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Creativity for Learning Biology in Higher Education

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Abstract

Learning biology is considered difficult, especially in some areas like cell division, genetics, and hormones (Cimer, 2012). On the other hand, there is a connection between student success in learning science with creativity (Son, 2009). As creativity can be defined as the formation of new and useful ways to solve a problem (Sternberg & Kaufmann, 2010), it can be used to help students to learn biology. Meanwhile, according to Guilford (1950), creativity includes divergent and convergent thinking. Research on creativity in learning biology helps to integrate different research findings, formulating ideas, and analogies (Dunbarr, 1997). Analogy is a process to explain a difficult topic, by referring to other more familiar topics. While integrating different research findings is important, students usually cannot find any relations among different topics. Formulating ideas is used to support students' skills in developing a hypothesis and a resulting conclusion. Although the benefit of creativity in science education is critical, the research on this field is still lacking. The research in creativity to support learning biology may help to improve learning result, as well as prepare students for their future career.

Biology is a subject that is difficult to learn. The difficulty affects student achievement. In addition, the difficulty makes students less motivated to learn the subject. As a result, it is hard for them to achieve a good result of their studies.

The difficulty is caused by misconceptions, difficulty in finding relation between biology topics and the nature of the topic in general. For example, students do not understand the structure of the chromosome in a cell nucleus and its role in genetic activities (Cimer, 2012; Kubika-Sebitosi, 2007). It is hard for the student to learn it since they do not have the skill to learn the specific topics.

There are many research studies that are conducted to find solutions for the learning difficulty. In order to learn biology effectively, students have to make connections between different topics (Law & Lee, 2004). Further, they have to be able to answer any question within their learning activities. This is the skill to produce and validate ideas (Lawson, 2001, Mumford, 2010). Some students do not have the skills, which makes them have trouble studying biology.

The student struggle is caused by their inability to describe the concepts of biology and they need skills to learn biology. They have to be trained to think, describe and evaluate concepts. Therefore, they need to think creatively, since creativity is a skill to formulate a problem, find out an answer, evaluate and disseminate it to others (Torrance, 1969). Students who have the skill will have an advantage to understand the concept, because they can evaluate ideas and produce solutions for actual problems.

At present, there is some research on creativity in the field of biology. Mumford (2010) and Dunbar (1997) did research on creativity of biology scientists. There are not many research

studies on how the creativity can be used to overcome students' difficulty in learning biology, especially at the undergraduate level.

Purpose

The purpose of the paper is to describe what types of creativity can be applied by university students to learn biology. The paper is a literature study on creativity in the field of biology education. Creativity is a skill that can be applied by biology students to learn more effectively.

In this paper, the main idea is defining an implementation of creativity to support undergraduate students in understanding the subject of biology. Suggested skills of creativity include defining problems, analogies, proposing treatment of unexpected results, and testing hypotheses. Those are required skills for the student to foster their creativity. The creative activities cover the classroom activities, online learning, and laboratory practices. The discussion includes the difficulties of learning biology, definition of creativity, and methods of application of creativity methods in learning biology.

Difficulties in learning biology

Biology covers some topics that are considered difficult to learn. According to Cimer (2012), there are five topics that are the most difficult, which are: matter cycles, endocrine system and hormone, aerobic respiration, cell division, and genetics. The result was gathered from an investigation of 177 students of a secondary school in Turkey. Several reasons were also found for the learning difficulty. Cimer (2012) explained that the nature of the topic, teachers' style of teaching, students' learning habit, students' negative feelings and attitudes towards the topic and lack of resources were the main cause of students' concern to study biology. Any improvement that is related to learning habit, teaching style and attitude will help students to learn biology. Moreover, it is possible that it can alleviate the difficulties caused by the nature of the topics and lack of resources.

According to Kubika-Sebitosi (2007), the student's difficulty in learning biology at university level is derived from their misconception about concepts of biology in their secondary school. The author did an investigation toward secondary school students in two provinces in South Africa about their understanding of the genetic concepts. It was found that students did not have a clear idea about the role of gene in a cell of an organism. They did not have a coherent conceptual framework about cell and gene. Based on the finding, it can be concluded that students could not find any correlation between the structure of cell, including the chromosome and DNA as the part of the cell structure that contain the gene itself, with the genetic trait of any organism.

