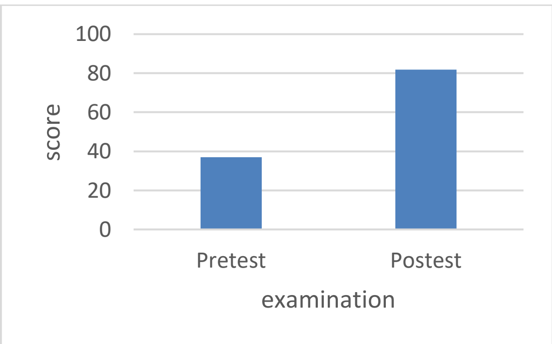


Figure 1. Comparison diagram of pretest and posttest

The data above shows that the use of inquiry-based chemical equilibrium module teaching materials with a chemical representation approach can significantly improve students' cognitive abilities. The paired test results showed that the price of tcount was 2.04 with 35 degrees of freedom, the value of t table for error was 5% 1.72. Because t count is greater than t table, it means that the learning outcomes of mastering the concept of students have exceeded minimal completeness criteria are 75 or achieved mastery learning. These results also show that cognitive abilities have met the effective criteria. The results of this research are in line with the research conducted by Pratiwi et al. (2018) stating that the ability of science processes will increase with the use of chemical representation based worksheets. Wardani (2016) states inquiry learning improves understanding of the concepts and oral activities of students. Attitude aspects are measured through observation using observation sheets during the implementation of learning. The average score of students' critical thinking reaches 3.35 from the highest score of 4.

Aspect of student attitudes observed was focused on creative attitudes which consisted of 7 components, namely focusing questions, analyzing arguments, asking questions and answering questions, observing and considering observations, identifying assumptions, determining actions, defining and evaluating the results of definitions. From the seven indicators the lowest critical thinking indicator is to identify assumptions with a score of 84.95. The results of the observations show that the average value of students' critical thinking abilities increases the initial and final meetings. The average value of each aspect of the assessment of students' critical thinking skills is presented in Figure 2.

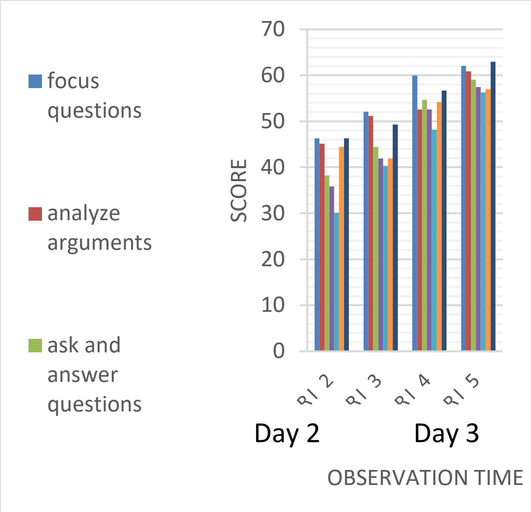


Figure 2. Critical Thinking Ability Score Chart

Based on Figure 2 it can be seen that the average value of each aspect assessed has increased. Overall aspects of students' critical thinking abilities are increasing from the beginning to the end of the meeting.

Results of Student Response to Modules

The results of the analysis of student response data showed that of 36 students who strongly agreed as many as 7 students, agreed as many as 28 students, disagreeing as much as 1 student. The full results of the student response questionnaire can be seen in Figure 3.

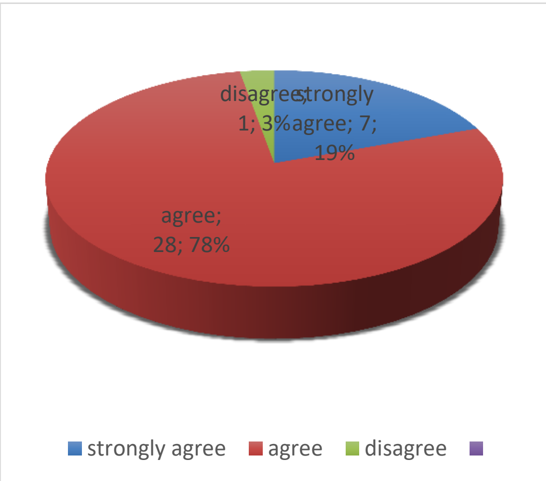


Figure 3. Student Response Diagram of the Module

Figure 3 shows that overall students in the development stage gave a very good response to the use of inquiry-based chemical equilibrium modules with a chemical representation approach. From the results obtained, 96% are in the agreed category and strongly agree.

