The potential of discovery learning models to empower students' critical thinking skills

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Abstract. Critical thinking skills have become the competencies of educational goals. This article aims to examine the potential of discovery learning models that are applied in science learning to empower students' critical thinking skills. The method used is qualitative with the main source of literature review about discovery learning models and critical thinking skills. The results of the analysis of the discovery learning model literature with orientation, hypothesis generation, hypothesis testing, conclusion, and regulation stages. Discovery learning model has the potential to empower critical thinking skills starting from the hypothesis generation stage which aims to provide a rational argument from a real phenomenon orientation phase which is continued by the process of interpretation, analyzing, evaluating, concluding the experimental results of the hypothesis testing stage until the right conclusion is obtained from the experimental results.

Keywords: discovery, critical thinking, skills

1. Introduction
Science education aims to teach students to be involved in scientific inquiry [1], so it is expected to be able to practice various science process skills [2]–[4]. The scientific skills students are able to have will help to develop their potential both personally and socially. Integrated self potential from aspects of knowledge, skills and attitudes will be useful in facing challenges in their lives.

Students who have good problem-solving skills mean showing ability in high-level thought processes. The ability to think highly that plays a role in moral development, social development, mental development, cognitive development, and scientific development include critical thinking [5], so it needs to be developed in students through the learning process.

The teacher needs to design and prepare an appropriate learning process so that the specified learning objectives can be achieved. The learning process which consists of the steps of the teacher and student activities will be implemented in a learning model. The learning model can be said to be the structure the blueprint provides and the direction for the teacher to teach [6], so that it functions as a conceptual framework that is able to describe systematic procedures in regulating learning experiences to achieve certain learning goals and to guide teachers' learning plans in carrying out learning activities.

Students are expected to follow the learning process can empower critical thinking skills so that they can find concepts through knowledge independently [7]. The discovery of the concept of knowledge independently was enhanced through inquiry activities. Investigation activities can be found in science learning including using discovery learning models [8]. Discovery learning is a learning model recommended by the 2013 curriculum to be applied in developing students' critical thinking skills [9], because students themselves try to find their own concepts through scientific methods, not through being given information or understanding concepts directly by the teacher.

Discovery learning model has five syntax, namely orientation, hypothesis generation, hypothesis testing, conclusion, and regulation [10]. Orientation is the behavior of students building initial understanding by involving information and knowledge that has been previously obtained. Hypothesis generation is the behavior of students compiling hypotheses from initial problems. Hypothesis testing is the behavior of students planning and conducting experiments to test hypotheses. Conclusion is the behavior of students reviewing the results of
an experiment and linking it to a hypothesis that has been prepared. Regulation is the behavior of students together with the teacher reviewing the results of an experiment to provide a final conclusion.

Discovery learning model can be divided into two namely pure discovery learning, and guided discovery. Learning pure discovery in the learning process itself, students find independently the problems and solutions of a case in an unplanned way [11]. While guided discovery, students begin learning with interesting questions and concrete material, by working as individuals or groups exploring material, making observations, and finding answers to questions when the teacher works as a facilitator [12]. Discovery learning activities can motivate students during search and discovery [13]. This activity also helps students to find their own meaning and systematize their own ideas [14]. Discovery learning models also have the potential to improve student performance during the learning process [15], because students do activities to formulate hypotheses and test hypotheses through evidence collected [16], so the discovery learning model includes constructivist learning that involves activating prior knowledge, problem interpretation, explanation of the results of the experiment, and modification and integration of concept understanding.

Besides having many advantages, the study also found several weaknesses of the discovery learning model when applied in learning. In general, discovery learning models do not have a positive impact if without using assistance [7], [17]. Students also experience confusion if not given instructions at the discovery stage [18]. In addition there is a main reason teachers do not teach using discovery learning is because it will not cover the entire lesson content, requires too much preparation and learning time [19]. Based on the above study, a potential study of discovery learning models was conducted to empower students' critical thinking skills.

