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ENHANCEMENT OF STUDENTS' BIOLOGICAL LITERACY AND CRITICAL THINKING OF BIOLOGY THROUGH SOCIO-BIOLOGICAL CASE-BASED LEARNING

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ABSTRACT

Biology is a leading science and a foundation in everyday life for all people. Biology student teachers need to be equipped with biological literacy and critical thinking skills in order to teach biology in the future. This research is aimed at determining the effect of socio-biological case-based learning on biological literacy and critical thinking skills of biology student teachers compared with the traditional learning (lecture-based learning). Socio-biological case-based learning is a model of problem-based learning by placing biological cases as a problem to be explained and solved through a series of investigative activities. This research was a quasi-experimental conducted at the Department of Biology, Universitas Negeri Malang. The research samples were the first year students who programmed the General Biology course, consisting of 29 students as a control group and 33 students as experimental group. This research was conducted in September-December 2015. The data of biological literacy and critical thinking were collected from pre-test and post-test. The data were analyzed using ANCOVA test. The research showed that there was a significant difference of biological literacy and critical thinking skills between the students taught by using socio-biological case-based learning and those taught by using lecture-based learning. The research indicated that the socio-biological case-based learning could enhance the biological literacy and critical thinking skills of biology students teachers.

Keywords: biological literacy; critical thinking skills; socio-biological case-based learning

INTRODUCTION

Students are more motivated to solve authentic problems and show the preference for learning activities through a process of thinking and working, rather than just learning by listening (Lombardi & Oblinger, 2007). Educators also believe that learning by doing is an effective learning process. A challenging, effective, and meaningful instructional approach for students in responding to the problems around them is to focus on understanding real-world problems and judging solutions (Lombardi & Oblinger, 2007; Bozalek et al., 2013).

Teaching science is to give the experience of discovering science concepts through the scientific process, connecting the science with technological advances and their impact on environment and society (Mansour, 2009) not just about ensuring science education to produce the next generation as an excellent scientist (Nurse, 2016). Currently, science education should prepare generations to become citizens who can apply their science knowledge to respond socioscienti-

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fic issues and participate effectively in democracy (Nurse, 2016). Science education should help people to have adequate knowledge so that they can make informed choices, engage in science development, make decisions on science issues and their impact on technology and society, and enrich the scientific knowledge needed to work in the era of knowledge-based economy (Umoren, 2007; Autieri et al., 2016).

Scientific literacy and critical thinking are the key components of science education which aims at preparing future generations to function as responsible citizens for the advancement of the world affected by science and technology and to understand its impact (Vieira & Tenreiro-Vieira, 2014). In higher education, scientific literacy and critical thinkings are a phrase that has become policy initiatives and educational purposes today (Heinsen, 2016). Scientific literacy and critical thinking trigger the development of knowledge, attitudes/values, thinking ability, and fostering the ability to take responsible action in the context and circumstances by their lives and social environment (Kek & Huijser, 2011).

Scientific literacy is the main goal of science education around the world (DeBoer, 2000). The purpose of scientific literacy education is to build a scientifically literate society, that is, a society that understands science and its relation to social issues. Thus the importance is not only the mastery of the concept of science but rather the ability to think. Scientific literacy involves mastery of thinking and using scientific methods of knowing and addressing social issues (Choi et al., 2011; Archer-Bradshaw, 2014).

Critical thinking is a required skill in the 21st century (National Education Association, 2014). Critical thinking is a necessary skill in both social life and the world of work (Lombardi & Oblinger, 2007). Critical thinking is an essential learning outcome for higher education learners (Perry et al., 2014). Critical thinking is a thinking process that involves higher cognitive processes in information processing to produce new thinking (Choy & Cheah, 2009) through questioning, reasoning, making decisions, and problem-solving (Willingham, 2008). Furthermore, it is said that critical thinking is not solving problems using a manner or a way that has been remembered but using new ways. The process of critical thinking to solve problems requires various components of skills, such as analyzing problems, inductive or deductive reasoning, making arguments, judging, evaluating, making decisions, and effective communication (Lai, 2011; Perry et al., 2014; Wagner, 2015).

In line with the growth of biological science, the demands for the ability to master biological literacy increases. Biological literacy is the development of scientific literacy in a biological context. Biological literacy is the ability to use scientific inquiry to understand and recognize biological issues in society and integrate these ideas into decision making and communicate results to others (McBride et al., 2013). In other words, biological literacy focuses on the use of key concepts in biology to make decisions in solving problems through scientific inquiry.

