Enhancing critical thinking skills and information literacy of students through integrated science teaching materials

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Abstract. Critical thinking and information literacy are skills that need to be developed to deal with the challenges of the 21st century. This study aimed to enhance critical thinking skills and information literacy of secondary school students through developed integrated science teaching materials in theme interaction of light with organisms. This study used quasi-experimental methods and the matching-only pre-test – post-test control group design. Subjects of this study were eighth-grade students. This research used two classes selected purposely with experimental class using developed teaching materials and control class using teaching materials commonly used in school. There were two instruments applied in this study, critical thinking skills test and information literacy test. Data was analysed by normalized gains, Cohen’s D, and t-test. Based on the results of data analysis, it could be concluded that, the used of developed integrated science teaching materials was effective in enhancing critical thinking skills and information literacy.

1. Introduction
Learning is a part of the education system. Learning has components that play a role and interact with other components in achieving defined learning outcomes. One of the important components of learning is learning resources. Generally, it uses teaching materials. Learning cannot be done without teaching materials. The conventional teaching materials used are textbooks. The result of book analysis indicated that thinking skills of secondary school students is still very low [1]. It is supported by the fact that secondary school teachers have different interdisciplinary educational backgrounds. This is the limitation of teachers in delivering interdisciplinary studies of science and hampering improvements in student achievement [2]. Therefore, teaching materials need to integrate various interdisciplinary of science.

Integrated science teaching materials is arranged in a theme or topic about the material discussed from various point of view. One of integration type in science learning is connected type. It can bridge the concepts in a topic or theme. It allows students to analyze, conceptualize, refine, and assimilate the concepts continuously, thus it can facilitate the process of concept transfer in a problem-solving [3].

The concepts in integrated science are presented from phenomena and issues close to the condition of students then studied with theories of science. The phenomena and issues should be close to students so that they are easier to understand the concepts. Teaching materials that present the real and contextual problems will facilitate the implementation of learning [4]. It supports the statement that teaching materials have an effect that is as great as or greater than the quality of teachers [5]. This means that not only teachers but teaching materials can affect learning. Teaching materials have advantages that the
interaction of students with teaching materials have unlimited time so students can learn independently to training their thinking skills. Students can learn with teaching materials whenever and wherever they are, both at school and at home, while they learn with teachers only at school.

The results of PISA 2015 showed that there was a slight increase of Indonesian score in science studies, though it is still low and far below the average score of PISA. Indonesia got 403 points while the average score was 493 [6]. Science education in Indonesia need to be fixed to deal with challenges of 21st century. As well as its quality, it needs to be improved, not only on the cognitive but also on the skill dimension to deal with the challenges. This is in line with national education objectives which indicate the quality of science education should be able to develop the needed skills in 21st century.

The needed skills in the 21st century are “The 4Cs” - communication, collaboration, critical thinking, and creativity. In addition, there are other skills that should be improved by interdisciplinary of 21st century, namely information, media, and technology skills that include information literacy, media literacy, and ICT literacy [7]. Assessment and Teaching of 21st Century Skills (AT21CS) categorizes the 21st century skills into four categories, namely way of thinking, way of working, tools for working and skills for living in the world [8]. Way of thinking includes creativity, innovation, critical thinking, problem solving, and decision making. Skills for living in the world is a skill based on information literacy, mastery of new ICT, and ability to learn and work through digital social networks. The competencies and skills required by students in dealing with life, work, and citizenship in the 21st century is emphasized on seven skills, two of them are: (1) critical thinking and problem-solving skills; and (2) able to access and analyze information [9]. Skills in the 21st century are in the curriculum, presented in the science-learning syllabus, which has the skills of thinking and acting creatively, productively, critically, independently, collaboratively, and communicatively through scientific approaches as studied in educational units and other sources independently. Critical thinking skills is one of the skills listed in the curriculum that needs to be trained.

Critical thinking is part of the complex thinking process [10]. It also describes other skills such as communication and information skills, and the ability to examine, analyze, interpret, and evaluate the evidences. The abundant information makes students need to have ability to select the source and relevant information, find the best of resources, and conduct an assessment of the source of various aspects. This is in line with research which concluded that critical thinking skills are closely related to information literacy [11,12].

