A preliminary investigation into critical and creative thinking skills of university students in integrated science class 7 course

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Abstract. The ability to think critically and creatively is necessary for learning. To determine the ability of critical and creative thinking of students, researchers conducted a preliminary analysis. Preliminary analysis was conducted in two research classes. The instrument used in this study was an essay test, interview and observation sheet. The research used a quantitative descriptive method. Aspects assessed were 5 indicators of critical thinking ability and 4 indicators of creative thinking ability. Results showed the control class had a score of 62.21 and 66.30 while the experimental group had a score of 64.33 and 67.38 for critical thinking and creative aspects.

1. Introduction

Kratwohl states that the educational objectives compiled by Bloom is a framework for classifying learning outcomes that are expected or intended to be achieved by students\cite{1}. The taxonomy is then revised by Anderson and Krathwohl and provides a new dimension of remembering, understanding, applying, analyzing, evaluating, and creating. The principal goal of education is to create. To achieve it requires the ability to think creatively.

Thinking is based on relating and obtaining conclusions on concept and phenomenon and involves a variety of different cognitive processes such as implicating, problem-solving, examining, reflecting and criticizing\cite{2}. Thinking is manipulating or managing and transforming information into memory\cite{3}. Thinking is aiming to form concepts and reason, thinking critically, making decisions, thinking creatively, and solving problems. Two types of thinking which will be explained in this paper are creative thinking and critical thinking.

Creative thinking is still an interesting issue among researchers. Designing learning which can give students more opportunities to explore problems that provide many solutions can enhance students' ability in creative thinking\cite{4} [5]. Identifying and recognizing students' creative thinking skills can be done by developing tasks or tests of creative thinking\cite{6} [7] [8] [9] [10]. Comparing and making connections between creative thinking skills and other skills can enrich teachers' insight into the potential or talents of their students\cite{11} but we need to concern about enriching the students' thinking skill because some of beneficial activities such as reading has no relation with students' curiosity\cite{12}.

Until now there has not been a single definition of creativity received or used in research, but creative thinking can be divided into two main approaches, processes and products\cite{6}. Creative
thinking in terms of process is the response of students in solving problems by using appropriate methods. In this study, the creative thinking process begins with knowing the problem until communicating the results of his thinking. Isaksen, Puccio, and Treffinger describe that creative thinking seen as a product, emphasizes fluency, flexibility, originality, and elaboration[13]. Fluency can be identified from the number of relevant student responses. The student's responses can still be categorized into several categories which are related to the flexibility aspect. There is a possibility of many student responses but only one category. The student's response is original, if it is unique, unusual, and done only by very few students. The response is detail if the procedure is coherent, logical, clear, and reasonable.

Creative personal characteristics are imaginative, broad-minded, independent in thinking, full of energy, self-confidence, risk-taking, and courage instance and belief[14]. The characteristics of creative thinking are shown in Table 1.

| No | Indicator                      | Sub Indicator                                      |
|----|--------------------------------|---------------------------------------------------|
| 1  | Ability to think fluently (fluency) | 1.1 Having many ideas                             |
|    |                                | 1.2 Having lots of questions                      |
|    |                                | 1.3 Having many alternative answers and problem solving |
| 2  | Ability to think flexibility (flexibility) | 2.1 Having a variety of approaches to solve the problem |
|    |                                | 2.2 Not fixating on old patterns of thinking      |
|    |                                | 2.3 Having the ability to convey various ideas without fear of wrong |
|    |                                | 2.4 Giving a variety of interpretations           |
| 3  | Ability to think originality (originality) | 3.1 Having the ability to generate ideas          |
|    |                                | 3.2 Being able to create combinations that are new and unique |
|    |                                | 3.3 Using uncharacteristic ways of expressing oneself, and being able to explore possible solutions |
| 4  | Ability to evaluate (elaboration) | 4.1 Giving consideration on the basis of own point of view |
|    |                                | 4.2 Determining an opinion about a thing          |
|    |                                | 4.3 Analyzing critical problems or regrets by always asking "Why?" |
|    |                                | 4.4 Having a rationale that can be accounted for  |

In addition to increase creative thinking skill, learning process is expected to enhance critical thinking skill. Teaching for critical thinking is an important goal of modern education, as it equips students with the competency necessary to reason about social affairs in a rapidly changing world[15]. To develop such competency, students must go beyond absorbing textbook knowledge and learn to build up skills involved in judging information, evaluating alternative evidence and arguing with solid reasons. These skills in critical thinking are not only vital for students to perform well in school but also needed in future workplaces, social and interpersonal contexts where sound decisions are to be made carefully and independently on a daily basis.