The idea of misconception by Kubika-Sebitosi (2007) is supported by Oztap, Ozay & Oztap (2003), in their survey toward biology teachers of secondary schools in Turkey. Teachers need to explain the dynamic nature of some biological process. A survey toward teachers of secondary schools in Turkey showed that they recognized difficulties in teaching topics of biology. For example, cell division process consists of two different processes. Therefore, teaching the subject requires appropriate method. According to the author, the use of supporting materials, like model, graph, video and laboratory activities can be used to overcome these difficulties, although it did not necessarily mean that it increased students' creativity.

Unfortunately, those supporting materials are not always available in every school in that country (Oztap, Ozay & Oztap, 2003). Therefore, the solution for the learning difficulty is not only about providing learning support material, but also the skill that will help students to overcome their own problem.

Definition of creativity

There are two kinds of creativity according to Craft (2001), high creativity and ordinary creativity. The high creativity is creative activities of extraordinary talented persons. It includes definition of creativity according to Fieldman, Csikzentmihalyi, & Gardner (1994) that described creativity as something remarkable and new, significantly transforming in global scale. Therefore, this kind of creativity is considered less relevant to application in the education sector, which is more related to solving daily life problem.

As opposed to high creativity, the ordinary creativity is more relevant to the problem that the students have. The ordinary creativity is about the creativity of ordinary people, including students. It covers originality and value (Craft, 2004). Creativity in producing novel idea that can solve the learning problem is considered as critical skill that helps the students who learn biology.

Creativity is defined by innovation, quality and relevance (Kaufmann & Sternberg, 2010). A creativity is related to a new thing or a new way of doing a job. In other words, creativity is also an innovation. Beside it is something new, creativity have to be a high quality. While creativity is unique and having a high quality, creativity has to be relevant with a certain job or context. Its relevance is a prerequisite for solving a problem (Kaufmann & Sternberg, 2010). Based on the definition, a creative person is capable of dealing with problem to create a solution.

Creativity is a product of both internal and external preconditions. According to Oral (2009), there are five steps of creativity that are affected by the preconditions. The internal preconditions influencing creativity are intelligence, abilities, interest, education and knowledge. Meanwhile, physical, cultural, and economic factors are the external preconditions are influencing creativity. Both factors have to be maximized in education, so that students can learn better. In this case, the effort to foster students' creativity is an example of the external preconditions.

Creativity is important in education. Guilford (1950) pointed out that education should not focus on memorizing information. Otherwise, the focus of education should be on how to use the information for solving problem, rather than the process of memorizing. Meanwhile the process of retrieving and using the information is divided into two processes, namely divergent thinking and convergent thinking. The divergent thinking is aimed at finding alternative solutions. On the other hand, the convergent thinking is a focused search to formulate one particular answer.

According to Csikszenmihalyi (1996), creativity is developed within the three components, which are people, field and domain. Therefore, the student creativity is developed within biology as the field, and the university where the students are learning as the domain. Hence, the role of the university as the learning place for the students is important to foster student's creativity.

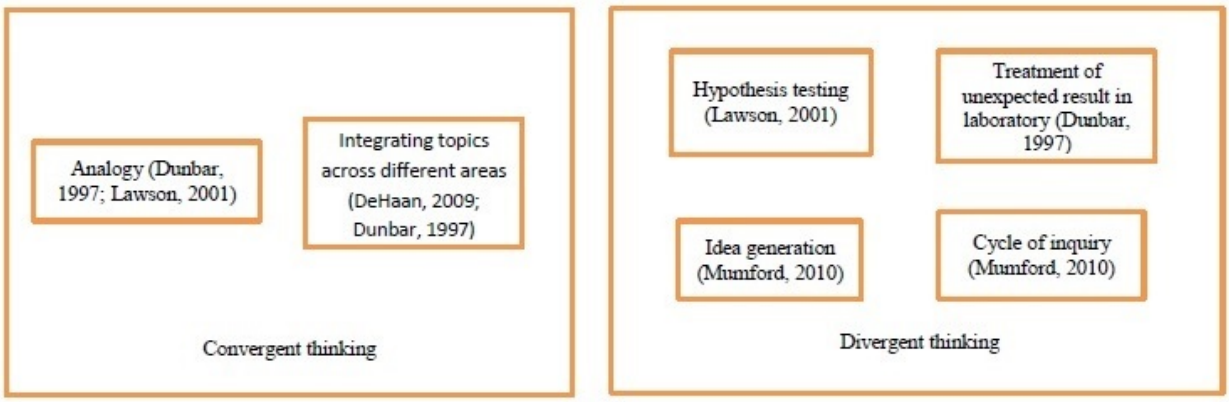
The connection between creativity and students' success in learning science was investigated by Son (2009). The author found out a correlation between scientific proficiency