Information literacy is an important thing in the present because more information is provided in the society, so there is a need to practice how to use this information effectively [13]. Information literacy allows us to know when information is needed, where to find it, and how to use it effectively and efficiently. This will assist in making decisions and useful productivity. Widespread information can be hoax news, unreal data and make all students and communities face difficulties to find, evaluate, use, and communicate information. Traditionally, students have information literacy skills automatically, but educators (teachers and librarians) need to training the information literacy skills of students [14]. Therefore, it is necessary to have integrated science teaching materials to enhance critical thinking skills and information literacy as well as the purpose of this study.

2. Methods
The type of this research was quasi-experimental method with the matching-only pre-test - post-test group design [15]. This research used two classes, the experimental class used integrated science teaching materials and control class used commonly used teaching materials. The control class is used as a comparison of whether the developed teaching materials have a greater effect than the commonly used teaching materials. Both of the class were given pretest and post-test to measure critical thinking skills and information literacy of students. Instruments used to collect data were critical thinking test and information literacy test. Instruments validation was done by 3 lecturers and 30 students before it was used. Data were analysed descriptively by determining the normalized gain (n-gain), effect size, and inferential statistics by using t-test. The normalized gain (g) showed the category of enhancement.
of critical thinking skills and information literacy according to criteria [16]. The effect size value was interpreted using the Cohen criteria [17]. Determination of t value on t-test was assisted by SPSS 16.

3. Results and Discussion

3.1. Critical Thinking Skills
The data of enhancing critical thinking skills was obtained from the results of critical thinking skills tests conducted in the beginning and the end of the learning in the experimental and control classes. Students' critical thinking skills in theme interaction of light with organisms measured using multiple choice test totalling 25 questions. The descriptive analysis results of critical thinking skills can be seen in Table 1 and the enhancement is categorized medium in the experimental class, and low in the control class.

| Class      | Maximum score | Mean score | Criteria |
|------------|---------------|------------|----------|
|            | Pretest  | Posttest | g       |
| Experiment | 25      | 14.09    | 18.24   | 0.40 | Medium   |
| Control    | 25      | 14.31    | 16.61   | 0.21 | Low      |

Critical thinking skill consists of five aspects, namely basic clarification, basic support, inference, advance clarification, and strategy and tactics [18]. The enhancement of critical thinking skills aspect are presented in Table 2. Information on Table 2 indicates that experimental class’s enhancement of critical thinking skills aspect are relatively higher than the control class.

| Aspect             | Class      | Mean score | Criteria |
|--------------------|------------|------------|----------|
|                    | Pretest  | Posttest | g |
| 1. Basic clarification | Experiment | 2.94 | 3.74 | 0.33 | Medium |
|                    | Control   | 2.69 | 3.22 | 0.21 | Low    |
| 2. Basic support   | Experiment | 2.26 | 2.97 | 0.38 | Medium |
|                    | Control   | 2.17 | 2.56 | 0.19 | Low    |
| 3. Inference       | Experiment | 3.65 | 4.76 | 0.35 | Medium |
|                    | Control   | 3.75 | 4.56 | 0.23 | Low    |
| 4. Advance clarification | Experiment | 2.85 | 3.74 | 0.35 | Medium |
|                    | Control   | 3.14 | 3.47 | 0.16 | Low    |
| 5. Strategy and tactics | Experiment | 2.38 | 3.03 | 0.32 | Medium |
|                    | Control   | 2.56 | 2.81 | 0.10 | Low    |

Based on Table 1, the experimental class obtained the medium criteria in the enhancement of critical thinking skills, while the control class obtains the low criteria. Effect size and t-test are used to determine the effect of teaching materials applications on critical thinking skills. The effect size is determined using the Cohen criteria. The result of effect size analysis about the used of integrated science teaching materials on critical thinking skills are presented in Table 3. Based on Table 3, the used of developed integrated science teaching materials has a large effect in enhancing critical thinking skills compared to the conventional one.
Table 3. Effect size of using teaching materials on critical thinking skills

| ME  | MC  | SD_E | SD_C | SD_pool | D   | Criteria |
|-----|-----|------|------|---------|-----|----------|
| 0.40| 0.21| 0.15 | 0.14 | 0.14    | 1.33| Large    |

The statistical analysis began with normality test of enhancing critical thinking skills data of the experimental and control classes. Normality test used Shapiro-Wilk test. The significant values of normality tests in experimental and control class were 0.216 and 0.054, where the values were greater than the level of $\alpha = 0.05$. It means that the critical thinking skills data of the experimental class and control class were normally distributed. Next step was the homogeneity test. Homogeneity test used Levene test which stated significant value = 0.825 and bigger than $\alpha = 0.05$, so that enhancement of critical thinking skill data of experimental class and control class was homogeneous.

