Promoting black soldier fly larvae (*Hermetia illucens*) to recycle organic waste in senior high school

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Abstract. The purpose of this study is as an initial step to introduce *Hermetia illucens* as one of the best ways to decompose organic waste in secondary schools as well as to see how students think about strategies in carrying out a waste recycling project. To accumulate and to analyse the data sincerely and comprehensively, researchers used a method of ADDIE method which has extensive steps: analysing, designing, developing, implementing, and evaluating. The participants which involve in this study is 44 senior high school students in one of secondary school in Bandung. The participants will receive learning in the implementation phase and work on metacognitive questions as part of the evaluation conducted. The data was taken to carry out certain students’ strategies to solve the problem of waste decomposition. Based on data analysis, there is already the ability of students to carry out certain strategies in conducting waste decomposition in secondary schools. In addition, the effect size that gained by the student through this study is 1.33 which is categorised as very strong.

1. Introduction

Waste management, both in the form of solid waste and liquid waste, is one of the most important environmental problems faced by developing countries such as Indonesia. Increasing population and uncontrolled urbanization have made this problem even worse. On various occasions, the government’s efforts to resolve waste problems continue to be carried out. These efforts need to be supported with increasing knowledge, awareness and participation to maintain the environment for senior high school students. They are one of the next generations who will inherit the environment in the future. One effort that can be used to educate young people so that they understand and care about environment. Learning theories and practices of environment can help foster a good culture, especially if it is done continuously [1]. Through good environmental education, students will be aware of their environmental surrounding. Thus, they might be contributing to solve the environmental problems with their critical thinking [2].

Recycling in organic waste, without knowing it, becomes unnoticed and carried out in limited way [3]. In fact, organic waste is the most amount of waste produced by the society. In Indonesia, research on various technologies to overcome waste problem has been carried out such as making biogas,
compos, etc. The results of the research that can be done as an effort to overcome the problem of waste unfortunately did not follow by the implementation and optimal socialization in the society. This causes information from the studies conducted to be less useful in the society. One of the newest approaches in recycling organic waste (Bio waste) is using Black Soldier Fly (BSF) insect larvae, *Hermetia illucenc*. This approach is considered to be quite effective and efficient. The use of BSF larvae as decomposers of organic waste is considered effective and efficient because BSF larvae that have been harvested can be used as source of protein for animal feed [3]. The remaining (residue) decomposition can be used as organic fertilizer for plants.

Some research results show that the use of BSF larvae has many advantages. Li et al [4] in his research stated that the use of BSF in processing organic waste is not only resolves waste problems. Decomposition of waste using BSF turns out to produce biofuels and sugar which can be utilized in industrial fields. Other research shows that the use of BSF does not produce bioaccumulation in the body of the larvae. Lalande’s [5] study, for example, states that processing pharmaceutical waste and drugs using BSF larvae does not cause larvae to accumulate these chemicals. In addition, the use of this strategy is considered easy to use. Decomposition of organic waste by using BSF larvae can be worked using simple technology and does not require extensive land.

Besides that, the usage of BSF larvae in handling organic waste has been used as a method of learning in school by some researchers. The introduction of this approach as a project in the learning can also be done to identify how students perceive various strategies that can be done in designing a project to deal with the waste problems. The ability to determine strategies in managing knowledge and the way the person learns is ability called metacognitive ability [6], [7]. This ability is assessed as an ability that describes the person’s independence in learning, thinking, and evaluating learning. Thus, through metacognitive abilities, the development of knowledge that is useful to students can be done by themselves according to their learning needs [7]. Based on this explanation, it is clear that metacognition in thinking is a good ability for students that should have. According to Purwandari’s research [8], learning in schools usually has not been able to accommodate the development of students’ metacognition. Learning is only centered on the concept, while the information obtained by the students, and the student process and use that information in learning process is often not a concern. Other researchers suggest that senior high school students have developed metacognition skills. The students have been able to think of several strategies that are useful for them in determining something, but still need to be improved [9]. For this reason, the school learning needs to be done in the right way and can accommodate the development of metacognitive abilities. The purpose of this study is as an initial step to introduce *Hermetia illucens* as one of the best ways to decompose organic waste in secondary schools as well as to see how students think about strategies in carrying out a waste recycling project.

2. Method
Learning instrument by introducing an organic waste decomposition project using BSF larvae were developed through five comprehensive steps, including: analysing, designing, developing, implementing and evaluating which called ADDIE. This research was applied to senior high school students, amounting to 44 people. Students who took part in this research were given a pre-test and post-test to find out how they thought about waste decomposition before and after the waste decomposition project was carried out. After answering the questions of the pre-test, students are asked to do a simple waste decomposition project, which is to carry out a decomposition project using the BSF as an organic waste decomposer. Students, then, are asked to answer questions related to efforts to reduce the amount of waste at the post-test. The questions used during the pre-test and post-test are also used to find out the categories of students’ ways of thinking and applying strategies for waste management projects. To find out the categories of ways of thinking and applying strategies for waste management projects, we used the metacognitive abilities test. The items in the test consist of five descriptive questions. Categorizing students’ ability to define metacognitive thinking/strategies used the categories in the Cambridge Assessment International Education [10].
This study was conducted in the 10th grade of one of the private high schools in Bandung in the second semester of the academic year 2018/2019. In this research, one teacher and one observer were involved in the learning.

