Development and application of learning cycle model on science teaching and learning: a literature review

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Abstract. The Learning Cycle Model is a constructivist instructional model whether student use their prior knowledge and experiences to construct their thinking. The purpose of this study is to review the development and application of Learning cycle model especially in the last 1 decade. Technique of collecting data was through literature study: obtained some comparisons of phases of Learning cycle models such as 3E Learning Cycle Models, 5E learning cycle model, and 7E learning cycle models. These models are related to each other in their developments. In addition, each of them has its own characteristic. This study found that 7E LC Models can enhance educational effects: student’s Achievement, critical thinking, Science process Skills and Moral reasoning. Therefore, educators, practitioner and researcher should be supported to implement the Learning Cycle Model in Science Teaching and Learning.

1. Introduction

Science is knowledge obtained by using methods based on scientific observation related to how we find out about nature systematically. Thus, in science learning, teachers must plan learning activities so that students do an activity in acquiring their knowledge. Many learning models can be used by the teachers in reaching the learning goal, one of them is Learning Cycle Model. Previous research states that the application of the Learning Cycle model can facilitate students in learning, because it directly interacts with the environment to analyze phenomena, so that they can understand the concept of teaching materials and achieve its learning goals[1]. Other studies state that the application of Learning Cycle involves students’ active role during the learning process and can improve learning outcomes. The learning cycle invites the teacher to be able to produce a series of meaningful activities so that students’ critical thinking skills are also trained [2]. Critical thinking skills is needed by the students to prepare themselves in the future life [3]. Trough Learning Cycle students have an opportunity to explain and express their arguments, interpret and refine their ideas [4], [5]. Therefore, the use of learning cycle models can improve students’ learning achievement[6].

The first person to introduce the concept of the Learning Cycle model is Robert Karplus through the Science Curriculum Improvement Study (SCIS). Some literature reveals the development of the learning cycle stage starting from 3 E [7], 5E [8], and 7E [9]. Each stage of the Learning Cycle model comes from English words which are learning processes symbolized by the capital letter "E". (see figure 1)[8]. Lorsbach (2006), Learning Cycle is a learning model in educational science that is consistent with contemporary theories about how individuals learn. Learning Cycle is a learning model with a constructivist approach which initially consists of 3 stages, namely: exploration, invention, and
discovery. The three stages are then developed into five stages: engage, explore, explain, elaborate, and evaluate (Learning Cycle 5E) [1]. Furthermore, based on the proposal of Einsenkraft (2003), the 5E Learning Cycle was further developed into seven stages, namely: Elicit, Engage, Explore, Explain, Elaborate, Evaluate, and Extend (Learning Cycle 7E).

Based on the above mentioned explanation, the present Article will describe and discuss about development and application of Learning Cycle in Science Teaching.

2. Research Method
This article aims to describe some models of Learning Cycle, try to compare them, and see the use of them in any researches. In this study, data collection techniques in the form of studying literature, especially in the last 1 decade. In this article, writers tried to get some theories about Learning Cycle in many literatures. This study tries to compare several studies related to theory, development and implementation specifically for science learning in the world. The literature review study was conducted in August-September 2018.

3. Result
In what follows, the overviewed articles are presented according to the following main categories: Comparison of Learning Cycle; Implementation Learning Cycle based on Education Level; and Effect of Learning Cycle to Education. See table 1.

3.1. Comparison of Learning Cycle Models
In this part there are various articles that discuss the development of the Learning Cycle model starting from 3E Learning Cycle, 4E, 5 E, 6E and 7E Learning Cycle Models. Learning Cycle is a model that is centered on students (student centered). Learning Cycle provides opportunities for students to develop confidence through active involvement of students during the learning process.

In 1970 based on Jean Piaget's cognitive development theory, the director of the Science Curriculum Improvement Studies, Robert Karplus, proposed a learning strategy in the form of a learning cycle. Learning Cycle is a teaching strategy that is formally used in elementary school science programs, namely the Science Curriculum Improvement Study (SCIS). Although this strategy was first implemented in elementary school, several studies have shown that the application of this teaching technique has been widespread at various levels of the class, including the University. Learning Cycle is an arrangement in such a way from a series of activities (stages) so that learning competencies are expected to be mastered by students through their active role in participating in the whole series of activities. [10]. The Learning Cycle Model is also a learning model that uses a constructivist approach where knowledge is built on students' own knowledge[11]. If the knowledge construction process occurs well then students' understanding of the material learned will be improved so that meaningful learning is achieved.