Critical thinking involves the evaluation of evidence which uses cognitive skills or strategies that increase the probability of a desirable outcome[16]. Critical thinking means effective and reliable mental processes[17] including the activities of analyzing ideas in a more specific way, differentiating them incisively, choosing, identifying, examining and developing them in a more perfect way.
Critical thinking is a purposeful and unique form of thinking which is practiced systematically and purposefully. It results in interpretation, analysis, evaluation, and interference, as well as an explanation of the evident, conceptual, methodological, criteriological, of contextual consideration upon which that judgement is based[18]. The thinker imposes standards and criteria on the thinking process and uses them to construct thinking[19]. The purpose of critical thinking is grasping the meaning of statements; judging ambiguities, assumptions or contradictions in reasoning; identifying necessary conclusions; assessing the adequacy of definitions; assessing the acceptability of alleged authorities[20]. The practice of critical thinking is an established norm in these disciplines, where the authority of particular theories or individuals is considered provisional, and the disciplines provide authority for education itself[21].

There are certain characteristics that can be observed to know how a person's level of critical thinking ability. The characteristics of critical thinking are [19]:

| No | Indicator             | Sub Indicator                                                   |
|----|-----------------------|-----------------------------------------------------------------|
| 1  | Analysis              | 1.1 Identifying unstated assumptions                            |
|    |                       | 1.2 Identifying logical fallacies                               |
|    |                       | 1.3 Identifying ambiguous claims or arguments                   |
| 2  | Inference             | 2.1 Distinguishing relevant from irrelevant information, claims, and reasons |
|    |                       | 2.2 Distinguishing between verifiable facts and value claims    |
| 3  | Evaluation            | 3.1 Determining factual accuracy of a statement                 |
|    |                       | 3.2 Determining credibility of a source                        |
| 4  | Inductive reasoning   | 4.1 Determining the strength of an argument or claim            |
|    |                       | 4.2 Detecting bias                                              |
| 5  | Deductive reasoning   | 5.1 Recognizing logical inconsistencies in a line of reasoning  |

2. Method

2.1 Research Design

The study applied a quasi-experimental research design with descriptive quantitative method. This research used descriptive research type with a quantitative approach. Quantitative research methods is a research method based on the philosophy of positivism, used to examine the population or specific samples, data collection using research instruments, quantitative data analysis/statistics, with the aim to test the hypothesis that has been set[22].

Participants were pretested for 45 minutes to determine creative thinking skill. The indicators were fluency, flexibility, originality, and elaboration. Then interview activities were implemented in 30 minutes. Interviews were conducted with 5 students. The interview contained questions about how students solve the problems given earlier in the pre-test session.

After that, students were conditioned to prepare for the next written test. The next test was a test to determine students' critical thinking skills for 45 minutes. The test had five indicators: analysis, inference, evaluation, inductive reasoning, and deductive reasoning. After conducting a written test, the interviews were conducted again for 30 minutes to determine students' critical thinking skills.

The series of activities above was done during one meeting. At the next meeting, researchers continued research activities with the aim of observing students during learning activities. Researchers observed during 120 minutes of learning.
2.2 Participants
Population in this research was all Physics Education student 2016 of Department of Physics, Faculty of Mathematics and Natural Sciences, State University of Padang. The sample was determined by using cluster random sampling technique, by taking the representative of every existing population. From the groups, two groups of samples were taken which will be used as an experimental class and control class. The total students from both classes were 75 participants. Most of the participants were female (89.33%), 10.67% were male. The number of participating students in the control class was 39 students and the experiment class is 36 students.