and scientific creativity. The author described scientific proficiency as a capability to comprehend the core concept of science, to make hypothesis and do research, make experiments and collaborate with peers. These skills are correlated to scientific creativity, as the creativity is the base for new development in science. Therefore, students need to learn about creativity, so that they can learn science better.

The need to understand the content, as well as creativity skill to learn science, is supported by Simonton (2004) and Mishra et al (2013). According to Simonton (2004), creativity in science requires understanding of science logic and content of a certain discipline. In addition, he pointed out the importance of making analogy across different discipline as the source of creativity. This idea is in line with Mishra et al (2013), who elaborated that students must be able to see ideas across discipline. However, unlike Simonton, the idea of Mishra et al is that both learning the content and mastering the creativity skill should be integrated, rather than as two different approaches.

Ideas to foster creativity in learning biology

Based on research on creativity in learning biology, it was found out that there is a need to integrate different finding of research across different subjects (Dunbar, 1997; de Han, 2009; Lawson, 2001). De Haan (2009) put emphasis on integrating material across subject areas. It was supported by both Dunbar (1997) and Lawson (2001) that suggested analogy as a way to connect different ideas to enhance creativity among students of biology. The different skills of creativity are presented in Graph 1.



Graph 1. Skills of creativity based on convergent and divergent thinking

Another suggestion for enhancing creativity was proposed by Mumford (2010) and Dunbar (1997), regarding unexpected finding of a research activity. Those unexpected finding, like any result of experiment that is different from what was expected, may lead to a new alternative for a certain problem. It will be a new thing that can be useful in certain situation. It can be applied in educational setting, as it can help student to find out a solution.

Creativity needs to be taught to students, in order to learn biology better. Torrance (1972) pointed out that creativity involves skills, beside motivation. Therefore, the skills have to be taught to students, so the students can think creatively. Dunbar (1997), de Han (2009), Mumford

(2010) and Lawson (2001) showed that creativity of students can be improved during studying biology, by means of certain methods.

Dunbar (1997) used scientific thinking, especially in biology, to develop an understanding of complex thinking, including creativity. The author interviewed molecular biology researchers of four leading US laboratories. As a result, three components were found as sources of creative cognition among scientist. Those are analogy, treatment of unintended findings, and distributed reasoning.

Analogy

Analogy relates two things, which are the base and the target. A concept that the scientist are trying to elaborate is called the target. On the other hand, another concept or example that is used to explain the target is the base. During the analogy process, the scientists use the base as an example to explain the target.

The use of analogy in the molecular biology experiments can lead to discovery of new findings. For example, it can be used to find the function of a newly found gene. The researchers may find a new gene with a certain DNA molecular structure. Then, the researchers will search other genes with almost identical structure of DNA molecule from databases. Once they find similar genes with almost identical structure, they can make further experiment about the real function of the gene, based on the analogy of the new gene structure, with the analogy.

The skill to relate previous knowledge and the newer one like in the analogy is also supported by McCabe (2011). The author did research of using visual learning support for learning microbiology among undergraduate students in Australia. The result showed that the skill to find out connection between two different ideas were beneficial for students. They can have better understanding of the subjects being learned.

The analogy and relating different knowledge important to learn topics of biology that is interconnected. An example is the difficulties of students who learn genetics according to Kubika-Sebitosi (2009). The students did not understand the relation between structure of chromosome within a cell, and the DNA as a structure of the gene itself. Training in making analogy and relating different knowledge is beneficial to solve the problem. Students may understand the two different concepts and the relation between those concepts.

Treatment of unintended findings

Treatment of unintended findings is crucial when a research produces different result from what is expected by the researchers. According to the McCabe (2011), most researchers tend to seek only the findings that support the idea. Meanwhile, they tend to put less attention toward unexpected findings. As there are two possible actions of a researcher who find the unexpected result, whether to follow the unexpected, or else the researcher should ignore it.