The first version of this model is in the form of learning with 3 phases or easily known as 3E, namely initial exploration, introduction of concepts and discoveries[4], [12], [13]. In this exploration phase, children are invited to collect data and explore it. Besides this phase also stimulates children's curiosity, develops the need to know something, learners are given the opportunity to utilize their five senses as much as possible in interacting with the environment through activities such as practicum, analyzing articles, discussing and observing natural phenomena, and others. From this activity, it is expected that mental imbalances arise so that questions arise that lead to the development of high level reasoning or commonly called children's critical thinking which begins with words such as why and how. The emergence of these questions is at the same time an indicator of students' readiness to take the next phase, namely the concept recognition phase. In the concept recognition phase, a process is expected to lead to a balance between the concepts that the learner has and the concepts that have just been learned through activities that require reasoning skills such as studying library resources and discussing. Here the child learns terms related to the new concept being studied. Whereas in the last phase, namely the application of concepts, learners are invited to apply the understanding of the
concept through activities such as problem solving. The application of this concept can improve understanding of concepts and motivation to learn, because children know the real application of the concepts they have learned.

Then the next 3 phases are revised to increase expression (Hanley, 1997) and develop from the exploration phase followed by the expansion phase (Expansion) where the Teacher guides students to interact to use concepts and ideas in everyday life[13].

In learning cycle 5e, there is a combination of the three phases in learning cycle 3e and the addition of the latest two phases, namely the engaging stage before exploring and the evaluate phase at the end of the cycle. In addition, the stages of concept introduction and concept application are each given the terms explain and elaborate. Therefore, the 5e learning cycle phase is often dubbed LC 5E (Engage, Explore, Explain, Elaborate, and Evaluate [14]–[17].

Besides LC 5E, based on the development of Einsenkraft[9] was born as a development of 5E which is included in the learning cycle model. The development of learning cycle 5e becomes learning cycle 7e occurs at certain stages, namely the Engage stage becomes Elicit and Engage while in the Elaborate and Evaluate stage there are three stages, namely Elaborate, Evaluate, and Extend. Based on the explanation of Einsenkraft[9], [18], [19], the seven stages of learning cycle 7E are:

1. **Elicit (raises students' initial understanding)**
   At this stage the teacher tries to generate or bring in students' initial knowledge by giving basic questions related to the material to be studied. These questions are taken from several easy examples that students know in their daily lives. This aims to get a response from students and stimulate curiosity about the answers to the questions raised by the teacher. Learning Cycle 7e, which is part of constructivist learning, prioritizes knowledge or initial understanding which will later become the foundation for new knowledge[2], [9], [11], [20]–[22]

2. **Engagement**
   Activities in this phase aim to get students' attention, encourage their thinking skills, and help them access the initial knowledge they already have. The important thing that needs to be achieved is the emergence of curiosity of students about the theme or topic to be studied. The teacher tells students to be more interested in learning concepts and paying attention to the teacher in teaching. This stage is carried out by demonstration, discussion, reading, or other activities.

3. **Exploration**
   In the exploration phase, students are given the opportunity to work both independently and in groups without instruction or direction directly from the teacher. Students manipulate an object, conduct experiments, investigations, observations, collect data, to make initial conclusions from the experiments carried out. The teacher acts as a facilitator, which is to help students work on the scope of the problem (previously made hypothesis) and provide opportunities for students to test the guesses / hypotheses they have set. Thus, students are expected to gain knowledge with direct experience related to the concepts learned.

4. **Explanation**
   Learning activities in the explain phase aim to complete, refine, and develop concepts obtained by students. The teacher encourages students to explain the concepts and definitions they understand in their own words and show examples related to the concept to complete the explanation. From the definition and concept, it is then discussed so that in the end it leads to a formal definition.

