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DEVELOPING SCIENTIFIC LITERACY-BASED TEACHING MATERIALS TO IMPROVE STUDENTS' COMPUTATIONAL THINKING SKILLS

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ABSTRACT

Computational thinking and scientific literacy are competencies compulsorily required by pre-service primary teachers in the 21st century. This study aimed to examine the effectiveness of scientific-based teaching materials that have been developed in improving the computational thinking skills of Primary School Education Department students of UniversitasMuria Kudus Indonesia. This research employed the Research & Development (R & D) procedure, which includes three stages, namely preliminary studies, development, and validation. In the validation stage, the scientific literacy-based materials were applied in large-scale trials with quasi-experimental control groups design for the fourth-semester students of Primary School Education Department in the academic year of 2018/2019, where class 4A as the control group and class 4C as the experimental group were taken randomly. The experimental class consisted of 44 students, while the control class consisted of 46 students. After being given the treatment, the two classes were given a post-test to examine its effectiveness. Based on the hypothesis testing using the right t-test, it has a tcountof 2,215 and ttableof 1.99. Thus, it could be concluded that the teaching materials of the developed scientific literacy concepts were effective in improving the students' computational thinking skills.

Keywords: computational thinking skills, scientific literacy, teaching materials

INTRODUCTION

Education is an essential element in science and human resource development in order to be reliable, qualified, and competitive. In this 4.0 Industrial and Evolutional era, higher education has an essential role in preparing competitive human resources in global industries. Syamsuar & Reflianto (2019) suggested that in this digital era competition, Indonesia needs to immediately improve the ability and skills of human resources through education to achieve competitiveness and high productivity. As an institution to educate teacher candidates, the Department of PrimaryEducational Teacher of UniversitasMuria Kudus, which has fixed curriculum content continuously, is still preparing its students with skills and competencies required in the 21st century in order to be able to compete globally. Among the skills required by the candidates of primary school teachers are computational thinking skills and scientific literacy.

Wing (2006) stated that a fundamental skill required by every individual in the 21st century is

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computational thinking (CT) skills. It is a pattern in problem-solving that integrates ideas, data, and logic through various disciplines and thought as if it is computer operation (Qualls, 2010). Meanwhile, scientific literacy is related to the ability of individuals to understand and implement science in their life (Bybee, 2009). Those skills and competencies become essential to be applied in primary and middle schools since they are related to reasoning logically, thinking algorithmically, thinking specifically and spending time efficiently, and thinking innovatively (Mohaghegh& Michael, 2016). Therefore, the students of the Primary Educational Teacher Department of UniversitasMuria Kudus must have those skills. They should be able to think in complex and solve the problems they face in order to realize professional learning.

The preliminary study showed that the scientific literacy level of the students was 66.2% on the nominal level (Fakhriyah et al., 2017). It indicated that students had difficulties to relate science concepts, but they could memorize scientific terms even though they still got a misconception. Besides that, the students could not connect to environmental phenomena, ultimately, which causing difficulties for the students in dealing with complex problems as complex problems cannot be separated from critical thinking and problem-solving. Jacob & Warschauer (2018) revealed that these computational thinking skills have become integrated into social functions to represent fundamental literacies. Thus, it indicated a low level of students' CT skills.

It is necessary to strengthen CT skills as it is a new literacy, based on the conditions of the 21st century, to integrate various kinds of thoughts starred by thinking abstractly, logically, creatively, and constructively (Liu & Wang, 2010). Computational thinking composed of fundamental concepts of computer science, along with the intellectual skills needed for algorithmic thinking, pattern recognition, abstraction, and decomposition (Grover & Pea 2013; Wing, 2006; Wing, 2008). On the implementation, CT skills do not only aim for the exact subjects but also social subjects, language, or humanities because CT skills involve various abstract thoughts by identifying and analyzing problems. This is in line with the opinion of Figueiredo (2017), where CT skills should not only be mastered by scientists but also by professionals such as teachers, lawyers, farmers, and doctors so that they can solve the problems they face. CT is not only used in the computer but also in education to develop individual potential and improve the social life of the community. CT teaches individuals to think like an economist, scientist, and artist to solve problems by computation (Hemmendinger, 2010). Those problems are first identified, then being abstracted and put into an algorithm to create automation and conclusion (Jacob et al., 2018). Abstraction activity aims to create specific patterns. Meanwhile, the algorithm aims to explain the steps in detail, called automation.