Data from these observations show that project-based chemical equilibrium modules with a chemical representation approach can improve students' critical thinking skills. This teaching material can be an innovation in chemistry learning where chemical learning does not only emphasize the achievement of learning outcomes, but also the ability of students to produce a real product. Thus, it is expected that students' abilities are not only limited to theory but also understand the application of a science so that it can create a generation of quality.

Discussion

The discussion of development research describes the steps in making inquiry-based teaching materials, the suitability of the final product with the development objectives and the advantages and disadvantages of the final product produced teaching materials.

Discussion of Product Design

The research procedure used by researchers adopted Sugiono's development which was limited to 8 steps of development research namely potential and problems, data collection, product design, design validation, design revision, small-scale product testing, product revision, large-scale product testing. Teaching materials that researchers develop are adjusted to inquiry syntax which consists of problem orientation, asking questions, making hypotheses or guessing answers, collecting data related to questions, formulating conclusions based on data (Hamruni, 2012). The module presentation is adjusted to the inquiry syntax and the chemical representation approach which includes macroscopic, sub microscopic and symbolic on chemical equilibrium material. The combination of inquiry syntax and chemical representation as follows the problem orientation stage, asking questions and hypotheses become part of the presentation of the concept of equilibrium in a macroscopic manner, the data collection stage represents sub-microscopic which includes micro-delineation of chemical equilibrium phenomena, and the stage of formulating conclusions representing chemical representation symbolic in the form of formulas, graphs and numbers.

Results of discussion on teaching material validation

Validation was carried out on teaching materials, syllabus, lesson plans, student response questionnaires, questions, and critical thinking observation sheets. The maximum validation score obtained for each instrument is different, depending on the number of validity assessment criteria. Based on the results listed in Table 2 it can be concluded that all research instruments have valid criteria. So that all instructional materials can be used to measure (Sugiono, 2015), and are appropriate to use.

Discussion of Teaching Materials to Improve Concept Understanding

This study produces inquiry based chemistry-based teaching materials that can improve concept understanding seen in critical thinking skills as indicated by students' cognitive learning outcomes in Table 3. The results of this study are in accordance with Septiani et al. (2014), Yotiani et al. (2016), Hairida (2016), Wardani et al. (2017), Riyani et al. (2017), Lestari et al. (2018) which states learning using the inquiry approach will improve the understanding of students' chemical concepts. In accordance with the research of Wahyudin et al. (2010), Ngertini et al. (2014), and Wibowo et al. (2015) who suggested the inquiry model is teaching that requires students to process messages so that they acquire knowledge, skills, and values. According to research Yulianingsih et al. (2013); Trisanti et al. (2013); Choerunnisa et al. (2017); Wardani & Sumarti (2017); Ika et al. (2017) students are free to develop the concepts they learn.

Teaching Materials Based on Inquiry with the Chemical Representation Approach

This study uses an inquiry learning model with a chemical representation approach, in which the product has been produced in the form of chemical representation based inquiry materials. Teaching materials produced in the category of valid and appropriate in accordance with the study. Based on the results of the study, the use of teaching materials is able to improve understanding of concepts and students' critical thinking skills. In accordance with the results of research by Kozma (2000, 2003), Cloonan et al. (2011), the use of chemical representations in macroscopic, sub microscopic and symbolic levels is the key explanation of chemical phenomena, Wijayanti et al. (2015) have made very good categories of chemical equilibrium-based material representation books, Muna et. al. (2016) stated that learning with inquiry can improve students' meta cognition skills. while Pratiwi et al. (2018) states that the ability of science processes will increase with the use of chemical representation based worksheets. While Wardani (2016) states inquiry learning improves understanding of students' concepts and oral activities.

Critical Thinking Skills and Chemical Representation Based Inquiry Learning models

The results of this study indicate the mastery of students' concepts which increases with the use of inquiry teaching materials and chemical representations. Mastery of concepts increases followed by critical thinking skills that increase also by using seven indicators of critical thinking skills obtained from derivatives of critical thinking indicators Ennis (1996). In line with the research of Budiarti et al. (2016), Maulida & Haryani (2016), Muna et al. (2016), Widowati et al. (2017), Khasanah et al. (2017). Adnan et al (2017) stated that inquiry learning is able to improve students' critical thinking skills. While Weaver (2016) reported that critical thinking skills, problem solving and analysis of middle school students increased by using inquiry-based learning in the provision of pharmaceutical organic chemical based projects. Hairida (2016) reported the results of his research that inquiry-based learning modules with authentic assessments on additive material proved to be effective in improving inquiry abilities and students' critical thinking abilities. Liliawati et al. (2014) which states inquiry learning in accordance with the characteristics of high school students, because it maximizes its ability to act as a party that controls learning according to the provisions at the level of inquiry learning.

