Content analysis of critical- and creative-thinking skills in middle-school science books on environmental pollution material

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Abstract. Critical- and creative-thinking skills are important competencies students must have to encounter the challenges of the 21st century. The development of teaching materials that emphasize critical- and creative-thinking skills is very necessary for students to improve these skills. This research aims to analyze three middle school science books based on critical- and creative-thinking skills on environmental pollution material. The research procedure consisted of developing an instrument for assessing critical- and creative-thinking skills, validating the indicators of the instruments using expert judgment, and conducting an assessment of middle school science book. The development of critical-thinking skill indicators refers to Facione while the indicators of creative thinking skills refer to Torrance. The results of the analyses show that the average critical-thinking skill indicator achievement for the environmental pollution material on interpretation is 2.83%, analysis 2.75%, conclusion 3.16%, evaluation 2.83%, explanation 2.91%, and self-regulation 2.33%. The achievement of creative-thinking skill indicators on average is 2.66% for fluency, 2.66% for flexibility, 2.41% for originality, and 2.75% for elaboration. Students have low critical- and creative-thinking skills on the air pollution and pollution sub-materials.

1. Introduction

The development of the 21st century is a progress in the field of technology, where information is abundant and human resources are being replaced by technology. This development is adjusted with the demands of 21st-century education. Skills that are prioritized in the 21st-century learning are known as 4C, namely problem solving and critical thinking, collaboration and communication, as well as creativity [1]. The five main domains of 21st-century skills are digital literacy, high productivity, effective communication, intensive thinking, and spiritual and moral values [2]. Skills and attitudes of the 21st century are classified based on 3 aspects, namely as a way of thinking (critical, knowledge and creative thinking), a way of learning (the ability to read and write), and a way of learning with others (personal, social, and citizenship responsibilities) [3].

Critical-thinking skills encourage students to be active, to develop trust and take action, and avoid misconceptions [4]. This shows that critical thinking will give consideration by using a certain size or standard that can develop the mindset [5,6,7]. Critical-thinking skills are strengthened by exposure using...
a proof, concept, methodology, criteria, or contextual considerations on which critical-thinking indicators are made including decisions in self-regulation or judging something that results in inference, evaluation, analysis, and interpretation [8].

Creativity is a significant skill in life, so creative thinking students must possess is in the form of actively participating in learning, divergent and productive thinking, new inventiveness and exploring real topics [9]. Creativity is also defined as the ability to find something new and original to develop and solve problems, involving the ability to generate varied and unique ideas [10]. A person’s creative-thinking skills can be seen in four aspects, flexibility, namely fluency, elaboration, and originality. First, fluency is the continuity in expressing thoughts and ideas within a certain time. Second, flexibility is the ability to express varied ideas from different perspectives by changing the approach or way of thinking. Third, originality is the ability to express thoughts and ideas with brand new combinations. Fourth, elaboration is the ability to develop, describe or elaborate the details of an object of thought or idea [11,12].

Environmental pollution and its impact on living ecosystems is one of the integrated natural science learning materials in middle schools that discusses the phenomenon of environmental pollution and its impact [13]. Mastery of environmental pollution materials in one school in Surakarta City, based on data from the National Examination results, has decreased from five consecutive years, 2015/2016 (80.85%), 2016/2017 (67.01%), 2017/2018 (81.89%), 2017/2018 (71.58%) and 2018/2019 (62.82%). The results of teacher and student interviews show that the environmental pollution material is the material that requires a more detailed understanding and is required to analyze complexly because the handbook used by both students and teachers requires that sub-material is less complex in answering problems in daily life.

2. Methods
This research used a descriptive-quantitative method. The research procedure consisted of developing an assessment instrument of critical- and creative-thinking skills, validating the indicators of the instrument using expert judgment, and conducting an assessment of middle-school science books. The context of the three science books is analyzed based on the completeness and use of data from the content analysis and the context of the module from descriptive percentages to determine aspects of critical- and creative-thinking skills.