Research showed that many students could not think critically because their teachers could not integrate critical thinking into their instructional practices every day (Choy & Oo, 2012). On our work in August 2015, the biological literacy of the first-year students of undergraduate biology education in State University of Malang with the sample of 67 students, was still relatively low. This is supported by the collected data that only 6 out of 67 students passed the passing grade of 60 scores. The efforts to improve the critical thinking ability and scientific literacy (including biological literacy) are not only for students but also for teachers and student teachers. Therefore it is necessary to incorporate critical thinking skills and scientific literacy into the curriculum, which trains the science teachers to become critical learners and able to manage to teach that to foster critical thinking and scientific literacy. Critical thinking skill builds the foundation of students' thinking so that they are ready to enter the world of professional practice.

Over the years many models of curriculum and the learning process have been researched and developed to improve the quality of science education, in which all of these associated with building scientific literacy (Lederman et al., 2013) and critical thinking (Masigno, 2014). Lederman et al., (2013) proposed a learning process to develop scientific literacy through scientific inquiry procedure.

Biological literacy and critical thinking issues require efforts to overcome it through the application of particular learning models. To promote biological literacy, it is necessary to examine the suitable learning strategies, that is the learning strategy which teaches the students to conduct an investigation on a socio-biological issue (Illingworth et al., 2012). It has been a lot of research that links between problem-based learning and inquiry with scientific literacy and biological literacy and critical thinking. Problem-based learning (PBL) and inquiry is a student-centered method that has been implemented in many courses

around the world for over four decades. Several studies have shown that PBL and inquiry promote critical thinking and lifelong learning (Carrió et al., 2011). PBL was an effective learning strategy to enhance critical thinking (Masigno, 2014). PBL has a positive impact on students' learning and stimulates students to become lifelong learners. PBL is also a learning strategy that must be mastered by the teachers. Teachers who have the mastery of PBL are capable of promoting critical thinking, collaborative learning, and self-regulated learning (Goh, 2014). The implementation of problem-based learning is important in higher education because it is effective to be combined with the work competition of the 21st century (Nguyen, 2009). Research by Baharudin & Jamaludin (2014) found that PBL maximally helped improve students' critical thinking skills and cognitive learning outcomes. Ardianto & Rubini (2016) showed that problem-based learning is an instructional strategy that can improve students' scientific literacy. The implementation of the STEM-based virtual lab through inquiry developed a scientific literacy of students (Ismail et al., 2016). Research by Hairida (2016) concludes that inquiry-based learning effective to develop students' critical thinking. The research by Illingworth et al., (2012) revealed that biological literacy of science students was higher if they study of science through socio-scientific issues.

The use of cases as problems to solve by students in teaching has been investigated. Instruction using case studies involves students making analysis, problem-solving, decision making, and justification (Barkley, 2010). The research by Zeidler et al. (2005) showed that the students who used case-based learning achieved a high learning outcome. The lecturer who implemented case-based learning improved students' thinking ability as much as 40% using up to date cases (Hasslöf et al., 2014). Case-based learning improves the content retention and decreases misconception (Rybarczyk et al., 2007).

Application of PBL in biology teaching is better by using contextual biological cases. The socio-biological case-based is a teaching model modified version of a problem-based learning that focuses on using biological cases and issues as problems to solved by students. We use the term model of teaching refers to the explanation Arends (2012). The socio-biological case-based learning is a pedagogical method that uses cases and issues in society related to the concept of biological science as a foundation of inquiry and scientific thinking (Rybarczyk et al., 2007). The socio-biological case-based learning provides students practice inquiry activities, high-order thinking skills, and collaborative skills in studying biological processes in the relevant real world context. This research aims to examine the effect of socio-biological case-based learning in improving biological literacy and critical thinking skills of biology student teachers compared with lecture-based learning..

METHODS

This research was conducted on two classes of biology student teachers. The study used a nonequivalent pretest-posttest design (Creswell, 2012). The independent variables were teaching model consisting of socio-biological case-based learning (SocBioCBL) and lecture-based learning (LBL). The dependent variables were students' critical thinking skills and biological literacy. This research was conducted in September-December 2015 in the General Biology course.

This research was conducted at the Biology Education, Universitas Negeri Malang, Indonesia. The total sample of this research was 62 students. Through random sampling, class B with a total of 33 students were selected as SocBioCBL group, and class C with a total of 29 students selected from LBL group. Before the research, both groups were tested for the equality, and the results showed that the learning outcome was equal.