Based on the research there are seven indicators observed including focusing questions, analyzing arguments, asking questions and answering questions, observing and considering observations, identifying assumptions, determining an action, and defining and evaluating the results of definitions. Kartimi (2013) reports that there are four indicators of critical thinking skills that are used to measure the understanding of the concept of chemical equilibrium.

CONCLUSION

Inquiry-based chemical equilibrium teaching material with a chemical representation approach that was developed valid for use in learning with the validation results from experts in all aspects of the module obtained values of 3, 41 with a very good category. The results of the learning device validation by experts show the average validation for the syllabus is 3.37 in the good category; the average score of lesson plan 3.26 with a good category; inquiry inquiry table 3.30 with a very good category; critical thinking observation sheet of 3.20 in good category; and the 3.33 student response questionnaire was very good category.

Inquiry-based chemical equilibrium material modules with a chemical representation approach are declared effective. This is indicated by the learning outcomes of students who use learning devices to achieve minimal classical completeness criteria where the results of mastery of concepts are 86.11% and the average value of N-Gain is 0.72 with a high category.

Inquiry-based chemical equilibrium material modules with a chemical representation approach can improve students' critical thinking skills. This is indicated by the average score of observations of students' critical thinking skills including seven indicators amounting to 84.95. Positive student responses to inquiry-based chemical equilibrium material modules with a chemical representation approach that is equal to 96%.

ACKNOWLEDGEMENT

Our gratitude is delivered to:

Al Irsyad Al Islamiyyah Foundation as the research funding facilitator

SMA-IT Al Irsyad Al Islamiyyah Purwokerto as the research site facilitator

REFERENCES

Aliyah, A. A., Endang, S., Kasmui, Nurchasanah, & Pudji, A. (2018). Desain Media Peta Konsep Multi representasi pada Materi Buffer dan Hidrolisis. *Jurnal Inovasi Pendidikan Kimia,* 12(1), 2055 – 2064.

Amalia, N. F. & Endang, S. (2014). Pengembangan Instrumen Penilaian Keterampilan Berpikir Kritis Siswa SMA pada Materi Asam Basa. *Jurnal Inovasi Pendidikan kimia*, 8(2), 1380-1389.

Archambault, J. 2008. "*The Effect of Developing Kinematics Concepts GraphicallyPrior to Introducing Algebraic Problem Solving Techniques". Action Research Reguared for the Master of Natural Science Degree with Concentration in Physics*. Arizona State University.

Bowen, C.W. & Bunce, D.M. (1997). Testing for Conceptual Understanding in

General Chemistry. *The Chemical Educator*, 2(2), 1-17.

Budiarti, S., Murbangun, N., & Edy Cahyono. (2016). *Guided Inquiry* Berbantuan E-Modul untuk Meningkatkan Keterampilan Berpikir Kritis. *Journal of Innovative Science Education*, 5(2), 144-151.

Carson, J. (2007). A Problem With a Problem Solving: Teaching Thinking Without Teaching Knowledge. *The Mathematic Educator*, 17(2), 7-14.

Chandrasegaran, A. L., David, F. T., & Mauro, M. (2007). The Development of A Two-Tier Multiple Choice Diagnostic Instrument for Evaluating Secondary School Students' Ability To Describe and Explain Chemical Reactions Using Multiple Levels of Representation. *Chemistry Education Research and Practice*, **8**(3), 293-307.

Chittleborough, G. & David, F. T. (2007). The Modeling Ability of Non major Chemistry Students and Their Understanding of The Sub microscopic level. *Chemistry Education Research and Practice*, 8(3), 274-292.

Choerunnisa, R. & Wardani, S. (2017). Keefektifan Pendekatan *Contextual Teaching Learning* Dengan Model Pembelajaran Inkuiri Terhadap Literasi Sains. *Jurnal Inovasi Pendidikan Kimia*, 11(2), 1945–1956.

