Improving students’ creative-thinking skills in biotechnology using creativity-learning based discovery skill (Cel-Badis) model

I R W Atmojo, S Sajidan*, W Sunarno and A Ashadi

The Doctoral Program of Science Education, Faculty of Teacher Training and Education, Sebelas Maret University, Ir. Sutami Street 36A, Kentingan, Jebres, Surakarta 57126, Indonesia

* sajidan@fkip.uns.ac.id

Abstract. There are four technologies that will play a role in human life in the 21st century, one of which is biotechnology, and there are 4 skills needed in the 21st century, one of which is creativity. This research aimed to determine the effectiveness of the creativity-learning based discovery skills (Cel-Badis) model to improve the students’ creativity on the topic of biotechnology. This research was a quasi-experimental research with a pretest-posttest control-group design at Sebelas Maret University Surakarta Indonesia in the 2017/2018 academic year with one class as the experimental class using the Cel-Badis model and the other class as the existing class taught with the inquiry learning model. The data were obtained using the creativity test instrument in the form of essays that have passed the experts’ validations, namely the validations from the education and evaluation experts, science expert, and certified science lecturer, as well as empirical validation through trials. The results showed that the average score of the students’ creativity skills in the experimental class was 0.70 higher than that in the existing class of 0.52. The independent sample t-test shows the difference between the experimental class and the existing class with a value of 3.544 and a sig value of 0.001 < 0.05. The effect size test results are in the large criteria. Based on the results of the research, it can be concluded that creativity in novelty, fluency, flexibility, and originality aspects can be increased effectively through the activities of the Cel-Badis model.

1. Introduction
There are four technologies that will play a role in human life in the 21st century. These four technologies are microelectronics, alternative energy technology, aeronautics, and biotechnology [1]. At the beginning of the 21st century, biotechnology as a multidisciplinary field gives hope to solve problems faced by humans as one of the pillars of the industrial activities in various countries. The application and development of biotechnology in developing countries are still faced with many problems, one of which is the low understanding of the concept of biotechnology. To understand the concept of biotechnology, this research uses the concept of Rainbow Code Biotechnology (RCB) [2]. The concept of RCB is distinguished by colours namely green, red, white, and blue. Green biotechnology focuses on agriculture and food. Red biotechnology focuses on the health sector. White biotechnology focuses on industry and blue biotechnology covers the fields of water and sea. Based on the results of research conducted on the understanding of the pre-service elementary school teachers having some difficulties
in understanding and explaining the concept of biotechnology [3]. The characteristic of the biotechnology topic emphasized in this research is the green biotechnology which consists of sub-topics on the principles of fermentation, traditional and modern food and beverage preservation, and introduction of food additives. 21st century learning needs to be emphasized on understanding concepts using learning models that facilitate the 21st century abilities and skills so that the pre-service elementary school teachers understand the biotechnology topic and have 21st century skills.

The 21st century development requires everyone to have skills in facing developments in the globalization and disruptive era [4,5]. There are a number of competencies or skills that must be possessed in the 21st century i.e. critical-thinking and problem-solving skills, communication and collaboration skills, creative-thinking skills (CTS), information and communication technology literacy skills, contextual learning skills, and information and media literacy skills [6,7]. CTS is one of the recommended ways that one can see a problem from many perspectives. A creative thinker produces more alternatives to solve a problem. Thus, this skill needs to be accustomed to being trained in learning so that it becomes the students’ provision to face the future [8,9]. The low level of CTS is the reality faced in education both nationally and internationally [10]. Low CTS are found in many parts of Indonesia. The fact is that in Universitas Sebelas Maret Surakarta, the students' CTS are still low [11]. This fact is seen from the symptoms of the problems that dominate the results of the observation during the learning process of science in the classroom. The symptoms of problems that arise include: (1) students are less innovative in making products during practicum; (2) they have difficulty doing high-level questions (C4-C6); (3) some students are passive in doing group work; and (4) many of them find it difficult to express their ideas. The students’ low CTS are the problem that must be solved. Solutions are needed to improve these skills because CTS have a strategic value in life [12,13]. When CTS exist, students can have the ability to produce many new thoughts or ideas because of the insight they have, the ability to produce many combinations of different ideas, the novelty of thoughts or ideas raised [14,15]. CTS can be trained in many ways. Some research results using certain learning models can improve CTS, namely the use of models [16,17].