SocBioCBL and LBL Learnings were implemented for 12 weeks at the General Biology course in two different classes. Learning topics in both strategies were similar, namely Basic Concepts of Biology and History of Life, Cell as System and Its Role In the advancement of Biology, Biodiversity, Growth and Development of Plants, Anatomy of Animals and Their Relation with the Physiology Process, Systems In Living organisms, Immunity Systems and Bioprocess, Growth and Development of Animals, Inheritance, Evolution, Ecology, Microbiology and Biotechnology.

SocBioCBL Learning uses the stages of problem-based learning according to Arends (2012) which has been modified, namely orienting the students to socio-biological problems, organizing student to plan problem-solving process, group investigation, developing and presenting artifacts and exhibits, and analyzing and evaluating the problem-solving process.

The research data of biological literacy and critical thinking skills were collected through a pretest and posttest. Biological literacy was measured using biological literacy tests, a multiple-choice test consisting of 20 items. The key indica-

tors of biological literacy were adapted from the scientific literacy indicators referring to Gormally et al. (2012), namely understanding methods of inquiry that lead the discovery of scientific knowledge; and organizing, analyzing, and interpreting the quantitative data and scientific information. Critical thinking skills test referred to the indicators according to Greenstein (2012), namely making a conclusion based on the evidence, formulating assumptions, deducing, interpreting, and evaluating arguments.

Data in this research were pretest and posttest of biological literacy and critical thinking. Covariance analysis (ANCOVA) was used to determine the significant differences in biological literacy and critical thinking between SocBioCBL and LBL.

RESULTS AND DISCUSSION

Biological Literacy

The data of biological literacy were collected from pretest and posttest. In the LBL group, the mean pretest score was 38.18 and the mean posttest was 33.29. In the SocBioCBL group, the mean pretest score was 52.12 and the mean posttest score was 69.22 (Table 1). In the calculation of corrected scores, the mean score of LBL becomes 34.35 and SocBioCBL are 68.29. There was a decrease in the mean score of biological literacy as much as 12.79%, while on the SocBioCBL the mean score of biological literacy increased as much as 32.81%.

Table 1. The Mean Corrected of Score Biological Literacy

Model	Pre-test	Post-test	Difference	Corrected mean
Lecture based learning	38.18	33.29	-4.88	34.35
SocBioCBL	52.12	69.22	17.10	68.29

The data of biological literacy were analyzed using ANCOVA to know the difference of biological literacy between the students taught by using SocBioCBL and those taught by using LBL. The Summary of ANCOVA of biological literacy analysis is presented in Table 2. The results of ANCOVA show that there was a difference in the biological literacy between the students taught by using SocBioCBL teaching model and those taught by using LBL (Table 2). Based on this analysis showed that biological literacy of the students taught by using SocBioCBL teaching model was significantly higher than that of the students taught by using lecture based learning.

Table 2. The Summary of ANCOVA of Biological Literacy Data

Source	Type III Sum of Squares	Df	Mean Square	F	Significance
Corrected Model	20090.990(a)	2	10045.495	115.806	0.000
Intercept	7569.573	1	7569.573	87.263	0.000
Literacy	166.420	1	166.420	1.919	0.171
Model	13007.059	1	13007.059	149.948	0.000*)
Error	5117.893	59	86.744		
Total	195550.820	62			
Corrected Total	25208.884	61			

*) Significance at $p \leq 0.05$

SocBioCBL improves students' biological literacy because students recognize biological problems and issues, find information that explains the problem, propose a hypothesis in solving problems, investigate, and solve problems arising from this problem. Students analyze the clarity of the problem by referring to valid biological information. Problem-solving starts from the question formulation. Questions identified in problem-solving according to students' way of thinking, so this question helps students solve science problems in everyday life. The example is in the case of biological use of alcohol in beverages. Students assess whether alcohol gives warmth to the body. Students analyze whether the information is correct by using data from investigation and reference. After finding the best solution for the problem and issue, the students presented information that alcohol does not give warmth to the human body. Students taught with SocBioCBL can assess the validity of issues based on correct scientific arguments. Using the correct argument is one of the most important indicators of literacy as a basis for scientific thinking.

Critical Thinking Skills

The corrected mean of the critical thinking skills of the students taught by using lecture-based learning was 51.12 and the corrected mean of the critical thinking skills of the students taught by using SocBioCBL was higher, which was 73.32 (Table 3). The students implementing SocBioCBL and lecture-based learning increased by 74.03% and 62.88%, respectively. The data of students' critical thinking skills on the pretest and posttest were analyzed using ANCOVA. The results showed that the *p*-value of the teaching model was 0.008 (Table 4).