Cloonan, C. A., Andrew, J. A., Nichol, C. A., & Hutchinson, J. S. (2011). A Simple System for Observing Dynamic Phase Equilibrium via an Inquiry-Based Laboratory or Demonstration. *Journal of . Chemical Education*, 88, 975–978.

Corlu, M.A. & Corlu, M.S. (2012). Scientific Inquiry Based Professional Development Models In Teacher Education Educational Science: Theory & Practice Educational Consultancyand Research Center,Winter,12(1), 514-521.

Demircioglu, G., Demircioglu, H., & Yadigaroglu, M. (2013). An Investigation of Chemistry Student Teachers' Understanding of Chemical Equilibrium. *International Journal on New Trends in Education and Their Implication*, *4*(2), 192-199.

Effendy. (2007). Kimia Koordinasi Jilid I. Malang:Jurusan Kimia Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Malang(UNM).

Ennis, R.H.(1995). Critical thinking. New Jersey:Prentice Hall, 17.

Ennis, R. H. (2015). Critical Thinking: A Streamlined Conception. In *The Palgrave Handbook of Critical Thinking in Higher Education*, 31–47.

Facione, P.A. (1990). *Critical Thinking: A Statement of Expert Consesus for Purpose of Educational Assessment and Instruction*. California: California Academic Press.

Fitriana, M. & Haryani, S. (2016). Penggunaan Strategi Pembelajaran Inkuiri untuk Meningkatkan Metakognisi Siswa SMA. *Jurnal Inovasi Pendidikan Kimia,* 10(1), 1702-1711.

Gabel D.L. (1993). Use of the Particle Nature of Matter in Developing Conseptual Understanding. *Journal of Chemical Education*,70(3), 193-194.

Hairida. (2016). The Effectiveness Using Inquiry Based Natural Science Module With Authentic Assessment to Improve The Critical Thinking and Inquiry Skills of Junior High School Students. *Jurnal Pendidikan IPA Indonesia,* 5(2)*, 209-215.*

Hamdani. (2010). *Strategi Belajar Mengajar*. Bandung: Pustaka Setia.

Hamruni. (2012). Strategi Pembelajaran. Yogyakarta: Insan Madani.

Haryanti, Sudarmin, & Murbangun, N. (2016). Penerapan Model Pembelajaran Inkuiri Materi Kelarutan dan hasil kali Kelarutan untuk Meningkatkan Kemampuan Berpikir Kritis. *Journal of Innovative Science Education.* 5(2), 170-177.

Herawati, R F. Mulyani, S., & Redjeki, T. (2013). Pembelajaran kimia Berbasis

Multiple Representasi Ditinjau dari Kemampuan Awal Terhadap Prestasi Belajar Laju Reaksi Siswa SMA Negeri 1 Karanganyar Tahun Pelajaran 2011/2012. *Jurnal Pendidikan Kimia (JPK)*, 2 (2), 38-43.

Ika, J., Sumarti, S. S., & Widodo, A. T. (2017). Penerapan Model Pembelajaran Inquiry Terbimbing Terhadap Self Efficacy Dan Hasil Belajar Kimia Pada Materi Koloid. *Journal of Innovative Science Education*, 6(1), 49-58.

Johnstone, A. H. (1982). *Macro and Micro Chemistry, School Science Review*, 227(64), 377-379.

Johnstone, A. H. (2000). Teaching of Chemistry -Logical or Psychological Chemistry Education:Research and Practice in Europe, 1(1), 9-15.

Kartimi, K. (2012). Pengembangan Alat Ukur Berpikir Kritis Pada Konsep Termokimia untuk Siswa SMA. *Scientiae Educatia: Jurnal Pendidikan Sains*, *1*(1), 1-14.

Khasanah, N. A., Sajidan, S., & Widoretno. (2017). Effectiveness of Critical Thingking Indicator – Based Module in Empowering Student's Learning Outcome in Respiratory System Studi Material. *Jurnal Pendidikan IPA Indonesia JPII,* 6(1), 187-195.

Kozma, R. (2000). "The use of multiple representations and the social construction of understanding in chemistry". In M. Jacobson & R. Kozma (eds.), *Innovations in science and mathematics education: Advanced designs for technologies of learning,* 11-46.

Kozma, R. (2003). Material and social affordances of multiple representations for science understanding. *Learning and Instruction, 13* (2), 205-226.

Lestari, P, S Wardani, & S Susilogati. (2018). Influence of Guided inquiry model on Students Cognitive Learning Outcome in Stoichiometrytopic. *Journal of Innovative Science Education,* 7 (2), 130-135.