The use of models is a preferred method of solving problems related to low CTS in learning science at Sebelas Maret University in Surakarta, Indonesia because the learning models can be easily applied in classroom learning [18]. The learning model used to empower students' CTS is a model that is able to stimulate the 21st century thinking skills. The model used is the creativity-learning based discovery skills (Cel-Badis). Cel-Badis is an innovative learning model developed and based on the discovery skill about the innovator’s DNA which is the ability to find something creative and innovative [19]. Based on the results of the analysis and development, the stages of the discovery skill are developed into 6 syntaxes (learning stages) namely Associating, Questioning, Observing, Experimenting, Effective Communicating and Persuasive Networking. The six skills were implemented through learning activities with the aim of empowering CTS. Based on the description of the background above, this research aimed to examine whether the application of the Cel-Badis model is effective in increasing the students’ CTS, especially on the biotechnology topic.

2. Method

2.1. Research design

This research was a quasi-experimental research with pretest-posttest control-group design. The research was conducted by applying Cel-Badis learning model in the experimental class whereas in the existing class the researcher applied inquiry learning model the lecturer used to teach in the university. Both classes took pre-test before receiving the treatment followed by post-test. The pretest-posttest results were scored according to the scoring rubric, and then analysed statistically. The data were analysed using SPSS 22.0 for Windows to find out the results of the descriptive pretest-posttest analysis, normality test with one sample Kolmogorov-Smirnov, homogeneity test with Levene’s Test, N-gain calculation [20], and Independent Sample t-Test while the effect size test was done with the interpretation [21,22].
2.2. Population and sample
The population in this research were the students of the Elementary School Teacher Education Study Program at Sebelas Maret University in Surakarta. The samples used in this research were 62 fifth-semester students in 2017/2018 academic year. The sampling was done purposively in the elementary teacher program based on the data of the final semester exam analysis and the results of the initial profile test of the CTS. 31 students were in the experimental class using Cel-Badis model while the other 31 were in the control class using the inquiry learning model used by the teacher at the school.

2.3. Research instruments
The data were obtained by using the creativity-test instrument in the form of multiple-choice questions which were prepared based on four indicators of the CTS aspects including novelty, fluency, flexibility, and originality, which have passed the experts’ validations consisting of the expert of education and evaluation and a certified science education lecturer as well as the empirical validation through the experimental test showing that the instrument was valid and reliable. 40 multiple-choice questions have 5 answer choices with the score of 1 for the correct answer of each question. The instrument validity test was conducted using Pearson’s Product Moment correlational test with the following requirements: if \( r > r_{table} \), the item is considered as valid; and if \( r < r_{table} \), the item is considered as invalid and is removed. The instrument of the validity test obtained the lowest score of 0.515 and highest one of 0.892 > \( r_{table} \), with 20 students as the respondents with \( r = 0.443 \), meaning that the instrument of the critical thinking skill items is valid. On the other hand, the reliability test obtained from Alpha Cronbach is 0.941 > 0.443 meaning that each of the items is reliable to be applied in the experimental and existing classes.

3. Results and discussion
3.1. The gain-score analysis results of pre-test and post-test scores of the CTS
The pre-test and post-test scores of the CTS were then calculated to determine the level of improvement of the results of the Cel-Badis model on the topic of biotechnology. The summary of the results of the average score improvement on the results of the CTS is presented in table 1 below.

| Classes          | Mean of gain score | Criteria |
|------------------|--------------------|----------|
| Experimental class | 0.70               | Medium   |
| Existing Class   | 0.52               | Medium   |

Table 1 indicates that the average gain score of the class using Cel-Badis shows a result of 0.70. In the existing class, the result is 0.52 in the medium category [20]. The average score of the calculation of the obtained score of the experimental class is higher than that of the existing class.