2.3 Instrumentation
Instrumentation used to determine students' critical and creative thinking skills were essays, observation and interview sheets. The observation sheet consisted of 4 indicators (fluency, flexibility, originality, and elaboration) for creative thinking skills and 5 indicators (analysis, inference, evaluation, inductive reasoning, and deductive reasoning) for critical thinking skills.

In this study, researchers used a sound recorder and image to facilitate researchers in data retrieval. In addition, researchers also used stationery to back up interviews and also to record data that could not be recorded by a voice recorder during the interview. In this interview, researchers tried to look back at the creative thinking process and critical students when doing a written test through the statement expressed students during the interview.

In order to get maximum results, the researcher needed to do expert validation of the instrument because the research instrument was closely related to the final assessment or evaluation in a study. Evaluating is obtaining data about the status of something compared to a predefined standard or size[22]. Thus, before the instrument is given to the subject, it needs to be checked and validated by an expert validator. Where the expert validator consists of lecturer of physics education program.

The main instrument in this study was the researchers themselves[22]. The supporting instruments were as follows: Interview guide, which was a tool used by the researcher when collecting data through question and answer with the student to know the target of the investigation; sheet question which was a tool in the form of written test about environmental pollution material, and observation sheet.

This written test was an essay test. The test questions were to explore creative and critical thinking obtained from various sources including research journals on environmental pollution materials.

2.4 Data Collection and Analysis
The data collected consisted of student value data from the written test, data from the observation sheet and data from interview questionnaire. The data was analyzed descriptive quantitative technique. Descriptive statistics such as percentages and mean were used to analyze the initial profiles of participants.

The data analysis process was adopted and developed an interactive pattern developed by Milles & Hiberman[22], namely data reduction. Data reduction was an election process activity, focusing attention on simplification, abstraction, and transformation of raw data obtained from written records in the field. Data reduction began at the beginning of the research activity until it is continued during data collection activities. Qualitative data can be simplified and transformed in various ways such as through rigorous selection, a brief summary, classifying it in a larger pattern and so on.

Presentation of data was the process of arranging information systematically in order to obtain conclusions as research findings and taking action. In this study the data obtained in the form of student test results, sentences, words related to the focus of research in arranged in the form of tables, the sequence of words so that the presentation of data that was a collection of information arranged in a systematic can provide the possibility to be drawn conclusions.
3. Findings

3.1 Initial Creative Thinking Skill Profile of the Participants

After giving test of creative thinking ability, interview, and observation to experiment and control class, the following profiles of students' creative thinking ability are obtained.

| Table 3. Written test results for creative thinking skills |
|----------------------------------------------------------|
| Class | Indicator | Average |
| Control | Fluency | 70.4 |
| | Flexibility | 62.5 |
| | Originality | 62.5 |
| | Elaboration | 69.8 |
| | Average | 66.3 |
| Experiment | Fluency | 72.3 |
| | Flexibility | 63.4 |
| | Originality | 63.7 |
| | Elaboration | 70.2 |
| | Average | 67.4 |

3.2 Initial Critical Thinking Skill Profile of the Participants

After giving test of critical thinking ability, interview, and observation to experiment and control class, the following profiles of students' critical thinking ability are obtained.

| Table 4. Written test results for critical thinking skills |
|---------------------------------------------------------|
| Class | Indicator | Average |
| Control | Analysis | 61.3 |
| | Inference | 62.5 |
| | Evaluation | 70.2 |
| | Inductive Reasoning | 57.4 |
| | Deductive Reasoning | 59.67 |
| | Average | 62.2 |
| Experiment | Analysis | 62.3 |
| | Inference | 61.2 |
| | Evaluation | 71.08 |
| | Inductive Reasoning | 62.8 |
| | Deductive Reasoning | 64.31 |
| | Average | 64.3 |

4. Discussion

The research titled "A Preliminary Investigation into Critical and Creative Thinking Skills of University Students in Integrated Science Class 7 Course" was a research conducted to find out the level of students' creative and critical thinking ability in solving integrated science problem, especially on environmental pollution. This level of creative and critical thinking ability of the students will be measured using the indicators described earlier.