5. **Elaboration**
   In the elaborate phase students apply symbols, definitions, concepts, and skills to problems related to examples of lessons learned

6. **Evaluation**
   Evaluation is the stage where the teacher evaluates the results of the learning that has been done. At this stage various assessment strategies can be used both formally and informally. The teacher is expected to continuously make observations and pay attention to the abilities and skills of students to assess their level of knowledge, then see changes in students' thinking towards their initial thinking.
7. Extend
In this final stage, students are required to think, search, find, and explain examples of the application of new concepts and skills that have been learned. The teacher can direct students to obtain alternative explanations using data or facts that they explore in new situations. In addition, through this activity the teacher stimulates students to look for the relationships of concepts they learn with other concepts that have been or have not been studied.[2], [9], [11], [20]–[22]. See Figure 1.

![Figure 1: Development of LC](image)

**Figure 1:** Development of LC
Note: created by Arthur Eisenkraft

3.2. Implementation of Learning Cycle based on Education Level
Science learning is on average in the curriculum system at any level of education. The nature of science which is the object of knowledge whose object of observation is nature with all its contents obtained through scientific methods[6]. The use of scientific methods in science learning is done through learning processes and activities, one of them is through the method and learning model based on constructivists, one of which is the Learning Cycle model. Of the 27 articles discussed in this paper, the average research is directly related to educational institutions ranging from elementary to tertiary education. This is because everyone's IPA complies with the idea of the National Science Education Standards (NRC) that science in schools must be for all students, regardless of age, sex, ethnic and cultural background, students with special needs or normal and all should be get a chance to reach a high level of scientific literacy[23]. One of the strengths of the strategy is through the use of the Learning Cycle model because of several studies that have a positive influence on science education[8], [23].

Articles related to the use of the Learning Cycle model in elementary schools reported that the implementation of this model made a tremendous influence in elementary school[1], [13], in Junior High School [6], [17], [24], Senior High School [15], [20], [21], [25]–[28], College [14] and Teacher.

3.3. Implementation of Learning Cycle in Science and Learning Models
The previous discussion was related to the implementation of the Learning Cycle model at the education level, to further discuss some of the effects of the learning cycle model on the object of education itself. Many articles explain that the impact of this model has a positive effect on education,
especially science learning in schools. Starting from the positive influence on learning outcomes, student critical thinking to the affective and psychomotor domains as well as the development of learning devices that use this model. The following will be explained respectively:

3.3.1. **Learning Cycle Model can Increase Students’ Achievement.** This research was conducted by Hasret NUHOGLU [12]. His focus research Laboratory. This research was conducted to see the comparison and influence of the use of the Learning cycle model with Traditional Teaching Methods on the attitudes of prospective teachers in the Physics laboratory. The type of this study are quasi experiment.

Based on the statistical analysis of this study, it was found that there were no significant differences between the attitudes of prospective teachers towards physics laboratories in the two sample classes. However, there are differences in the scientific success test where the Learning Cycle model produces more effective and meaningful learning so that students are able to apply their knowledge not only to focus on one field and even develop outside the original context.[2]

Other research was conducted by Ira Nofita Sari1, Dwi Fajar Saputri and Yupensius Beno (Prodi Pendidikan Fisika, IKIP PGRI Pontianak)[6]. The focus research was Application of 5E Learning Cycle Model in Basic Units and Derived VII Class of SMP 1 Sengah Temila. The method used in this research is quasi-experimental use posttest-only control design. The result of this research show that this Model can increase student’s achievement[4],[6], [12], [20], [29]

3.3.2. **Learning Cycle Model can Improve Student’s Critical Thinking Ability.** This research was conducted by Partini, Budijanto, Syamsul Bachri (Post-Graduate of Universitas Negeri Malang). The focus research was the application of 7E Learning Cycle Model to Improve Students' Critical Thinking Ability on geography subjects. This study uses classroom action research design[30].