Liberna, H. (2011). Peningkatan Kemampuan Berpikir Kritis Matematis Siswa Melalui Penggunaan Metode Improve Pada Materi Sistem Persamaan Linear Dua Variabel. *Jurnal Formatif*, 2(3), 190-197.

Liliawati, W., Purwanto, T. R., Hidayat, R., Megawati, E., & Puspitasari, F. T. (2014). Analisis Kemampuan Inkuiri Siswa SMP, SMA Dan SMK Dalam Penerapan *Levels Of Inquiry* Pada Pembelajaran Fisika. *Journal Berkala Fisika Indonesia*, 6(2), 34-39.

Muna, K., Haryani, S., & Endang, S. (2016). Pengaruh Guided Inquiry Learning Terhadap Keterampilan Metakognisi Siswa dalam Materi Kelarutan dan Hasil Kali Kelarutan. *Journal of Innovative Science Education*, 5(1), 19-27.

Ngertini, N., Sadia, W., & Yudana, M. (2014). Pengaruh Implementasi Model Pembelajaran Inquiry Terbimbing Terhadap Kemampuan Pemahaman Konsep Dan Literasi Sains Siswa Kelas X Sma Pgri 1 Amlapura. *E-Journal Program Pascasarjana Universitas Pendidikan Ganesha*, 4(1), 1–11

Nyachwaya, J. M. & Wood, N. B. (2014). Evaluation of chemical representations in physical chemistry texbooks. *Chemistry Education Research and Practice, 15*, 720-728.

Oguz-unver, A. & Arabacioglu, S. (2011). Overviews On Inquiry Based And Problem Based Learning Methods. *Western Anatolia Journal of Educational Sciences (WAJES)*. Tersedia di http://web.deu.edu.tr/baed/giris/ baed/ozel_sayi/303-310.pdf [diakses 01-02- 2018]

Petrucci, R. H., Harwood, W. S., Herring, F. G., & Madura, J. D. (2011). *Kimia Dasar: Prinsip-Prinsip dan Aplikasi Modern. 9th ed. Jilid 2.* Penerbit Erlangga; Jakarta.

Pratiwi, R., Sumarti, S. S., & Endang, S. (2018). Identification of Students Basic Science Process Skills Assisted of Practical Worksheet Based on Multiple Representations. *Journal of Innovative Science Education,* 7 (1),107-113.

Qing, Z., Guo, J., Liu, Y., Wang, T., & Ma, J. (2010). Promoting preservice teachers' critical thinking Disposition by inquiry-based chemical experiment. *Procedia Social and Behavioral Sciences* 9:1429–1436.

Redhana, I W. & Liliasari. (2008). Program Pembelajaran Keterampilan Berpikir Kritis pada Topik Laju Reaksi untuk Siswa SMA. *Forum Kependidikan*, 27(2), 103-112.

Riyani, A., F., Ersanghono, K., & Harjito. (2017). Pengembangan Lembar Kerja Siswa Berpendekatan Inkuiri Terbimbing pada Konsep Kelarutan. *Jurnal Inovasi Pendidikan Kimia*, 11(2), 2008 – 2019.

Septiani, D., Sumarni, W., & Saptorini (2014). Efektivitas Model *Inquiry Based Learning* Berbantuan Modul Dalam Meningkatkan Pemahaman Konsep Dan Keterampilan Generik Sains Peserta didik. *Jurnal Inovasi Pendidikan Kimia*. 8 (2): 1340-1350.

Sheppard, K. (2006). High School Students' Understanding of Titrations and Related Acid-Base Phenomena. *Chemistry Education Research and Practice*, 7(1). 32-45.

Snyder, L. & Snyder, M.J. (2008). Teaching Critical Thinking and Problem Solving Skills. *The Journal of Research in Business Education*, 50 (2), 90-99.

Sugiyono. (2015). *Metode Penelitian Pendidikan: Pendekatan kuantitatif, kualitatif, dan R&D*. Bandung: Alfabeta.

Sunyono, Yuanita, L., Ibrahim, M. (2015). Mental Models Of Students On Stoichiometry Concept In Learning By Method Based On Multiple Representation. *The Online Journal of New Horizon In Education*, 5(2), 30-45.