It means that there was a difference in the critical thinking skills of the students taught by using SocBioCBL and those taught by using lecture-based learning. The data reveal that the critical thinking skill in SocBioCBL is higher than CBL. The data showed that SocBioCBL improves critical thinking skill of students than lecture-based learning.

Table 3. The Mean Corrected of Score Critical Thinking Skills

Model	Pre-test	Post-test	Difference	Corrected Mean
Lecture based learning	28,96	47,17	18,21	51,12
SocBioCBL	49,87	86,79	36,92	73,32

**)* Significance at $p \leq 0.05$

The challenge of teaching and learning process in higher education to preparing biology teacher is to equip them with global life skills such as scientific literacy (including biological literacy) and critical thinking skills (Dani, 2009). Teachers should teach critical thinking skills to the students because critical thinking skill is used in everyday life (Sendag & Odabasi, 2009). According to Paul & Elder (2007), critical thinking encouraged students to select cases and solve them using various ways.

Biological literacy and critical thinking can be developed using the appropriate learning strategies or learning model. This study provides experimental evidence that socio-biological case-based learning fosters biological literacy and critical thinking skill.

Table 4. The Summary of ANCOVA on The Data of Critical Thinking Skills

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	2156.237(a)	2	1078.118	15.964	0.000
Intercept	11831.243	1	11831.243	175.188	0.000
XC.Thinking	729.116	1	729.116	10.796	0.002
MODEL	34.458	1	34.458	0.510	0.008*)
Error	3984.537	59	67.535		
Total	330146.000	62			
Corrected Total	6140.774	61			

The teaching strategy that develops the ability of students to read critically, to write ideas, and to discuss ideas (DeBoer, 2000) is used to increase scientific literacy. Socio-biological case-based learning is the development of problem-based learning, by presenting the biological problems that are happening today in our daily lives. Problem-based learning is a student-centered learning model that uses problems as a foundation for learning to solve problems through a series of scientific process skills and scientific thinking skills. Students who learn through problem solving have good knowledge because problem solving fosters critical thinking and critical thinking triggers the development of knowledge (Kek & Huijser, 2011).

The results of the data analysis showed that SocBioCBL improved students' critical thinking skills and biological literacy. Research conducted by Cahyarini et al. (2016) showed that the instructional model of socioscientific issues can improve critical thinking on acid-base. The improvement of students' critical thinking and biological literacy is because SocBioCBL learning model familiarized the students to analyze cases and to process information that was considered correct, effective and productive. Barret (2005) reveals that students taught using case analysis will explain the facts of the case and determine the solution of the problem so that his/her critical thinking skills develop.

Developing someone's scientific literacy can be done by identifying questions, connecting background knowledge and new knowledge, explaining the phenomena that occur in accordance with science, illustrating the fact between science and related issues (Bybee et al., 2009). On SocBioCBL learning model, the students were taught using cases which were presented in questions. After that, the students searched for the best solution to the cases. Teaching science to students should balance the teaching of theories and field practices which involve the identification of facts, explanation, and investigation.

The challenge in solving learning problems through cases depends on the ability of teachers to select and expose biological based cases or issues in the community. Cases are descriptions of a story which is rich of problems, knowledge, and skills that are used to encourage students to think, so that it can help student think to solve the problems (Lee & Jieun, 2009). According to Delisle (1997), the formulation of problems must be adapted to the students' skills. Thus, the success of SocBioCBL depends on the problem selection by the teacher. Teachers can formulate problems by developing an interesting form of questions for the students.

Socio-biological case-based learning provides benefits to the achievement of learning outcomes, which is to link the mastery of biological concepts and their relationship to the social context (Allchin, 2013). Using real-world problems in teaching will lead to the discovery of biological science concepts and encourage students to view biology not only as a collection of concepts but provide experience of making biological connections with other disciplines including sociocultural issues (Kloser, 2012). In socio-biological case-based learning, lecturers act as facilitators to monitor the increase of students' thinking skills (Wee, 2004). The facilitator encourages the students to think creatively and critically in finding the best solution to the problems, ranging from less structured to complex problems (Hmelo-Silver, 2004).

CONCLUSION

This study provides experimental evidence that socio-biological case-based learning enhances biological literacy of biology students as well as a critical thinking skill. The evidence presented in this study offers additional support for the use of socio-biological case-based learning as a curricular vehicle for student learning about biological literacy and critical thinking skill. The faculty members are advised to use this teaching model in conducting teaching biology. The challenge in implementing this teaching model is the instructors' creativity in identifying socio-biological cases that require solutions faced by society and students in everyday life. Faculty member should understand that problem solving requires the instructor to function as a facilitator to help students can actively think, judging, and making a decision to response the biological issues.

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