3. Result and Discussion
This research was conducted to analyze middle-school science books on environmental pollution based on the instrument of critical- and creative-thinking skills. The results of the research content refer to the completeness of the material that science books must contain [14]. Context is how to use teaching materials in accordance with the learning material [15]. The analysis of the content and context of critical- and creative-thinking skills based on the science book on the environmental pollution material and its impact on ecosystems is shown in tables 1 and 2.

| No | Indicator     | Achievement (%) | Mean (%) |
|----|---------------|-----------------|----------|
|    | Indicator     | Book 1 | Book 2 | Book 3 | Mean  |
| 1  | Interpretation| 22.5 | 30.0  | 32.5  | 28.3  |
| 2  | Analysis      | 25.0  | 30.0  | 27.5  | 27.5  |
| 3  | Conclusion    | 30.0  | 35.0  | 30.0  | 31.6  |
| 4  | Evaluation    | 32.5  | 30.0  | 22.5  | 28.3  |
| 5  | Elaboration   | 22.5  | 35.0  | 30.0  | 29.1  |
| 6  | Self-Regulation| 22.5 | 25.0  | 22.5  | 23.3  |
|    | Average       | 25.8  | 30.8  | 27.5  | 28.0  |
Based on Table 1, the achievement of indicators of critical-thinking skills in Book 1 shows that the interpretation aspect obtains 22.5%, analysis 25%, conclusion 30%, evaluation 32.5%, elaboration 22.5% and self-regulation 22.5%. In Book 2, interpretation obtains 30%, analysis 30%, conclusion 35%, evaluation 30%, elaboration 35% and self-regulation 25%. While in Book 3, interpretation obtains 32.5%, analysis 27.5%, conclusion 30%, evaluation 22.5%, elaboration 30% and self-regulation 22.5%.

The results of the content analyses of three science books show that the aspect that obtains the highest score in Book 1 is evaluation (32.5%), in Book 2 conclusion and elaboration (35%), and in Book 3 interpretation (32.5%).

The lowest percentage of the three books is in the aspect of self-regulation (23.3%) because the sub-material of pollution and air pollution requires more attention in introducing the description of problem solving related to daily life before entering into the discussion of the material being studied [16].

Interpretation and evaluation in the book discourse on the environmental pollution sub-material do not describe the topic of investigation to build background knowledge and independence. It lacks the concrete explanation about 3R (reduce, reuse, recycle) that is not contained in the sub-material of pollution, water pollution, air pollution and soil pollution. The picture that shows the pollution in each sub-material is not explained in the form of a description. The analysis and explanation in the book discourse on the environmental pollution sub-material do not illustrate the perspective of the source and exemplifies the conflicting viewpoints as in the sentence: humans play a role in the biotic component and this role has a great influence on environmental quality. We have often heard that forest destruction, pollution of rivers, sea, land and air are caused by human behavior that utilizes natural resources and is less aware of the environmental damage it will cause. An assumption that indicates the ability to draw conclusions from the experience of the investigation clearly is not included in the conclusions in the book discourse on the environmental pollution sub-material; for example, in the book is stated that environmental quality can decline and can affect human survival in the future due to human activity. The strength in the sub-material of environmental pollution, water, soil and air pollution is each describes the impact of pollution, the effects, and how to mitigate it. The self-regulation aspect of the book appears in example of the material about waste pollution that is not included either through pictures or descriptions that illustrate waste pollution in everyday life. As a result, students cannot do well in monitoring the process of thinking and articulating or describing during the investigation. Then, they cannot describe how the assumptions that affect critical-thinking skills in investigations on the soil pollution sub-material of the waste pollution material. Integrating aspects of critical-thinking skills in science books in general must be a serious concern to be developed given the relatively low percentage, in this case on the sub-material of pollution and air pollution. Automatically, the results generally show that the analysis of every aspect of critical-thinking skills of science books is not fulfilled because of less problem solving and comprehensiveness so that most of the books have not been able to build critical arguments and are still relatively low [17,18].