Students could train CT skills if they have proper scientific literacy. Computational Thinking is a new form of literacy, meaning that integrating CT into literacy practices will affect students' literacy skills to improve computational results and develop students' literacy through computational practice (Jacob &Warschauer, 2018). Therefore, to mediate the development of science with all fixation of curriculum contents and students' necessities, appropriate learning materials containing scientific literacy are needed.

Based on some previous studies, scientific literacy is improved by applying various appropriate learning models; for example, Project-Based Learning (Afriana et al., 2016). PjBL can improve students' understanding of concepts because students find their concepts through projects they worked on (Masfuah & Fakhriyah, 2017). Concept discovery through this project is able to develop processing skills such as observing, classifying, measuring, asking, interpreting, analyzing data, reasoning, and critical thinking that can develop scientific knowledge and scientific competencies, which are aspects of scientific literacy (Lederman et al., 2013). PjBL is able to create active learning, and make students think critically in solving problems through projects in groups as the main characteristic of PjBL is student-centered learning, teaching through skills, process-centered learning, group-based learning, and experiential learning (Uziak, 2016). Besides, those meaningful learning processes can improve cognitive learning outcomes (Baran & Maskan, 2011), shape environmental care attitudes (Kılınç, 2010; Tseng et al., 2013), scientific process skills (Özer & Özkan, 2012), and effective learning (Cook et al., 2012; Movahedzadeh et al., 2012). Capraro et al. (2013) emphasized that Project Based Learning naturally involves various skills, such as reading, writing, mathematical, and helping that construct conceptual knowledge through assimilation among different subjects so that it is expected to build students' scientific literacy and be able to develop CT skills. Therefore, in this study, the students were given project-based learning to be able to improve their scientific literacy and CT skills.

Based on the results of the preliminary study, one of the causes of the low-level competence in scientific literacy and students' CT skills was the lack of availability of supporting teaching materials that can develop scientific literacy competencies and students' CT skills of Primary Educational Teacher Department of Universitas-Muria Kudus. Questionnaire results also proved that the students wanted teaching materials that can develop thinking skills through project-based inquiry and investigation in languages that are easy to understand science learning materials by integrating various concepts, ideas, sources, and phenomena of scientific literacy. Teaching materials containing science concepts provided in the reading park are still textual or materials content-oriented. This is also proven in the research of the Word (in Adisendjaja, 2008), which stated that the teaching materials available so far emphasize the dimensions of content rather than the dimensions of the process and context. So, it may cause low levels of scientific literacy of students in Indonesia.

Therefore, particular alternative teaching materials involving scientific literacy aspects, such as content, process, and science attitudes in a real-life context, are required. For that reason, it is necessary to reconstruct the current teaching materials. Teaching materials are essential to support the learning process in the classroom since they can affect the students' learning outcomes. The teaching materials are vital since it has a contribution to the quality of students' achievement in which it covers targeted competencies (Bauer, 2010). The learning process equipped with teaching materials will occur systematically and ease students to understand the materials being studied. According to Taber (2015), textbooks are an indispensable component in the educational process, so that the currently available books must be based on current research without scientific errors. The textbook plays an essential role in learning-oriented to certain types of the curriculum so that the contents of the book must consider students' cognitive levels, readability, misconceptions, and scientific vocabulary (Abdel-Hameed et al., 2014). Students prefer learning materials, even though they enjoy the flexibility offered by ICT-based teaching materials (Horsley et al., 2010).

In this research, teaching materials are developed based on scientific literacy and computational thinking. These teaching materials present concepts by integrating the scientific context, which consists of environmental, health, natural resources, disaster, and technological science. The materials cover the context of science in daily life. The students are lead to analyze the concepts related to the phenomena. After that, the students were given problems related to the theory that the activity involves investigations, projects, and problem-solving. The students have to solve the problems through CT to obtain a solution through the algorithm, abstraction, simulation, and conclusion. Students will think like a computer with the principle of Algorithm, which is finding solutions and solving problems according to the CT steps. Students can arrange the results of their thinking systematically and meaningfully. This opinion is reinforced by the statement of Jacob & Warschauer (2018) that algorithmic thinking involves textual decoding or block-based programming commands and sequencing them in syntactically and semantically meaningful ways. This is the following research conducted by Khaeroningtyas et al. (2016), who found that learning by involving science, technology, engineering, and mathematics can improve students' literacy in science.