Then t-test is used to test the statistical hypothesis of enhancement of critical thinking skills data. The t-test results can be seen in Table 4. Table 4 states significant values = 0.000 and smaller than $\alpha = 0.05$, so it can be concluded that the developed integrated science teaching materials enhance student’s critical thinking skills significantly than the conventional one.

Table 4. t-test results of critical thinking skills enhancement

| t   | df | Sig. (2-tailed) |
|-----|----|-----------------|
| -5.553 | 68 | 0.000           |

Based on data analysis of critical thinking skills enhancement, effect size and t-test data, it was found that the used of integrated science teaching materials was effective to enhance critical thinking skills than the commonly used teaching materials. The teaching materials presented activities that have been adjusted to indicators to enhance critical thinking skills. Students cannot develop their critical thinking skills properly if they are not trained to think critically [19]. Critical thinking skills is the need ability to solve problems in daily life.

Figure 1 is an example of students’ answers whose the answer can be categorized as critical and less critical in strategy and tactics aspects on indicators interaction with others. Students interact with others by giving their opinions in writing. Figure 1(a) is an example of a less critical opinion, because the student can give his opinion on the effect of UV rays on the skin, but not with the effect on the skin of Indonesians. The student's answer in Figure 1(b) shows critical opinions because he analysed the data given (in the form of picture and article) so that his opinion was in accordance with the question given, namely the effect of UV rays on the skin of Indonesians. A person who thinks critically can consider the information or data given in a logical way so as to make conclusions or opinions that can be trusted [20]. If the student can analyse and synthesize the information provided on the activity, then the student can provide critical opinion. Overall, students can use strategy and tactics well after using integrated science teaching materials because the mean of this aspect enhancement is included in the medium criteria.

![Figure 1](image1.png)  
(a)  
(b)  

Figure 1. Example of (a) less critical opinion and (b) critical opinion in strategy and tactics
3.2. Information Literacy
The data of enhancing information literacy was obtained from the results of information literacy tests conducted in the beginning and the end of the learning in the experimental and control classes. Students' information literacy in theme interaction of light with organisms were measured using multiple choice test totalling 15 questions. The descriptive analysis results of information literacy can be seen in Table 5 and the enhancement is categorized medium in the experimental class, and low in the control class.

Table 5. Enhancement of information literacy

| Class | Maximum score | Mean score | Criteria |
|-------|---------------|------------|----------|
|       | Pretest       | Posttest   | g        |
| Experiment | 15 | 6.74 | 9.41 | 0.35 | Medium |
| Control   | 15 | 6.33 | 7.72 | 0.16 | Low    |

The information literacy standards defined in this study were: (1) determine the nature and extent of the information needed; (2) access needed information effectively and efficiently; (3) evaluate information and its sources critically and incorporate selected information into prior knowledge [21]. The enhancement of each information literacy standard is presented in Table 6. Based on Table 6, the information literacy in both classes roughly showed the same enhancement on each standard. The experimental class showed enhancement with medium criteria, while the control class showed low criteria in all standards. Overall, the enhancements shown by the students of experimental class were relatively higher than the control class on each standard of information literacy.

Table 6. Enhancement of information literacy standard

| Standard                                                                 | Class    | Mean score | Criteria |
|--------------------------------------------------------------------------|----------|------------|----------|
| 1. determine the nature and extent of the information needed             | Experiment | 2.53 | 3.29 | 0.35 | Medium |
|                                                                           | Control  | 2.36 | 2.72 | 0.16 | Low    |
| 2. access needed information effectively and efficiently                 | Experiment | 2.21 | 3.15 | 0.37 | Medium |
|                                                                           | Control  | 2.00 | 2.50 | 0.17 | Low    |
| 3. evaluate information and its sources critically and incorporate selected information into prior knowledge | Experiment | 2.00 | 2.97 | 0.34 | Medium |
|                                                                           | Control  | 1.97 | 2.50 | 0.15 | Low    |

Based on Table 5, the experimental class obtains the medium criteria in the enhancement of information literacy, while the control class obtains the low criteria. Effect size and t-test are used to determine the effect of teaching materials applications on information literacy. The effect size is determined using the Cohen criteria. The result of effect size analysis about the used of integrated science teaching materials on information literacy are presented in Table 7. Based on Table 7, D value indicates that the used of developed integrated science teaching materials has a large effect in enhancing information literacy compared to the commonly used teaching materials in schools.