Other research The results showed that the 5E learning cycle model can improve students' critical thinking skills are the indicators of problem-solving N-gain score of 0.43 in the medium category, the indicator makes a decision with an N-gain score of 0.42 with the medium category, an experimental inquiry indicator with an N-gain score of 0.33 with medium category and the indicator concludes with an N-gain score of 0.37 with the medium category. From this result means that student’s critical thinking skills can improved by applied of learning cycle models. [5][17], [28]

3.3.3. **Learning Cycle Model can Increase Learning Motivations, Self Esteem, Attitude and Moral Reasoning.** This research was conducted by Ismy Aulina Candra, Hainur Rasid Achmadi (Pendidikan Fisika, Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Negeri Surabaya). Focus research was Learning Cycle Model 7E to Increase Student Motivation and Learning Outcomes in Class X Harmonic Motion Material in SMA 1 Kejayan. In this study, we know how the learning process is carried out, how motivation and learning outcomes and student responses can increase because of the use of this model, especially on the subject of Harmony Motion. This is a quantitative research design pre experimental -one group pre-test post-test design. From the discussion of the analysis of students' motivation before and after being treated, it was concluded that students' motivation increased by 89.42% to Excellent category. Its means that application of Learning Cycle model can increase learning motivations[31].

Other study was conducted by Firdaus (Program Studi Pendidikan Matematika, UPI Bandung)[24]. The research about effect of 7E learning cycle learning toward self-esteem. Based on the results there are significant differences in self-esteem student learning with 7E Model compared with conventional’s student. Because in this models, student can do many discussion, presentation and evaluation on classroom activities and this stage can improve student’s self-esteem [24]

3.3.4. **Learning Cycle Model can Increase Science Process Skill (SPS).** This research was conducted by Ferdinandus Bele Sole, Insihwilujeng (STKIP Weetebula NTT, Universitas Negeri Yogyakarta). From this study we find out how process skills can be improved through learning models. This is a
quantitative research design pre experimental. Based on Resul areThe experimental class which implements the learning cycle 4-E learning model has a higher average score increase than the control class that implements expository learning. The normal mean increase in knowledge variables, basic process skills and scientific attitudes of science is respectively 0.388; 0.342; 0.564 and all are in the moderate classification. Whereas in the control group, the increase in normal average in knowledge variables, basic process skills and scientific attitudes of the Natural Sciences is 0.253; 0.173; and 0.280 and all are in a low classification.

From the discussion of the analysis of students' Science Process Skills before and after being treated, it was concluded that students' SPS increased to Excellent category. Its means that application of Learning Cycle model can increase students' Science Process Skills[13]. Other study was conducted by Titiworada Polyiern, Prasart Nuangchalerm, Prayoon Mongchantra (Thailand) and Sutee Sornsakda, Paitool Suksringarn and Adisak Singsewo (Thailand)[1,11]. From this study it was concluded that the Learning Cycle Model can improve the skills of the science process because in one step of the model is the exploration that can train children to master all the science process skills ranging from basic Science Process Skills to Integrated Science Process Skills [1].

3.3.5. Development of Science Learning Tools using 7 E Learning Cycle Models. 2 research articles that discuss the development of the learning cycle model on learning devices, namely research conducted by Fembriani, Khumedi, Chatarina Tri Anni who develop learning tools in the form of syllabus, lesson plans, teaching materials and worksheets and evaluation sheets. From the results of the study it was found that the validity level of science learning devices to improve students' critical thinking skills was valid criteria, as well as their effectiveness. The average value of the experimental group using the 7E learning cycle model was able to be higher than conventional addition, the level of acceptance of students and teachers for learning devices is also in the good category [19].

Other research from this categorie is the development of the lesson plan by Selahatin Gonen and Serhat Kocakaya[22]. He modified learning physics on the topic of Electrostatics using 2D and 3D animations. Uniquely, this model combines the seven stages of the Learning Cycle Model so that students easily understand the core learning in the classroom. And In conclusion, using the 7E Learning Cycle Model, teachers are better able to integrate their educational goals to select and maintain the suitability of the technology chosen according to their needs. [22].