The learning materials with science concept based on scientific literacy has been developed according to the content of science concept materials needed by Primary Educational Teacher Department Universitas Muria Kudus students. The results of the learning validity test were: the expert judgment validation score was 90.4, indicating that the learning material movement system was reliable to use (Fakhriyah et al., 2017). The teaching materials of CT must contain indicators of scientific literacy, which consisting of content, context, competencies, and scientific attitudes. The indicators of science content are reflected in the environment theory along with an in-depth discussion of the materials. The context of science is reflected in the corner of the story that connects science with people's lives related to the environment, natural resources, disasters, and technological science. This story corner is equipped with a thinking corner, while for competencies and attitudes can be seen from practical activities and conclusions. These teaching materials lead students to think by linking the materials that have been learned with everyday life based on existing phenomena.

Experts have validated learning materials for the suitability of the content. The readability of teaching materials was measured with the cloze test technique. The results of the readability test of teaching materials got the score around

55.4, with the criterion that teaching materials can be understood and appropriate for students (Fakhriyah et al., 2018). Indirectly, it can be interpreted that students can read and understand things written in teaching materials referred to as the statements of readability and vocabulary that contribute to reading fluency (Graves, 2016) and text comprehension (Bravo & Cervetti, 2008). From the several steps of research that have been carried out, namely the expert judgment validation and the readability test of teaching materials, it can be said that the development of teaching materials was done appropriately, and then it is necessary to test their effectiveness. The objective of this research was to test the effectiveness of the developed learning science concepts to improve the computational thinking skill of the students of Primary Educational Teacher Department of UniversitasMuria Kudus.

METHODS

This research employed the Research and Development method, which include preliminary study, development stage, and validation step (Samsudi, 2006). Based on the results of the preliminary study, it was found that the learning materials containing science concepts were very demanded to be developed. Also, the measurement of student literacy also showed the low scientific literacy of the students of Primary Educational Teacher Department UniversitasMuria Kudus that was 66.2% at the nominal level and 33.8% at the functional level (Fakhriyah et al., 2017). After conducting a preliminary study, the researchers developed learning materials based on scientific literacy to improve CT skills.

The initial step was related to the arrangement of learning materials based on preliminary study results. The arrangement was started by analysis of learning achievement, indicator elaborations, and learning materials formulation. The developed learning materials contained scientific literacy competencies and CT including cover, table of contents, preface, manual guide, purposes of study, conceptual map, scientific phenomena based scientific literacy (application and science contexts) as warming up, investigation activities based science competency, science content-based materials, reasoning skills to solve problems based on CT guidelines, summary, assignment, glossary, evaluation, and reference. In the development stage of the expert validation, the readability test of the teaching materials and the limited scale trial had been completed.

The validation was carried out by three validators whose task was to assess the content validity and the feasibility of teaching materials. From the result, the teaching materials validity got a score of 90.4, which belonged to a very valid criterion so that the teaching materials were worth to use. The next research step was readability test using the cloze test technique. The results of the readability test of teaching materials got the score around 55.4 with the criterion that teaching materials can be understood and appropriate for students (Fakhriyah et al., 2017). The validation step was an implementation stage of the developed, evaluated, and revised product, and it would be tested on a larger scale. The validation steps included larger-scale tests, readability tests, and evaluation of computational thinking skills post-test after using the learning materials. The validation was done using a quasi-experimental design with a post-test only control group design (Arikunto, 2019). Both groups were differently treated, the class 4C, which was being the experimental group, was taught using conceptual science learning with the developed learning materials. Meanwhile, the class 4A, which was being the control group, was taught using handout from the lecturer. The researcher did not give any pre-test for both groups directly; the researchers implemented the product and gave a post-test to find out the effectiveness of the developed learning materials.

After a limited scale trial, the massive trial run scale was given under the topic of "Movement System." The materials consisted of movement of living creatures, movement of an object, and the influences of movement toward a particular object. On this test, there was only one theme given on four meetings with three credit allocations for each meeting.