2. Method

The method used is a qualitative analysis with the main source obtained from a literature review on discovery learning models related to the development of students' critical thinking skills. The learning model studied was discovery learning and critical thinking skills from Facione. Based on this, the potential of discovery learning models is then examined to empower students' critical thinking skills in science learning.

3. Results and Discussion

From the results of a literature study on discovery learning models, syntax characteristics are obtained which are the sequence of learning that contains the activities of teachers and students. Furthermore, critical thinking skills were also studied so that six dimensions were obtained based on the results of the Delphi method conducted by Facione. Then the last is a study of the potential of discovery learning models to empower students' critical thinking skills.

3.1 Discovery Learning Model

Discovery learning model has five syntax, namely orientation, hypothesis generation, hypothesis testing, conclusion, and regulation. The syntax of orientation is the process of learning to build first ideas from initial knowledge which is done by providing initial information to explore knowledge and identify material variables. At this stage simulations are given to students, then the teacher leads students to identify problems based on the simulations they face. Simulation is one of the ways teachers motivate students to encourage students' curiosity.

The second syntax, hypothesis generation, is a step-in student learning to formulate a hypothesis about a problem that has been formulated. Hypotheses are prepared by asking various questions, so that basic knowledge is obtained as a reference in preparing hypotheses [20]. In line with previous opinions, this stage also accommodates students to encourage articulating ideas, understandings, experiences and personal opinions [21].

The third syntax is hypothesis testing, which is the student's activity to find the real answer to the problem that has been formulated. Activities at this stage are: designing experiments, conducting experiments, and interpreting experimental data. At this stage the data collected is then discussed by students for analysis [22]. This opinion is reinforced by the opinion that provides experience in forming predictions based on evidence to students, helps students in thinking causally and directs students in learning [23].

The fourth syntax is the conclusion is a step for students to draw conclusions based on the findings. Students conclude the results of experiments conducted in accordance with the hypotheses that have been prepared or there is a difference between the results of experiments with hypotheses, and identify the differences between the results of experiments and hypotheses [10]. In line with the previous opinion that this stage serves to encourage students to find clues or evidence, the results of the analysis, and make determinations about possible conclusions that are useful for connecting between components of learning material [23].
The fifth syntax is regulation which consists of planning, monitoring, and evaluation [10]. Evaluation is a systematic and ongoing process to determine the quality of objects based on certain considerations and criteria in the context of making conclusions [24].

3.2 Critical Thinking Skills

Attention to teach thinking skills has influenced the education system in various countries. Society agrees that thinking skills are important for someone to be able to survive and compete in a fast-paced and competitive life. In the era of information and technology survey, there is an urgent need for students to learn in various thinking skills [25]. Life in the 21st century requires students to practice problem solving skills and thinking abilities. The ability to think that supports problem solving one of which is the ability to think critically.

Critical thinking skills are important for individuals to live, work and function effectively in society. Almost all professions, including education, engineering, management, medical, finance, politics and law, require the ability to think critically on individuals, because it requires clear and rational thinking to solve problems systematically. To produce the right solution for a problem, existing practices may have to be evaluated and modified to improve results and to find alternative ways and ways of doing things.

Some experts argue about the definition of critical thinking [26], which is summarized in Table 1.

| Expert                  | Definition                                                                 |
|-------------------------|-----------------------------------------------------------------------------|
| Ennis, 1987             | Reasonable reflective thinking that is focused on deciding what to believe or do |
| Richard Paul, 1988      | The ability to reach strong conclusions based on observations and information |
| Laporan Delphi, 1990    | A purposeful assessment, self-regulation that results in the interpretation, analysis, evaluation, and inference, as well as an explanation of the consideration of the evidence, conceptual, methodological, criteriological, or contextual basis on which the assessment is based |
| Scriven & Paul, 1994    | The process of intellectual discipline that actively and skillfully conceptualizes, applies, analyzes, synthesizes, and or evaluates information collected from, or generated by, observations, experiences, reflections, reasoning, or communication, as a guide for beliefs and actions. |
| Angelo, 1995            | Intentional application of rational, high-level thinking skills, such as analysis, synthesis, problem recognition and problem solving, inference, and evaluation |
| Beyer, 1995             | Make a reasonable judgment |
| Halpern, 1996           | Thinking aimed, reasoned, and directed at the goal. This is the type of thinking involved in solving problems, formulating conclusions, calculating possibilities, and making decisions |