| Table 1. Research that Concerning Learning Cycle Model in Science Education |
| Author                  | Objective          | Lesson/Topic     | Sample                          | Major Findings                                      |
| Mitrayani Saleh         | Student’s Achievement | Biology         | 2 classes Class XI              | Student learning outcomes have an effect of 86 percent because they use the 7E Learning Cycle model |
| Hidayat Noviantyn       | Biology            | 2 classes Class XI | SMAN 4 Potianak               |                                                |
| Irhamna, Haris Rosdianto*, Eka Murdani | Critical Thinking FluidaSt atis | All eighth grade students of Torsina Singkawa ng Middle School | Cyle 5E learning model can improve students' critical thinking skills, namely on problem solving indicators with an N-gain score of 0.43 with the medium category. |
| Authors                  | Title                                                                 | Summary                                                                                                                                                                                                 |
|-------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Erva Rosa Prima Gayatri, Amrul Bahar, Dewi Handayani, 2017 | model and method Chemistry XI IPA 2 and XI IPA 3 City of Bengkulu 7 Plus High School | Understanding and student learning outcomes increase because it uses an LC learning model.                                                                                                               |
| Ferdinandus Bele Sole, Insihwilujeng, 2013 | Science Knowledge, Basic Process Skill and scientific attitude Science / Style IPA / Gaya Class V TA 2012/201 3 SD Kererobbo, Loura district, West Sumba district-NTT, class XI IPA SMAN 2012/201 3 SD Kererobb o, Loura district, West Sumba district-NTT, class XI IPA SMAN 107 SD Kererobbo, Loura district, West Sumba district-NTT, class XI IPA SMAN 2012/201 3 SD Kererobb o, Loura district, West Sumba district-NTT, class XI IPA SMAN 107 Jakarta | The experimental class which implements the learning cycle 4-E learning model has a higher average score increase than the control class that implements expository learning. |
| Izzah Imaniyah, Siswoyob, Fauzi Bakri, 2015 | Students Achievement, Physics/ Fisik Class XI MIPA SMAN 107 Jakarta | There is an effect of the application of LC7E and LC5E to learning on the acquisition of pretest and posttest.                                                                                          |
| Ira Novita Sari, Dwi Fajar Saputri, Yupensius Beno, 2016 | Students Achievement, Physics/ Besaran Pokok dan Turunan Fisik Class VII students of SMP N 1 SengahTe mila Middle school | Student learning outcomes after applied 5E Learning Cycle Model is better than student learning outcomes that are applied conventionally on the subject matter and the amount of derivatives in class VII SMPN 1 SengahTemila Kab. Pontianak Porcupine. |
| Rina Rahayu Ningsih, M. Masykuri dan Budi Utami, 2012 | Learning process and Student Achievement Chemistry 40 students of Class XI Science 1 SMA N 1 Kertapura | Application Learning cycle 5 E apply Map can improve the quality of student learning processes and the quality of student learning outcomes on the material of Solubility and Solubility Times of Class XI IPA SMA NI Kartasura TA 2011/2012 |
| Wawan Sturisno, Sri Dwia stuti dan Puguh Karyanto, 2012 | Student’s Motivation Biology Class XI Science Students of SMA Negeri 1 Banyudono 2011/201 | The sign value (a) = 0.039 <0.005 this means that the application of the Learning Cycle model has a significant effect on student learning motivation. |
| Rina Rahayu Ningsih, M. Masykuri dan Budi Utami, 2012 | Learning process and Student Achievement Chemistry 40 students of Class XI Science 1 SMA N 1 Kertapura | Application Learning cycle 5 E apply Map can improve the quality of student learning processes and the quality of student learning outcomes on the material of Solubility and Solubility Times of Class XI IPA SMA NI Kartasura TA 2011/2012 |
| Wawan Sturisno, Sri Dwia stuti dan Puguh Karyanto, 2012 | Student’s Motivation Biology Class XI Science Students of SMA Negeri 1 Banyudono 2011/201 | The sign value (a) = 0.039 <0.005 this means that the application of the Learning Cycle model has a significant effect on student learning motivation. |
| Author(s)                        | Title                                                                 |
|---------------------------------|----------------------------------------------------------------------|
| Anton Harmoko, Nika Kadaritna, Lisa Tania dan Nor Fadawati           | Skill of Communicating and Inference Chemistry of class XI IPA 3 and class XI IPA 4 SMA YP Unila Bandar Lampung from the study concluded that the learning device has a 84.7 level of validity and the device is also able to improve students' critical thinking skills with N-Gain achievement of 0.62% (medium criteria) The Teaching Plan using the 7E Learning Cycle is more effective than the socioscience issue based learning approach. |
| Fembriani, Khumedi, Chatarina Tri Anni                                | Perangkat pembelajaran Science Education Elementary science learning device Elementary school From the study concluded that the learning device has a 84.7 level of validity and the device is also able to improve students' critical thinking skills with N-Gain achievement of 0.62% (medium criteria) There is influence of experimental based learning Cycle 5E model to the critical thinking ability of Physics Student Class XI SMAN I Gerung. |