Table 7. Effect size of using teaching materials on information literacy

| M_E | M_C | SD_E | SD_C | SD_pool | D     | Criteria |
|-----|-----|------|------|---------|-------|----------|
| 0.35| 0.16| 0.17 | 0.14 | 0.15    | 1.26  | Large    |

The statistical analysis began with normality test of enhancing information literacy data of the experimental and control classes. Normality test used Shapiro-Wilk test. The significant values of
experimental and control class normality tests were 0.094 and 0.089, where the values were greater than the level of $\alpha = 0.05$. It means that the information literacy data of the experimental class and control class were normally distributed. The next step was homogeneity test. Homogeneity test used Levene test which stated significant value = 0.614 and bigger than $\alpha = 0.05$, so that enhancement of information literacy data of experimental class and control class was homogeneous.

Then t-test is used to test the statistical hypothesis of information literacy enhancement data. The t-test results can be seen in Table 8. Table 8 states significant values = 0.000 and smaller than $\alpha = 0.05$, so it can be concluded that developed integrated science teaching materials enhance student’s information literacy significantly than the conventional one.

Table 8. t-test results of information literacy enhancement

|       | $t$   | df  | Sig. (2-tailed) |
|-------|-------|-----|-----------------|
|       | -5.275| 68  | 0.000           |

Based on data analysis of information literacy enhancement, effect size and t-test data, it was found that the used of integrated science teaching materials was effective to enhance information literacy than the commonly used teaching materials. The teaching materials presented activities that have been adjusted to indicators to enhance information literacy. Figure 2 is an example of students’ answer to training the information literacy abilities in standard 3, which is to evaluate information and its sources critically and incorporate selected information into prior knowledge. Students compared new knowledge with prior knowledge to determine the added value, contradiction, or other characteristics of an information. The student's answer in Figure 2(a) is example of answer that are not able to literate the information, since the student does not compare the discovered information to the prior information, i.e. photosynthesis by green plants. The student's answer in Figure 2 (b) shows the ability to literate the information because the student reads the given information, determines the new information from the given data (in the form of articles), so that the answer represented the indicator, that is comparing the new information, photosynthesis by blue plants with prior information, photosynthesis by green plants. Reading is important in building information literacy. Reading affects the level of literacy, information and knowledge [22].

![Figure 2](image.png)

**Figure 2.** Example of answer that are (a) not able and (b) able to literate the information in third standard of information literacy

This finding was due to the used of an integrated science teaching materials development model. The teaching material development model used is Model for the Processing Writing Teaching Material [23]. The materials was prepared in accordance with applicable curriculum, indicators of critical thinking skills and information literacy, and the width and depth of materials that are suitable with the curriculum and cognitive level of student. The materials contains a variety of interdisciplinary science that arranged
like a connected type. Figure 3 is a connected type that used in this research where material from biology is the main topic and associated with physics, chemistry and earth & space science.

![Diagram](image)

**Figure 3.** Connected type in theme light interaction with organisms

A concept map was created to map out the scientific concepts to be presented in teaching materials and multimodal representation of concepts were created to help students understand the concepts. The representations are supported by other representations to reach all students who have different abilities in understanding the concept. Therefore, one concept in teaching materials is represented by at least two representation modes, namely text (verbal) and images (visual). In the presence of a meaningful relationship of various language components such as text, mathematical formulas, tables, diagrams and drawings. The materials was also equipped the activities and questions column of critical thinking skills and information literacy to improve the objectives that have been formulated, which is critical thinking skills and information literacy indicators. The used of this teaching material development model is an advantage of developed teaching materials. The model had complied the criteria of good quality materials in terms of coherence and cohesion [24].

The used of integrated science teaching materials is an effort to enhance critical thinking skills and information literacy of students. Efforts to enhance critical thinking skills and information literacy are the things that must be done sustainably so that 21st century challenges can be faced better.

4. Conclusion
Based on the objectives, the results of research, and discussion, it can be drawn the conclusion that enhancement of critical thinking skills and information literacy of secondary school students included in medium criteria and the used of integrated science teaching materials on theme light interaction with organisms have a large effect and enhance the critical thinking and information literacy significantly than commonly used teaching materials in school.

5. References
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