Sunyono. (2011). *Kajian Tentang Peran Multipel Representasi Pembelajaran kimia dalam pengembangan Model Mental Siswa.* Makalah Seminar Nasional Pendidikan : Surabaya

Thomas, T. (2011). Developing First Year Student's Critical Thinking Skills. *Asian Social Science*, 7(4), 26-35.

Trianto. (2010). *Mendesain Model Pembelajaran Inovatif-Progresif, Konsep, Landasan, Dan Implementasi Pada KTSP*. Jakarta: Kencana.

Trianto. (2013). *Mendesain Model Pembelajaran Inovatif –Progresif : Konsep, Landasan, dan Implementasinya Pada Kurikulum Tingkat Satuan Pendidikan (KTSP).* Jakarta : Kencana Prenada Media Group.

Trisanti, D. C. & Sanjaya, I. G. M. (2013). Pengembangan Media Permainan Stoichiogame Pada Materi Pokok Konsep Mol Bagi Siswa Sma Sekolah Berstandar Internasional.*Unesa Journal of Chemical Education*, 2(2), 181–187.

Van Driel, J. H. & Graber, W. (2002). The teaching and learning of chemical equilibrium. In J. K. Gilbert, O. de Jong, R. Justi, D. F. Treagust, & J. H. van Driel (Eds.), *Chemical education: Towards research-based practice* (271-281). Netherlands: Kluwer Academic Publishers.

Villalba, E. (2011). Criticel Thinking. Joint Research Center of The European Commission. Italy: Ispra, 323-325. Retrieved from https://www.sciencedirect.com/topics/psychology/critical-thinking

Wang, C.Y. (2007). The Role of Mental-Modeling Ability, Content Knowledge, and Mental Models in General Chemistry Students' Understanding about Molecular Polari. Dissertation for the Doctor Degree of Philosophy in the Graduate School of the University of Missouri. Columbia.

Wahyudin, Sutikno, & Isa, A. (2010). Keefektifan Pembelajaran Berbantuan Multimedia Menggunakan Metode Inquiry Terbimbing Untuk Meningkatkan
Minat Dan Pemahaman Siswa. *Jurnal*

Pendidikan Fisika Indonesia, 6, 58–62.

Wardani, S., Setiawan S., & Kasmadi, I. S. (2016). Pembelajaran Inkuiri terbimbing Terhadap Pemahaman Konsep dan Oral Activities pada Materi Pokok reaksi Reduksi dan Oksidasi. *Jurnal Inovasi Pendidikan Kimia*, 10(2), 1743 – 1750.

Wardani, S., Lia, L., & Kusuma, S. B. W. (2017). The Development of Inquiry by Using Android System Based Chemistry Board Game to Improve Learning Outcome and Critical Thinking Ability. *Jurnal Pendidikan IPA Indonesia,* 6(2), 196-205.

Wardani, S. & Sumarti, S. S. (2017). Guidebook Of Basic Analytical Chemistry
Lecture Using Laboratory Inquiry-Based Activity To Develop Multiple Intelligence. *11th Joint Conference on Chemistry in Conjunction with 4th Regional Biomaterial Scientific Meeting Proceeding of Chemistry Conferences*, 49–55.

Weaver, M. G., Andrey V. S, Robert B. L., & Morgan J. G. (2016). Developing Students' Critical Thinking, Problem Solving, and Analysis Skills in an Inquiry-Based Synthetic Organic Laboratory Course. *Journal of Chemical Education*, *93* (5), 847–851.

Wibowo, T., Supartono, & Kasmadi, I. S. (2015). Pengembangan Modul Termokimia Dengan Pendekatan Inquiry Terpadu Pendidikan Karakter.

Wu, H. K., Joseph, S. K., & Elliot, S. (2000). Promoting Conceptual Understanding of Chemical Representations: Students' Use of a Visualization Tool in the Classroom. Dalam: the annual meeting of the National Association of Research in Science Teaching. New Orleans, LA., 28 April-1 May 2000. Los Angelea: National Association of Research in Science Teaching. 1-15.

Yotiani, Kasmadi, I. S., & Murbangun, N., (2016). Pengembangan Bahan Ajar Hidrolisis Garam Bermuatan Karakter Berbasis Inkuiri terbimbing untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Jurnal Inovasi Pendidikan Kimia*, 10(2), 1731-1742.

Yulianingsih, U. & Hadisaputro, S. (2013). Keefektifan Pendekatan *Student Centered Learning* Dengan Inkuiri Terbimbing Untuk Meningkatkan Hasil Belajar. *Chemistry in Education*, 2(2), 149-155.