This research was conducted in physics education class 2016, Department of Physics, State University of Padang. The integrated science concept in this research was environmental pollution material studied in the semester of January - July. To facilitate the implementation and analysis of data and to maintain the privacy of the subject, the researcher did the encoding to each student. Student coding in this research was based on two parts namely the class letter and ID number of student. Here's one example: student code B054 has the meaning of Physics Education class B 2016 numbered ID 054.

In practice, the test was about environmental pollution material. This test consisted of 5 questions and was implemented with a time span of 45 minutes. This activity went well and smoothly. After completion of the test, the researcher analyzed the student's answers and determined the student who would be the subject of the interview. Analyzing student answers was by looking at responses of student answers. Response results of student answers were referred to the instructions about the problem and uniqueness of student answers. The uniqueness was considered based on indicators of
creative and critical thinking. Then the researcher took 5 students for the implementation of the interview. To facilitate understanding and analyzing data of interview result, the researcher used recording device and stationery. The implementation of this interview was conducted in Physics Education class B and C 2016.

From this study, researchers found something unique that researchers call the research findings. After performing the first essay test and interview, the researcher knows the level of students' creative thinking ability. The written test is given to students in the form of literacy about environmental pollution. The literacy problem is written in Indonesian. The literacy question can be seen in the figure below.

![Figure 1. Literacy question for creative thinking ability](image)

The first question asked students' opinions about the types of environmental pollution and its causes. Based on the analysis of test answers from Table 3, researchers found most students already have ideas or opinions. About 75% of students answered more than three types of environmental pollution and its causes. After the interview, the researchers found some students who could mention more than four types of pollution. It showed that students had the fluency indicator which means having many ideas, lots of questions and many alternative answers and problem-solving.

Next question was designed to determine students' flexible thinking skills. Students were asked about the impact of environmental pollution from various aspects. More than 50% of students have been able to explain the impact of environmental pollution from various aspects such as health and beauty aspects. There were also students who discuss the impact of environmental pollution from aspects of education and others. However, most of the student's explanations were still fixed on old patterns of thinking.

The third question was designed to determine students' originality thinking skills. Problem number 3 asks about how to prevent and completion environmental pollution. Half of the students have been able to explain their opinion about the prevention of environmental pollution. The students had the ability to generate ideas but still difficult to create combinations that are new and unique.

Last question asked about how to invite the community, especially the family, to control the environmental pollution. This question aimed to find the ability to evaluation thinking skill. Students
have given the answer quite deep and accurate. Students have given consideration on the basis of their own point of view. After the interview, it was known that the students give opinions according to the analysis of why environmental pollution can occur. By knowing the causes of environmental pollution, students can give an opinion on how to control environmental polluters.

Generally, students can express their ideas or ideas. However, the idea is still not a new idea obtained from deep understanding. Students are still having difficulty combining ideas so that most of the ideas delivered are still from one perspective. According to Isaksen, Puccio, and Treffinger the ability to think creatively is a product of the processes of fluency, flexibility, originality, and elaboration [13]. Therefore, an approach is needed that is able to direct students to process many ideas from different perspectives, able to create many concepts, and analyze and elaborate on ideas they have.

After analyzing the ability to think creatively, researchers collected data on students' critical thinking skills and analyzed them. It was found that the students' critical thinking skills were in average category. Students were not yet fully able to solve the problem of environmental pollution. Tests and interviews showed that students are less precise in identifying and solving environmental pollution problems. Concepts and ideas were less clear and precise. But the reasoning of problem-solving ideas was quite relevant.

In general, students' critical thinking skills were low enough. The percentage of scores obtained by the students in the control class was 62.2 while in the experimental class was 64.3. Researchers examined the five indicators of students' critical thinking skills by providing written tests and confirming student answers by interviewing several students.

The written test was given to students in the form of literacy about environmental pollution. The literacy question consists of five questions representing each indicator of critical thinking ability.