The investigation of the unexpected result focused on three categories of research result. Those are expected, unexpected and exploratory results. It was shown that the researchers pay significant attention toward the unexpected result and tried to elaborate the cause of the finding.

Distributed reasoning

Distributed reasoning is defined as different ideas that are resulted from different members of a research team. In the research, Dunbar (1997) investigated whether the distributed reasoning help scientists overcome different ideas within a research team. In a research team, the first idea produced in a discussion becomes an input for the next idea from other members. The

result showed that the distributed reasoning helped scientist in a research team to overcome problems that any individual researcher had.

Hypothesis testing

Student creativity can be improved, if they have proper training. Lawson (2001) did a research on how a curriculum was designed to improve student creative thinking. The author used a model of connecting different planes of thought. Analogical reasoning is the method o connecting the different thought. There are three phases of thinking, which are preparation, incubation and illumination phases. The principles of analogy are used by the author to explain Mendelian Law of genetics.

In the preparation phase, a person is using both conscious and unconscious thought. The unconscious thought was in the preparation phase. The author suggested a model for a creative thinking. In the unconscious phase, a person has two planes of thought. Only one plane has a connection to the target. Therefore, there must be a link between both planes of thought. Both planes of thinking must be active, so that the person can consciously see the relation of both thought, and find out a solution. The conscious phase is the illumination phase. In this phase, the person does verification. It is a process of making sure that all steps in the process are correct. In other words, the idea is implemented to the real question. Hypothesis is formulated; each hypothesis is explaining the possible solution for the process.

The model of thought pointed out the role of connecting planes of thought as a significant point in creative thinking. The connection is brought about by analogy. It is suggested that analogy is an application of an old idea into a new application in different field, to produce a new breakthrough (Lawson, 2001).

Apart from the analogy, students were trained to conduct tests of two hypotheses. Students have to develop If/and/then/But/Therefore arguments. They developed it during a laboratory session, where they can use the session to find out whether their hypothesis is valid or not. This is an exercise to validate a hypothesis, which was suggested by Torrance (1972) as a method of creativity.

According to the activities, suggested method to improve creativity in biology is provided by Lawson (2001). First, a novel inquiry is given to students, so that they can produce a question to the facts that they encounter. Then, students must develop different hypothesis to answer the question. Last, students are doing the process in sequences, from the simple and observable process, into the less observable process. As a result, the curriculum is designed sequentially, from the more familiar topics, like theories of inheritance, and theories of development into theories of ecology and theories of physiology. In the end, theories of molecular biology are introduced in the end of the semester.

The abovementioned process of analogy and building hypothesis are used in each theory that is elaborated during the semester. For example, the analogy and hypothesis are applied to explain the natural selection theory and Mendelian theory. Students have to formulate the hypothesis of natural selection from Darwin. While in the topic of Mendelian theory, students developed the hypothesis based on experiments using dice to represent possibilities of color variation on corn kernel. The hypothesis is based on kernel color distribution. Hence, students learned the concepts of dominant, recessive, allele, phenotype, and genotype. The experiment showed that students' thinking skills are improved. Creativity and critical thinking skills improved, if the curriculum is specifically designed (Lawson, 2001).

Creativity has to be taught toward learners of science, including biology. DeHaan (2009) that supporting student creativity during science teaching needs effort to tell students about how

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to become creative, how to integrate materials across different subjects, inquiring of assumption and reflect viewpoints and possibilities. The author suggested that creativity is a process consists of various components, like the divergent and convergent thinking that is suggested by Guilford (1950).

The integration of materials across different subject is an important part of creativity. Integrating different topics across different field to formulate a conclusion is called associative thinking (DeHaan, 2011). This is an enrichment of a person's perspective, since the person have broader perspective. Different perspectives allow incoming new ideas, which is a foundation for understanding the topic.

The author explained that creativity can be taught to students. However, students need minimum skills of creativity, without which the students cannot do the creative process of learning. Therefore, the author tried to integrate creativity instruction, into biology teaching. An example is the problem-based teaching of microbiology through a case study. Students were given an introduction about a case of a bacterial resistance toward an antibiotic. Later, the students had to make a plan to solve the problem, considering actual medical, economic, and political situation. They had to provide scientific data to support their plan. Finally, they had to make a plan for a medical clinic to solve the problem. While doing the case study, students are required to promote ideas, collaborate and share the ideas among themselves.