Of the several opinions in Table 1, the definition of critical thinking is a skill that involves active interaction with knowledge, the techniques used in problem solving and decision making tend to be more linear and serial, more structured, more rational and analytical, and more goal oriented, so it is sometimes referred to as left brain thinking (analytic, serial, logical, objective).

In the Delphi report which is the result of a consensus developed by forty-six experts from various disciplines, including science and education, presents a number of characteristics of critical thinkers [27]. Ideal critical thinkers are usually curious, knowledgeable, believe in reason, open-minded, flexible, fair-minded in evaluation, honest in dealing with personal biases, wise in making judgments, willing to reconsider, clear about problems, orderly in complex problems, diligently looking for relevant information, makes sense in the selection of criteria, focus on the investigation, and persistent in finding results that match the subject conditions and circumstances of the investigation. The six components of the cognitive skills of critical thinking, according to the Delphi Report, are presented in Figure 1.

![Figure 1. Six dimensions of critical thinking skills according to the Delphi Report](image-url)
The explanation in Figure 1 that is, interpretation is the condition of the subject to understand and express the meaning of experience, situations, data, phenomena, judgments, conventions, beliefs, rules, procedures or criteria. This component says that the subject must be able to provide arguments. These arguments are related to data and must provide clarification regarding data or information from the condition. Analysis (analysis) is the process of identifying inferential relationships between statements, questions, concepts, descriptions, data or other forms. On the other hand, analysis is the ability to identify information relationships to make statements or arguments. Evaluation is the ability to assess credibility, statements (other representations) that provide an explanation or description of a person's perceptions, experiences, situations, considerations, beliefs, or opinions and to assess logical statements of actual inferential relationships including descriptions, questions or other forms. The conclusion (inference) is a condition in which the subject identifies and determines the elements needed to make conclusions, and hypotheses; Consider relevant information and get consequences from data, reports, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms. At this stage, the subject must use the ability to identify the elements needed. The explanation (explanation) is to proclaim the results of reasoning, justifying reasoning based on consideration of evidence, concepts, methodologies, criteria, and context. This condition is useful to ensure a response. The last aspect of critical thinking by Facione is self-regulation which means the subject has the awareness to optimize the students' self-cognitive activities, the elements involved, the results, especially by applying the skills of analyzing and evaluating themselves.

3.3 The potential of the Discovery Learning Model to empower Critical Thinking Skills

The learning models recommended in the 2013 curriculum include discovery because students find their own knowledge and have a scientific approach [28]. Another reason to apply discovery learning is because it makes students faster to have a good increase in learning [29], gives students the opportunity to do scientific reasoning [30] and use critical thinking skills [31]. From some of these opinions it can be stated that discovery learning is student-oriented, so that it acts as an active participant, this condition makes students have more attention on learning in general so as to provide an opportunity to improve critical thinking skills by obtaining information and inquiry in authentic procedures.

The correlation of each steps in discovery learning with critical thinking skills is shown in Table 2.

| No | Critical Thinking Core Skills | The step (syntax) of discovery learning |
|----|--------------------------------|----------------------------------------|
|    | Dimension | Indicator | Orientation | Hypothesis generation | Hypothesis testing | Conclusion | Regulation |
| 1  | Interpretation | Classification | Making the code | Define the term | Orientation | Hypothesis generation | Hypothesis testing | Conclusion | Regulation |
| 2  | Analyse | Collecting idea | Argument | Hypothesis generation | Hypothesis testing | Conclusion | Regulation |
| 3  | Evaluation | Claim | Considering the argument | Conclusion | Regulation |
| 4  | Inference | Selecting the source | Making a conclusion | Conclusion |
| 5  | Explanation | Interpretade the result | Rate the arguments | Regulation |
| 6  | Self-regulation | Self correction |