Table 2. Analysis of students' creative-thinking skills

| No | Indicator | Indicator Achievement (%) | Mean (%) |
|----|-----------|---------------------------|----------|
|    | Book 1    | Book 2        | Book 3    |          |
| 1  | Fluency   | 20.0          | 32.5      | 27.5      | 26.6      |
| 2  | Flexibility | 25.0        | 30.0      | 25.0      | 26.6      |
| 3  | Originality | 17.5        | 30.0      | 25.0      | 24.1      |
| 4  | Elaboration | 15.0        | 37.5      | 30.0      | 27.5      |
|    | Average   | 19.4          | 32.5      | 26.9      | 26.3      |
Table 3. Criteria for the level of critical- and creative-thinking skills

| Percentage (%) | Criteria  |
|----------------|-----------|
| 81-100         | Very high |
| 61-80          | High      |
| 40-59          | Sufficient|
| 20-39          | Low       |
| 0-19           | Very Low  |

The percentage of aspects of creative-thinking skills in Book 1, based on Table 2, shows that the fluency aspect obtains 20%, flexibility 25%, originality 17.5%, and elaboration 15%; in Book 2, fluency obtains 32.5%, flexibility 30%, originality 30%, and elaboration 37.5%; and in Book 3, fluency obtains 27.5%, flexibility 25%, originality 25%, and elaboration 30%. The results of the analyses of the three science books show that the aspect that obtains the highest score in Book 1 is flexibility (25%) and in Book 2 and Book 3 elaboration (37.5% and 30%, respectively). Of the three books, the lowest percentage is in the aspect of originality (24.1%). This implies the ability to generate new thoughts or ideas in exploring reading materials in the pollution and air pollution sub-material requires a different point of view because the sub-dimension of the viewpoint depends on several factors that influence [19,20].

The fluency aspect in the book discourse appears in the example of industrial waste in the water pollution sub-material. The fluency aspect is strengthened by creating new and useful ideas (both incremental and radical concepts), where students are involved in evaluating the value and relevance of ideas but do not provide clear evaluations on the pictures and descriptions of the material. The advantage of the water pollution sub-material is the students can further develop the idea of the impact caused by industrial waste. The flexibility aspect in the book appears in the example of wastewater treatment material, but it lacks the aspect of planning and providing in the form of visual images that show wastewater treatment. As a result, students do not maximize efforts to elaborate their creative ideas. The originality aspect appears in water filtration material in water pollution. Students can develop new ideas and communicate to others through facts that occur in daily life, but in water pollution material, the water filtration is neither predicted nor described. The elaboration aspect in the book discourse appears in the example of the material on motor vehicle and industrial factory fumes in which the air pollution sub-material is neither predicted nor provided with concrete explanations. The elaboration aspect lacks the aspect of encouraging students to act on creative ideas to make tangible and beneficial contributions to the field where innovation occurs. Effective training for the contribution of creative thinking usually focuses on strategies related to problem definition, idea making, conceptual combinations, and implementation planning [21].

Based on the results of content and context analyses of the science books on the environmental pollution material based on critical-thinking skills, the pollution and air pollution sub-material obtain the lowest percentage. This is due to the lack of accuracy in establishing the relationship between the sub-material elements and the completeness of the material presented in each of the science books used [22,23].

Based on the results of the content and context analyses of the three science books on the environmental pollution material based on critical-thinking skills, the water and soil pollution sub-material obtain the highest percentage. This appears in aspects that involve the process of determining relevant information (in accordance with daily life), which means structural understanding in the parts of information presented in the form of images or short story descriptions [22,24]. Based on the results of the content and context analyses of the science books on the environmental pollution material based on creative-thinking skills, the water and soil pollution sub-material obtain the highest percentage.
4. Conclusion
We can sum up that creative- and critical-thinking skills are interrelated in terms of content and context in the environmental pollution material. The results of the analyses show that the average critical-thinking skill indicator achievement for the environmental pollution material on interpretation is 28.3%, analysis 27.5%, conclusion 31.6%, evaluation 28.3%, explanation 29.1%, and self-regulation 23.3%. The achievement of creative-thinking skill indicators on average is 26.6% for fluency, 26.6% for flexibility, 24.1% for originality, and 27.5% for elaboration. The environmental pollution material that has the content of critical- and creative-thinking skills must be a serious concern to be developed considering the achievement of low indicators, especially in the sub-material of pollution and air pollution.

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