Mumford et al (2010) did a research on cross-field comparison of problem solving skills among health, biology, and social science doctoral students. It was an elaboration of field and domain concept of Csickszentmihaly (1994). The respondents are doctoral students, who were given question that arouse their creative thought, like problem definition, conceptual combination, and idea generation. The aim of the research is to find out if there is a different problem solving skills in different field.

It was found that idea generation is less important in biology, which is caused by the nature of biology. According to Mumford et al (2010), biology is specific as it has integrated concepts, like DNA, energy cycles and ecology. It makes idea generation is less important in biology, as opposed to DeHaan (2009) and Lawson (2001). Therefore concept selection is becoming more important. Meanwhile, problem definition, conceptual combination, and idea generation are conducted in relation to concept selection.

On the other hand, creativity in social sciences is more related to conceptual combination and idea generation. This is because the field of social science is based on loosely related theoretical model. While in health science, implementation planning and definition of the problem is more critical, since this is an applied field.

The investigation used creative problem solving test that consists of 8 skills, which are (a) problem definition, (b) information gathering, (c) information organization, (d) conceptual combination, (e) idea generation, (f) idea evaluation, (g) implementation planning, and (h) solution appraisal. The eight skill are regarded as dependent variables of covariance test, while the independent variables are field (health, biology and social science), and levels (first, third and fourth level of graduate study).

The research conducted by Mumford et al (2010) had produced consistent findings of field differences, as shown in previous research. In biology, the most important skills are concept selection, information gathering, and idea generation. As suggested by Csickszentmihaly (1994) that problem finding is important part of creativity, the concept selection, information gathering and idea generation are three activities that can be described as the problem finding. Therefore,

the author suggested that for biology students, the focus of creativity skills should be on information organization and idea generation.

The researches by Dunbar (1997), DeHaan (2009) and Mumford et al (2010) disclosed that learning biology is supported by creativity. Student's creative skills, like the skill to organize information across different subjects being learned are important. Organizing information across different object is supported by Kozbelt, Beghetto & Runco (2010), as conceptual combination. In addition, the students need the skill to develop idea, and challenging it from different viewpoints.

Creativity in laboratory practice

Apart from the experiment in classroom and online setting, the research on using creativity in laboratory practice is conducted by Haigh (2007). Investigative practice is important, despite practical activities is very common in biology classes everywhere. As suggested by Cimer (2012) that practical activities help students to understand concepts of biology, the activities need to include investigative activities, like open ended problems. Investigative practical experience may foster students' creativity. Haigh (2007) made an experiment toward high school students in New Zealand. The students have to make decisions as to investigative design, validity or reliability of data, during the experiment.

By involvement in the scientific investigation, students understand the role of creative activity in the construction of knowledge. Therefore, students were designing their own experiment, to answer a given biology problem. In other word, problem solving is the main idea of the experiment (Haigh, 2007). An example of the problem solving is when they find an unexpected result within their experiment. According to Dunbar (1997), the unexpected result will give a student an opportunity to develop unique way to solve it, as well as analogy. It can help student to clarify their misconception about some topics in biology, and difficulty to find relation between biology topics (Cimer, 2012).

Creative process is the main idea of investigative practice. The investigative practice is a way that a student or a group of students were developing their ideas within their class. This ideas were a new one for them. Later, the ideas were validated by their peers and teachers (Haigh, 2007). It supported the suggestion of Lawson (2001) that used the sequence of inquiry, from preparation, incubation, illumination, and verification. The students have the data from the experiment. The data was the base for further activities for the sequence of inquiry. Then, the students have opportunity to exercise the skills that are useful to learn biology, which is their creativity, in real activities.

Creativity in online learning

Creativity method is also used in computer-supported learning activities. As the online activities becomes widely used as media of learning, it is important to include the method in online media. The idea is suggested by Northcott (2007), and Law & Lee (2004). However, the experiment by Law & Lee (2004) was not conducted online, though it is possible that the software can be used otherwise.