Methods and instruments of the research were questionnaires and tests. Meanwhile, the analysis of data covered the following steps: (1) analysis of CT competency test instrument integrated with scientific literacy, which was started by measuring content validity, reliability, levels of difficulties, and distinguishing power of task number. Before the instrument being used, first, the instrument is validated by experts. Furthermore, the test instrument was tested on Class 4B, with the amount of 40 students. The analysis showed that the reliability of the instrument was 0.783 compared to the r table of 0.312, likewise the discriminating power and the difficulty level of tests. That means the instrument was reliable and suitable to use in research; (2) homogeneity test to find out whether the sample was homogenous or not and to determine whether the experimental or control groups were on the massive trial run scale. Then, the sample was determined using a random sampling technique based on the homogeneity test result of the midterm test score. Based on Bartleet's test, both classes had homogenous variants. Therefore, it could be concluded that all four classes had equal abilities so that it could be selected by random sampling. Based on the determination, finally, it was gained Class 4A as the control group and Class 4C as the experimental group. Both groups were then given different treatments. Class 4C, the experimental group, was taught using conceptual science learning with scientific literacy concept learning materials. Meanwhile, the control group, Class 4A, was given a *handout* by the lecturer while learning. The researcher did not give any pre-test for both groups directly; the researchers implemented the product and gave a post-test to find out the effectiveness of the developed learning materials. The step in this test was: students were given the learning materials in advance to be studied at home.

The final step was analyzing which included: (1) normality test; (2) CT skill test integrated with scientific literacy; (3) research hypothesis was tested by t-test with two average differentiation; and (4) descriptive analysis to find out the CT skills of each indicator in the control class and the experimental class.

RESULTS AND DISCUSSION

This research belonged to R&D, precisely on the validation stage (massive trial run scale) using a quasi-experimental design with the *post-test only control group.* Before testing, the researchers conducted expert validation and a limited trial run scale. The results of the initial stage about the validity of the learning materials were: *expert judgment* validation score was 90.4, showing the learning materials movement system was reliable to use. On the limited trial run scale, it showed that the judgment on the practicability of the learning materials based on questionnaire responses of the students was 82.5, belonged to a very good category (Fakhriyah et al., 2017).

The validation stages consisted of *expert validation,* results of limited trial run scale, and massive trial run scale. On a massive trial run scale was implemented on fourth-semester students of Primary Educational Teacher Department of Universitas Muria Kudus in the academic year of 2018/2019 with four classes: 4A, 4B, 4C, and 4D. Then, the samples were determined by a random sampling technique based on the homogeneity test result of the midterm test score. Based on Bartleet's test, both classes had homogenous variants. Therefore, it could be concluded that all four classes had equal abilities so that it could be selected by random sampling. Based on the determination, finally, it was gained Class 4A as the control group and Class 4C as the experimental group.

The massive trial run scale under sub-materials "Movement System" consisted of movement materials of living creatures, movement of objects, and the influences of movement toward an object. In this trial run, there was only one theme given in four meetings with 3 credit allocation for each.

On the initial step, students were asked to read the conceptual map and science context that were the application of science in real life. After that, the students were divided into five groups to conduct simple practice to find the already learned concept. The practices included observation of movement system of the low-level animal and higher-level animal using a microscope, and analysis of movement system on plants and humans, and movement of an object in which the students lately found gravitational acceleration on a particular place. This activity aimed to train the science competency aspect integrated by CT competency. It was in line with Yadav et al. (2014) that CT skills are metal activity to theoretical problems and formulated a solution to be automated. Therefore, it was essential to conduct a practical activity to train students in abstracting a specific problem; also, to grasp concepts based on their accumulated experience. It aligned with Bower et al. (2017), who stated that CT skills could be improved through professional learning, such as centralization on students through self-conceptual investigation.

Then, after the practice, students discussed and worked on the examples of presented CT tasks in the form of problems or science phenomena in society. It could strengthen and develop the already owned CT skills by the students because the skill was used to explain the more complex problem using abstraction, model, and simulation (Voskoglou & Buckley, 2012). After the discussion, the students presented their results. In this step, there was an argument and opinion exchanged among students so it could enrich their understandings of the materials. Afterward, the teacher gave emphasis related to the materials.