From Table 2 the syntax relationship between discovery learning models and the potential to empower critical thinking skills from the orientation stage can be drawn, the teacher presents problems to stimulate students to classify, make the code and define the term so that they will practice their ability to interpret [32]. The second stage, hypothesis generation, is a step that makes students give rational arguments for problems at the orientation stage and also collects ideas to build reasons for problems that arise [33]. The initial hypothesis will then be proven through a series of activities observing, collecting data, and analyzing at the hypothesis testing stage. This stage accommodates students to articulate ideas, understandings, experiences and personal opinions [21]. The fourth stage, namely the conclusion, contains the activities of drawing conclusions based on the activities of observing, collecting data, and analyzing the previous stage. The conclusion stage has the potential to link between learning material components [23]. The last stage is regulation containing student activities with the teacher reviewing the results of the experiment so that it can be feedback for students to realize and identify their performance [34].
4. Conclusion

Overall, the effects of the discovery learning model without assistance seem not to run smoothly, while the discovery learning model that is enriched helps so that students to be actively involved and constructively look optimal results. Discovery learning model has the potential to empower critical thinking skills starting from the hypothesis generation phase which aims to provide a rational argument from a real phenomenon orientation phase which is continued by the process of interpretation, analyzing, evaluating, concluding experimental data through the hypothesis testing stage until the right conclusions are obtained from the results trial.

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Daftar Pustaka

[1] A. H. Zeidan and M. R. Jayosi, “Science Process Skills and Attitudes toward Science among Palestinian Secondary School Students,” World J. Educ., vol. 5, no. 1, pp. 13–24, 2015.
[2] W. Harlen, “Purposes and procedures for assessing science process skills,” Assess. Educ. Princ. policy Pract., vol. 6, no. 1, pp. 129–144, 1999.
[3] J. Huppert, S. M. Lomask, and R. Lazarowitz. “Computer simulations in the high school: Students’ cognitive stages, science process skills and academic achievement in microbiology,” Int. J. Sci. Educ., vol. 24, no. 8, pp. 803–821, 2002.
[4] H. Aktamis and Ö. Ergin, “The effect of scientific process skills education on students’ scientific creativity, science attitudes and academic achievements,” in Asia-Pacific Forum on Science Learning and Teaching, 2008, vol. 9, no. 1, pp. 1–21.
[5] S. A. Hashemi, E. Naderi, A. Shariatmadari, M. S. Naraghi, and M. Mehrabi, “Science Production in Iranian Educational System by the Use of Critical Thinking.,” Online Submit., vol. 3, no. 1, pp. 61–76, 2010.
[6] R. J. Marzano, Designing a New Taxonomy of Education Objective Thousand Oaks. California: Corwin Press, 2001.
[7] L. Alfieri, P. J. Brooks, N. J. Aldrich, and H. R. Tenenbaum, “Does discovery-based instruction enhance learning?,” J. Educ. Psychol., vol. 103, no. 1, p. 1, 2011.
[8] F. Fios, “Pengantar filsafat ilmu dan logika,” Jakarta: Salemba Humanika, 2013.
[9] Kementerian Pendidikan dan Kebudayaan, Materi Pelatihan Guru Implementasi Kurikulum 2013. Jakarta: Kementerian Pendidikan dan Kebudayaan, 2013.
[10] K. Veermans, “Intelligent support for discovery learning,” 2002.
[11] N. Senemoğlu, “Development, learning and teaching, from theory to practice,(12th), Ankara.” Gazi Press, 2005.
[12] J. E. Bass, T. L. Contant, and A. A. Carin, Teaching science as inquiry. Allyn & Bacon/Pearson, 2009.
[13] P. B. Sears and W. Kessen, “Statement of purposes and objectives of science education in school,” J. Res. Sci. Teach., vol. 2, no. 1, pp. 3–6, 1964.
[14] J. McTighe and G. Wiggins, “Understanding by design framework,” Alexandria, VA Assoc. Superv. Curric. Dev., 2012.
[15] M. A. Akanmu and M. O. Fajemidagba, “Guided-discovery learning strategy and senior school students performance in mathematics in Ejigbo, Nigeria,” J. Educ. Pract., vol. 4, no. 12, pp. 82–89, 2013.
[16] J. Zhang, Q. Chen, and D. J. Reid, “Simulation-based scientific discovery learning: a research on the effects of experimental support and learners’ reasoning ability,” in Proceedings of Conference on Educational Use of Information and Communication Technology, 2000, pp. 344–351.
[17] R. E. Mayer, “Should there be a three-strikes rule against pure discovery learning?,” Am. Psychol., vol. 59, no. 1, p. 14, 2004.
[18] W. Wagner, R. Göllner, A. Helmke, U. Trautwein, and O. Lüdtke, “Construct validity of student perceptions of instructional quality is high, but not perfect: Dimensionality and generalizability of domain-independent assessments,” Learn. Instr., vol. 28, pp. 1–11, 2013.
[19] C. C. Bonwell, “Active learning: Energizing the classroom,” in Green Mountain Falls, CO: Active Learning Workshops, 1998.
[20] P. S. Oh, “How can teachers help students formulate scientific hypotheses? Some strategies found in abductive inquiry activities of Earth Science,” Int. J. Sci. Educ., vol. 32, no. 4, pp. 541–560, 2010.
[21] A. W. Oliveira, “Improving teacher questioning in science inquiry discussions through professional development,” J. Res. Sci. Teach. Off. J. Natl. Assoc. Res. Sci. Teach., vol. 47, no. 4, pp. 422–453,
[22] C. Scott, T. Tomasek, C. E. Matthews, T. Tomasek, and C. E. Matthews, “Thinking like a Ssssscientist! Fear of Snakes Inspires a Unit on Science as Inquiry,” Sci. Child. XLVIII, vol. 1, pp. 38–42, 2010.