3.2. The analysis results of independent sample t-Test
An independent sample t-test was conducted to determine whether there was a difference between the N-gain score of the CTS in the experimental class and the existing class. The prerequisite tests in the forms of normality and homogeneity tests carried out before the t-test showed that the average gain score of the pre-test and post-test of the CTS of the experimental and existing classes was normally distributed, but not homogeneous. Therefore, the advanced test using an independent sample t-test was carried out by reading the calculation results in the same assumed column of variance. The results of the independent sample t-test can be seen in table 2 below.

| Data             | t-Test for the equality of means |
|------------------|----------------------------------|
| N-gain           | Equal variances not assumed       |
|                  | \( T \)  \( df \) Sig. (2-tailed) | |
|                  | 3,544   54,923  0,001            |
The results of the independent sample t-test show that the sig value of (2 tailed) is 0.001 < 0.05, then H0 is rejected and Ha is accepted. Thus, there is a difference of the average N-gain score between the experimental and existing classes. This difference shows that the Cel-Badis model applied to the experimental class is effective in improving the students’ CTS. The level of effectiveness of the model in enhancing the CTS can be known by the advanced test after the independent sample t-test and effect size test.

3.3. The analysis results of the effect size test
The results of the effect-size test analysis using Cohen's test for independent sample t-test, Hedges's g, and Glass's with Rstat Effect-Size Calculator for t-Test on N-gain scores are shown in Table 3 below. The results of the effect-size test showed that the use of the learning model has a large effect on the improvement of the CTS shown by the results of the effect-size test based on Cohen's formula d of 0.876, Hedges's g of 0.866, and Glass's of 0.740.

| Classes | Mean | Std | Cohen's d | Hedges's g | Glass's | Interpretation |
|---------|------|-----|-----------|------------|---------|----------------|
| Experiment | 0.70 | 0.11 | 0.876 | 0.866 | 0.74 | Large |
| Existing | 0.52 | 0.18 | | | | |

The use of the Cel-Badis model in science learning on the biotechnology topic turns out that the Cel-Badis learning model is a learning model based on the constructivism learning theory. Cel-Badis is a model that facilitates students to find something and know how to solve a problem so that it is possible to become creative and independent problem solvers [23]. The Cel-Badis conceptual model is built on and underlies three learning theories; they are information processing theory (cognitive theory), constructivism theory, and behavioural change theory as learning outcomes. The six learning syntaxes can be described in science learning. Associating is the associative thinking skill that can be empowered so that students are able to synthesize the information obtained [24]. Questioning is the activity of asking questions about the information that is not understood or a statement to get additional information about what is understood [25]. Observing is an activity that puts forward direct observations on objects to be produced to obtain facts in the form of objective data followed up by experimental activities [26]. Experimenting is a detailed activity planned to produce a creative product as the result of associating information and observation [27]. Networking is an activity of finding and testing various ideas through a network of individuals with different backgrounds and perspectives [28].

The effectiveness of the Cel-Badis model on the biotechnology topic in the activities that enhance the CTS aspects is also supported by the observations of the lecturers' and students’ activities during the learning process. The observations on the application of the Cel-Badis model syntaxes went well, indicating that the Cel-Badis model has proven effective in empowering CTS on the biotechnology topic. However, empowering CTS in students also involves many other factors such as the character of psychology, intelligence, and the learning environment [29]. Therefore, in empowering the CTS to the students, the lecturers need appropriate learning and the pedagogical approach in developing it, and taking the right steps to think creatively is empowered well [30]. The lecturers are also required to have the ability to manage classes well and facilitate their students to engage in active learning so that they are accustomed to using information well and not only receiving information.

The CTS is a high-level thinking skill that is able to form the students who are capable of thinking neutral, innovative, objective, logical and far ahead. Therefore, good CTS will be very beneficial for the students in the short term at the university or later in the long term in the world of work in their lives in the future. The CTS will also help in facing the challenges of the 21st century especially in the era of innovation and disruption.
4. Conclusion
Based on the results of this research, it can be concluded that the Cel-Badis model applied to the biotechnology topic can improve CTS. The effectiveness of the Cel-Badis model can be seen from the independent sample t-test which shows that there is a difference between the experimental and existing classes with a t of 3.54 in the sig value of 0.001 < 0.05 and the effect-size test results are in the large criteria. The results of the average significance score of the score increase analysis of the acquired skill in the experimental class were 0.70 higher than that in the existing class of 0.52 in the medium criteria. This increase in the gain score occurs in every aspect of the CTS in intermediate criteria. Therefore, CTS in every aspect, namely novelty, fluency, flexibility, and originality, can be effectively enhanced through the activities of the Cel-Badis model.

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