Proper use of online learning may support creativity. Northcott (2007) explained that online learning activities, including wiki, blog, social media, provide ways to collaborate that foster creativity. However, the use of the online activities should be done carefully, to optimize

creativity. According to Greene (2002), online software that encourage creativity has characteristics as follows: Encouraging users to explore, promoting active learning and discovery, allowing users to access information easily, enabling users to record their ideas, and allowing users to develop a new strategy to complete the task.

However, the use of online activities has to allow creative methods, like the methods suggested by Mumford (2010), deHaan (2009) and Lawson (2001). For example, the characteristic that students can develop a new strategy to complete a task that is suggested by Greene (2002) is giving students opportunity to make a novel idea that is a characteristic of their creativity.

Computer simulation can be used to solve learning difficulty in biology. Law & Lee (2004) investigated the difficulties of learning biology by using a computer simulation in Hong Kong. It was found that there were three difficulties in learning genetics. The first is to find a connection between observable physical trait and less observable genetic equation. The second is a failure to comprehend genetics as a concept including its factor and conditions. And the last one is to understand that a simple interaction can bring about complex consequences.

The use of computer simulation with a proper design can promote a better understanding of genetics concepts. It can show the effect of genetic ratio. Furthermore, Law & Lee (2004) suggested that the simulation may allow students to create and modify the model of simulation. It means that the design of the computer simulation has to allow students to find out their solution on problems that are assigned to them. The students are challenged to find out novel way that can solve the problem.

Mumford (2012)' idea focused on the cycle of idea generation and the resulting feedback from the following steps of the cycle. It may help students who have difficulty in understanding complex concepts of biology. However, the idea is not clearly support the students to understand the relation of one concept with another. In a certain concept of biology, students found that this is their problem to learn biology. One example is the difficulty to learn genetics that Law & Lee (2004) discovered that the students cannot find the important relation.

Dunbar (2001) idea focused on relating one topic into other topics. It may help students to find out relation of one phenomenon, into a bigger picture of the concept. Students may find the relation of a concept and the whole idea. The problems of relating two different topics were disclosed by both Kubika-Sibetosi (2007) and Oztap, Ozay & Oztap (2003). Therefore Dunbar's idea answered the problem of relating two different topics.

Both Mumford (2012) and Dunbar (2001) have a relation to some point. An example is when a person is learning to understand new information. Mumford (2012) suggested that creativity for solving problem requires a person to have a previous knowledge about a subject. The person has to reorganize both the present knowledge and the new information, to understand the new information. The reorganization will result a new and unique idea. The person may also connect the new information with other subject that seems unrelated, but will help to comprehend the process, as indicated by Dunbar (2001). According to Dunbar, the skill of analogy and relating among different subjects are part of creative process. Both processes will help to develop a more creative process to solve the problem.

The connection between Dunbar (2001) and Mumford (2012) idea is related to the idea of Guilford (1950) about the connection between divergent and convergent thinking as part of creativity. Dunbar's idea about connecting different topics is related to divergent thinking. Meanwhile, Mumford's idea of the reorganizing and testing the novel idea is almost the same as convergent thinking.

The research of Haigh (2006) about investigative laboratory practice is supported by Mumford (2001) about error identification and Dunbar (2001) about unexpected finding. Both supporting ideas are elaborating the benefit of doing the laboratory practice that allows students design their laboratory practice to solve an assigned task. By doing the experiment, the students are encountering unexpected results in their activities. Therefore, they are exercising their skill in dealing with the unexpected result.

Conclusion

Creativity is important for students to learn in biology. As creativity is formulating novel and useful ideas, it can be applied in the education sector, to help student solve their own problem. Therefore, students need practice in the skills.

Learning activities need to include investigative activities, to allow students do inquiry while learning biology. It will foster students' creativity, as they are to solve their difficulties in learning biology. Those activities include developing idea, connecting different ideas, formulating suggestion for a certain problem, implementing solution into practical activities, treating unexpected result and evaluating result. The creativity activities are applied in various learning activities, including classroom, online learning and laboratory practice.

The process of analogy, connecting different ideas (Dunbar, 1997) and sequence of inquiry (Lawson, 2011) will help students to have an understanding of biological concepts. They can learn to clarify the misconception about some topics in biology by doing the sequence of inquiry, as they can receive feedback within the process. The process also helps them to learn the relation between biology topics through the analogy.

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