| I’in Senja Septiana, Ahmad Harjono, Hikmawati                          | Critical Thinking Ability Physics Student Class XI MIPA-3 dan XI MIPA -2 SMAN I Gerung For Elementary school Higher scores were obtained by students who conducted inquiry-based learning compared to scores of students who learned through traditional methods. |
| Kuan-Jhen Huang, Tzu-Chien Liu, Sabine Graf and Yi-Chun Lin           | Natural Science Learning Biologi Mobile and ubiquitous technologies in outdoors Science For Elementary school Higher scores were obtained by students who conducted inquiry-based learning compared to scores of students who learned through traditional methods. |
| Ali Abdi, 2014                                                         | Students’ Academic Achievement Science Course 20 experimental and 20 control group girl students at 5th grade in primary schools in Kermanshah, Iran. SD Higher scores were obtained by students who conducted inquiry-based learning compared to scores of students who learned through traditional methods. |
| Titiworada Poliyiem, Prasart Nuangchaler m, Prayoon Wongchantra        | Learning Achievement, heredity Science Process Skills, Biologi 35 of 9 grade students from 4 classes studying The Teaching Plan using the 7E Learning Cycle is more effective than the socioscience issue based learning approach. |
| Author(s)                        | Title                                                                 | Details                                                                                                                                 |
|---------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Nuri Balta, Hakan Sarac, 2016   | Science Teaching in the 2nd semester, academic year 2010.             | Based on the meta-analysis calculation in this study illustrates that the 7E learning cycle is a useful strategy that must be included in the science curriculum. |
| Sute Sornsakda, Paitool Suksringarm and Adisak Singseewo | Learning Achievement, Integrated Science Process Skills and Critical Thinking Students Self-esteem | The overall students: the overall of experimental student group studying by 7E Learning Cycle with Metakognitive Techniques had average learning achievement score, overall and each aspect form 5 aspect of integrated Science Process Skills. |
| F.Firdaus, N.Priatna and S.Suhendra | Mathematics Student of Junior High School (SMP)                      | Self-esteem’s Students learned The 7E Learning Cycle Model is better than student learned conventional learning.                         |
| Seven, S, Tiryaki and Ceylan    | Academic Success and Students Attitude                                | There is no significant difference between the use of the 5E Learning Cycle model                                                   |
| Erdal Tashdere                  | Science Teachers’ Achievement Photoelectric Effect, Physics          | The instruction developed for the experimental group affected participants' post-achievement and post-open-ended exam scores significantly. |
| Gonen, S and Kocakaya           | Lesson Plan Physics                                                  | Learning plans that use the 7e model are better                                                                                  |
| Hasret N.G Lu and Yalein        | Students’ Achievement Physics                                        | There are differences in the scientific success test where the Learning Cycle model produces more effective and meaningful.          |
In the concept of elasticity most are found that students hold alternative conceptions before treatment and after treatment some students have more scientific understanding than before.

Motivation And student learning outcomes are increasing because of using this model.

Increasing students' critical thinking skills better and encouraging fidelity to instructional models designed to help students.

4. Conclusion
In total there are 27 literature studies on the use of the learning cycle 3E, 5E and 7E as ways and strategies in improving the education process in all level education because the main problem in teaching scientific knowledge through this model can be helped to be solved. It Facilitates student to learn effectively and organize the knowledge in a meaningful way. Success is more easily achieved by students who are educated with inquiry-based learning supported by a Learning Cycle model rather than education that uses traditional methods. Because Learning cycle 7E model connects prior knowledge of students to form new knowledge through seven stages or phases which are interrelated, thus making students easy to understand the concepts learned and apply it to practice questions, as well as connect it to examples in life daily.

The high influence of this Learning Cycle model encourages teachers to incorporate this strategy in their teaching and gradually the teacher must be able to adapt their learning style to this model. This is evidenced by the success of several schools and colleges based on the 27 literature so that this could be a research finding that could be developed by educational researchers. This study found that 7E LC Models can enhance educational effects: student’s Achievement, critical thinking, Science process Skills and Moral reasoning. It is hoped that the study will provide useful guidance to educators, practitioner and researcher in Science Teaching and Learning.

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