At the beginning of the learning, students were asked to read the context and content of scientific literacy, such as phenomena and science applications in daily life. After that, the students were involved in the literacy of phenomena consisting of answering and discussing questions as the initial hypothesis. Then, the students practiced to inquire, compose a report, create graphs, abstract, and solve problems based on CT guidelines. Therefore, the students could understand the materials from the learning materials properly. Indirectly, the students could read and understand the written materials inside the learning materials, although some parts the students needed to clarify the guideline to more understand. It was caused by inquiry learning to develop scientific literacy (Gormally, 2009). Besides that, CT was oriented to inquiry learning, which is more comfortable for individuals to solve problems (Gao, 2011).

Some criticisms for revision were: there were some unfamiliar foreign terms, scientific terms or formula, and denomination in which had not been understood by students, so they needed glossary, term assertion, and index to let them understand. In the final step, students were given a post-test to find out the effectiveness of learning materials with concepts of scientific literacy implemented in the experimental group. The evaluation task was given in the form of an essay with 16 numbers, consisting of 8 CT skill indicators. According to Hoover et al. (2016), CT assessments can potentially be automatic to encourage the development of CT skills.

The learning materials with scientific literacy were more useful to improve the CT skills of the experimental group than the control group. The proposed hypothesis was H_0: the average CT skills of the experimental group is lower than the average CT skills of the control group. H_a: the average skill CT skills of the experimental group were better than the CT skills of the control group. Hypothesis test was done by normality test, homogeneity test, and t-test. The recapitulations of normality and homogeneity tests are in Table 1.

Table 1. The Result of Normality and Homogeneity Tests

Tests	Sources of Variations	Post-test (Experimental Group)	Post-test (Contro Group)
Normality	X^2_{count}	6.87	9.92
	X^2_{table}	11.07	11.07
	Criteria	Normally Distributed	Normally Distributed
Homogeneity	F_{count}	2.00	Homogenous
	F_{table}	2.37	

Based on Table 1, both groups have normal data distributions and homogenous variants. Therefore, the hypothesis test was done by using a t-test in the right way. The recapitulation of the t-test can be seen in Table 2.

Table 2. The Result of Right Party T-test of CT Skill Post-test

Variations	CT Skill Post-Test Score	
	Experiment	Control
Average	76.69	71.11
dk	44	46
T_{count}	2.215	
t_{table}	1.990	
Criteria	CT skill of experimental group is better	

Based on Table 2, $t_{count} > t_{table,}$ so H_0 is denied, and H_a is accepted. Therefore, it could be concluded that the CT skills of students taught using science conceptual learning materials with scientific literacy was better than students taught by using the *handout.* It was strengthened by Brackmann et al. (2017) that the result of students taught by active participation such as investigation and discussion was better in improving the CT skills of students. Besides that, in the book, students experimented and were given problems related to the materials. Students created abstract and pattern of problem-solving based on CT guidelines. It was in line with Aho (2012) that the core of CT thinking is on abstraction. Besides that, Dong et al. (2019) revealed CT was described as problem-solving included formulating problems, managing data logically, presenting data through abstraction, automizing solutions, reflecting possible solution efficiency, and generalizing and transferring process to various problems. The flow of CT invites human to think critically, creatively through integral thinking so the complex problem can be solved as if it was computer software (Fakhriyah et al., 2018). This opinion is reinforced by Grover (2015) that the CT mindset can build and broaden students' insight since CT students must be able to use logic and create a model. Voogt et al. (2015) added that CT learning does not require every student to think like a computer, but mostly, CT learning teaches students to think like economists, scientists, and an artist in solving problems that are full of consideration.

After that, a descriptive analysis was done to find out the CT skills of each indicator. CT score on each indicator can be seen in Diagram 1.