**Wacana 2**

Pak Sardi sangat suka memancing. Biasanya Pak Sardi memancing ikan di sungai kampung sebelah dekat pabrik sepatu. Walau pun berada di kawasan pabrik, namun sungai tersebut sangat bersih dan jernih dengan pH air relatif normal sehingga banyak ikan yang hidup disana. Namun sejak tahun 2014, air sungai tidak lagi bersih dan banyak ikan yang mati. Pak Sardi mengamati bahwa pH air sungai meningkat lebih dari 7. Perubahan perilaku ikan dalam sungai pun berubah, diantaranya mata merah, perut buncit, mengeluarkan feses, overkulum berdarah.

**Pertanyaan**

1. Lakukanlah analisis fakta yang terdapat pada fenomena pencemaran air di sungai?
2. Berdasarkan fakta yang telah diungkapkan pada soal nomor 1, tuliskan penyebab perubahan perilaku ikan di sungai!
3. Apakah dampak pencemaran air sungai terhadap lingkungan sekitar sungai tersebut jika ditinjau dari berbagai aspek?
4. Apakah upaya yang dapat dilakukan untuk mencegah terjadinya pencemaran tersebut?
5. Simpulkanlah jawaban yang telah kamu ungkapkan pada soal no 1 sampai 4 sesuai dengan wacana yang telah diberikan.

**Figure 2.** Literacy question for critical thinking ability

The first question asked about the facts on the phenomenon of water pollution in the river. This question was structured to determine students' analytical skills. From Table 4, as many as 60% of students have described facts other than those contained in the reading. While 40% of students wrote facts that were only found in the reading. This shows that students' analysis ability was still low. Despite that, the students who belong to the 60% already able to show some of the characteristics of analytical skills. Some of them were able to identify facts that not written in the reading. Some students argued the facts of social aspects such as pollution of water in rivers familiarize people live dirty and unhealthy. There was also the fact that the government has not fully given the warning and punishment for factories that dispose of waste carelessly into the river.
The second question inquired about the cause of changes in fish behavior in the river. This question was to determine students' inference skills. More than 50% of students were able to write down the causes of fish behavior changes in the river based on the facts that have been disclosed in question number 1. Some students could already distinguish information relevant to the question and verify facts found in the field. These two were sub-indicators of students' inference abilities.

The third question asked about the impact of river water pollution on the environment around the river if considered in various aspects. This question aims to find out the aspect of deductive reasoning of students. As with the ability of inductive reasoning, this ability is only owned by 60% of students. Students are able to recognize a common event and conclude into something more specific.

The fourth question asked about the possible efforts to prevent water pollution in the river. This question was structured to determine students' inductive reasoning abilities. Students who have this ability reach 60% for each class. Students made special observations that were believed to be the solution to a problem and could generally apply.

The last question aimed to determine the ability of student evaluation. This question asked the students to give a conclusion based on the answers to the previous questions. As many as 71% of students have provided answers that relevant to the previous answer.

According to Torrance and Safter[22], students prefer to learn creatively by exploring, questioning, experimenting, manipulating, listening, and testing. Reacting to powerful cultural forces, however, educational institutions encourage intelligence and logic, insisting that students learn by authority. Notably, students do not learn exclusively through authoritarian command. Authoritarian systems of learning lack flexibility, originality, elaboration, uniqueness, novelty, fluency, and purposiveness of creative thinking. “The preservation of this nation’s way of life and future security depends upon its most important national resources; intellectual abilities and, more important, creative abilities. It is time, then, that we learn all we can about those resources”[22].

Many of these students seemed to learn better and think more critically and more creatively in a “safe environment,” a term which students and teachers used frequently during their interviews. To their way of thinking, safe environments are settings in which they do not feel threatened but feel comfortable to express opinions and ideas. Many of these students are intuitive, courageous risk takers; they are brilliant, open to change, creative, emotional, dedicated, and care much about their learning experience. In return, they also hold the same expectations of their teachers.

5. Conclusion

From the discussion, it can be concluded that the control class had a score of 62.21 and 66.30 while the experimental group had a score of 64.33 and 67.38 for critical thinking and creative aspects. The teacher must improve the ability of creative thinking and crisis students by directing students to solve problems that are more contextual and using research based learning in learning.

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