[23] J. A. Walsh and B. D. Sattes, Thinking through quality questioning: Deepening student engagement. Corwin Press, 2011.

[24] Z. Arifin, Evaluasi pembelajaran, vol. 8. Bandung: Remaja Rosdakarya, 2009.

[25] S. L. Kong, “Effects of a cognitive-infusion intervention on critical thinking skills and dispositions of pre-service teachers,” 2006.

[26] V. P. Smitha, Inquiry training model and guided discovery learning for fostering critical thinking and scientific attitude. Lulu. com, 2012.

[27] P. A. Facione, Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction. Millbrae, CA: The California Academic Press, 1990.

[28] D. Klahr and M. Nigam, “The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning,” Psychol. Sci., vol. 15, no. 10, pp. 661–667, 2004.

[29] Y. W. Kwan and A. F. L. Wong, “Effects of the constructivist learning environment on students’ critical thinking ability: Cognitive and motivational variables as mediators,” Int. J. Educ. Res., vol. 70, pp. 68–79, 2015.

[30] J. A. Bianchini and A. Colburn, “Teaching the nature of science through inquiry to prospective elementary teachers: A tale of two researchers,” J. Res. Sci. Teach. Off. J. Natl. Assoc. Res. Sci. Teach., vol. 37, no. 2, pp. 177–209, 2000.

[31] G.-J. Hwang and H.-F. Chang, “A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students,” Comput. Educ., vol. 56, no. 4, pp. 1023–1031, 2011.

[32] Y.-J. An, “Collaborative problem-based learning in online environments,” 2010.

[33] Y. C. Yang and H. Chou, “Beyond critical thinking skills: Investigating the relationship between critical thinking skills and dispositions through different online instructional strategies,” Br. J. Educ. Technol., vol. 39, no. 4, pp. 666–684, 2008.

[34] R. W. Cheng, S.-F. Lam, and J. C. Chan, “When high achievers and low achievers work in the same group: The roles of group heterogeneity and processes in project-based learning,” Br. J. Educ. Psychol., vol. 78, no. 2, p. 205, 2008.