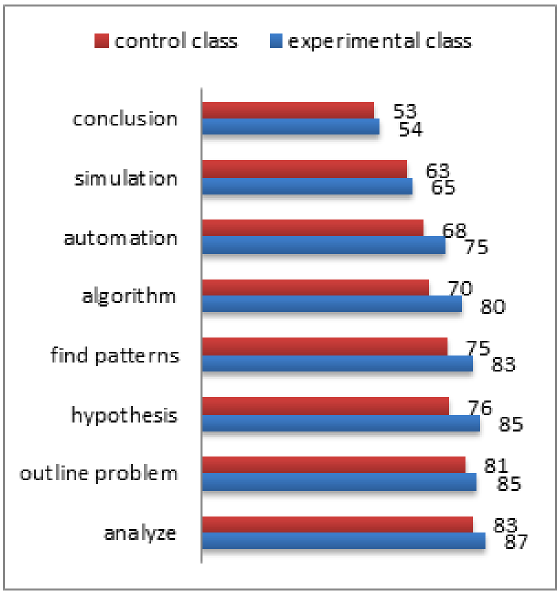

Figure 1. The Scores of Each CT Skill Indicator

Based on the diagram, the CT skills of students in the experimental class in analyzing, explaining, hypothesizing, and finding patterns of problems show high results. Based on these results, indicators that had a significant difference were algorithms and hypotheses indicator. That was because the learning by the experimental class was following the developed teaching materials, which was directed learning inquiry finding concepts through investigative activities, experiments, and projects based on aspects of scientific literacy. In contrast, control class learning was done classically using lecturer handouts through joint discussion. Teaching materials containing investigation, analysis, and modeling activities to solve phenomena contribute to CT students (Bower et al., 2017).Through inquiry, CT skills eased individuals to solve problems (Gao, 2011). According to Mishra et al. (2013) that CT can move students from being consumers of technology to creating new forms of expression by fostering creativity. In addition, inquiry-based learning and projects can increase student scientific literacy (Afriana et al., 2016; Nurwahidah et al., 2017). Likewise, Lye & Koh (2014), from his research, found that project-based learning can promote student CT skills.

The experimental class students' algorithmic skills were still good enough. The skills required students to solve problems systematically and orderly. The algorithmic activity was based on the content of the developed teaching materials, in which students must analyze phenomena, conduct inquiry practicum activities following the aspects of scientific literacy that must be done according to the CT mindset. In the inquiry experiment activities, students must determine the objectives of the practicum and the project and conduct hypotheses. Students must study the literature first. From these activities, they were directed to think critically and creatively to create ideas to find solutions. After obtaining a solution pattern, then students must determine specific steps to solve the problem by choosing the right step information based on the algorithm so that simulation was formed to get a conclusion.

However, on this step, students faced difficulties then affected their concluding skills. Basically, students already knew the conclusions or answers of the hypotheses given, but they had not been able to describe the specific steps, choose and use the right information. The essence of CT required students to think step by step simultaneously and be able to make decisions about the quality and feasibility of the information and the products (Romero et al., 2017). Students were not yet accustomed to systematic problem-solving mindsets to the conclusion skills. The students' habit of CT needed to be done continuously as the algorithmic process involved decoding textual or block-based programming commands and sequencing them in syntactically and semantically meaningful ways (Jacob & Warschauer, 2018). Besides, the low ability of students' algorithms was due to the fact that most of the scientific literacy abilities of students were at the nominal level (Fakhriyah et al., 2017). The students were only able to understand theory without any explanation using their ideas, students were able to recognize scientific terms but were unable to correct the term and students experienced misconceptions (Holbrook & Rannikmae, 2009). The results of the questionnaire also explained that students experienced confusion when explaining the concept in detail and coherently. This indicates that students experienced misconceptions and missed the concepts.

It was suggested for the lecturer to revise the implementation of CT. CT did not aim to teach students to think like a computer or scientist, but rather teach students to apply the CT flow to solve problems by integrating various disciplines (Barr & Stephenson, 2011).CT could be done by emphasizing the long term discussion about CT by identifying on which part of the curriculum, where students struggled and sought an opportunity to integrate CT and coding to facilitate them learning (Dong et al., 2019). Also, Jacob & Warschauer (2018) defined CT as literacy, which provides a way to unify well-researched theories on literacy instruction. According to DiSessa (2001), the decision to define a particular practice as a literacy relies heavily on socially constructed contexts.

CONCLUSION

The teaching materials contained indicators of scientific literacy that direct students to computational thinking. Through the development research steps, the content and feasibility of teaching materials are valid, and the results of the readability of teaching materials can be used and easily understood by students. Then the results of a wide-scale validation test can show that the developed learning materials with scientific literacy competence integrated to CT guidelines showed that the effectiveness of the test of the science conceptual learning materials was known that $t_{count} > t_{table}$, so H_o is denied and H_a is accepted. Therefore, it can be concluded that science conceptual learning materials influence the CT skills of the students with scientific literacy is better than those learning using the lecturer's handouts. The learning materials can be implemented in learning to develop CT skills.

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