3. Result and Discussion
The development of learning through the introduction of the project to decompose organic waste using BSF larvae was carried out with the ADDIE development model which has five steps. In detail, the five steps consist of: 1) Analysing, 2) Designing, 3) Developing, 4) Applying and 5) Evaluating will which will be explained through the explanation below.

3.1 Analysing
The analysis was also carried out on the 10th grade Biology in Indonesian curriculum. This stage was very important to determine the concept and material that will be used in the learning. As the result, environmental change concept is sufficient to carry out by introducing the organic waste decomposition project. In addition, the analysis of the metacognitive abilities that will be identified in the learning process produces a number of indicators of ability that will be tested using descriptive questions instrument, which has five questions.

In this step, the introduction to the problems and needs of the research is carried out. The result of this step included the introduction of the problem to be raised in the learning, and the kind of abilities will be identified in the learning process. The ability to be identified is the ability of the students to set strategies in the waste decomposition project. At this analysing stage, researchers also conducted literature studies by looking at the results of the previous studies that related to the problems in this study.

3.2 Designing
This stage is identical to the planning process. The form of the project will be determined to be introduced in the learning. This form is a project to decompose organic waste using simplified BSF Larvae with reference to the implementation of similar projects carried out by the sanitation, water and solid waste departments of Switzerland [3] which described by Figure 1.

![Design project for decomposition of organic waste by using BSF larvae](image)

*Figure 1.* Design project for decomposition of organic waste by using BSF larvae [3]

In addition to determine the form of the project introduced in the learning, designing also included the instruments used to identify metacognitive abilities in this project. The instrument used was a metacognitive question which has five questions, as described earlier.
3.3 Developing
The developing stage is the process of developing projects and instruments so that they become good and feasible forms of projects and instruments. In this step, the instrument that will use is prepared, so when the instrument is implemented it could be fully well and prepared. The assessment indicators for questions in accordance with those listed in Table 1. In addition, in this phase, there are several stages, namely; the judgment process by the experts, trials, and revisions.

**Table 1. Components and Indicators in Metacognitive Questions**

| No. | Components and Indicators of Metacognitive Abilities |
|-----|-----------------------------------------------------|
| 1   | **Strategic Knowledge**                             |
|     | 1. Determine the purpose of the project             |
|     | 2. Detail the things that need to be prepared/studied|
| 2   | 3. Determine several alternative solutions to the problems |
|     | 4. Provide relevant arguments in choosing one of several alternative ways to solve the problems |
| 3   | **Cognitive Task Knowledge**                        |
|     | 5. Select the information that is accordance with the tasks performed |
|     | 6. Determine the steps to manage the time when execute the tasks |
|     | 7. Determine the steps to divide the tasks to be carried out |
| 4   | **Self-Knowledge**                                  |
|     | 8. Give an explanation of the efforts that have been made when solve the problems |
|     | 9. Detail the concept whether understood or not about the tasks/project |
| 5   | 10. Determine the extent to which one’s ability to realize ideas/projects |

3.4 Implementing
In this phase, learning is carried out by introducing the process of decomposing organic waste using BSF larvae as one of the emphasized concept. 10th grade senior high school students as many as 44 students were selected as research subjects. The learning process was carried out for two weeks with a total of 6 times face-to-face. Students were given a pre-test problem to find out how the metacognitive ability to decompose waste. Furthermore, for two weeks the students conducted a waste decomposition project using BSF larvae. In its implementation, students were asked to design, monitor, and evaluate the project. At the end of two learning weeks, students were asked to work on the questions for metacognitive abilities related to strategic knowledge, task knowledge, and self-knowledge.

3.5 Evaluating
In this phase, the metacognitive ability questions are worked by students. The questions of metacognitive abilities consist of questions relating to strategic knowledge, cognitive task knowledge, and self-knowledge. The result of student achievement in this learning was analyzed using metacognitive categorization adapted from the categories in the Cambridge Assessment International Education [10]. The metacognitive ability category consists of four categories, namely Tacit, Aware, Strategic, and Reflective. The results of the assessment and analysis of the students’ answer are categorized and recapitulated as in Table 2. The results can be summarized the level of students’ thinking to determining their strategies about waste decomposition projects and efforts to reduce waste problems.
Table 2. Recapitulation of Category of Metacognitive Knowledge

| No. | Number | Category (n=44) | Tacit | Aware | Strategic | Reflective |
|-----|--------|----------------|-------|-------|-----------|------------|
|     |        |                | Pre   | Post  | Pre       | Post       | Pre        | Post       |
| 1.  | Number 1 | 20             | 3     | 22    | 25        | 2          | 16         | 0          |
| 2.  | Number 2 | 24             | 3     | 20    | 22        | 0          | 19         | 0          |
| 3.  | Number 3 | 13             | 0     | 25    | 17        | 6          | 27         | 0          |
| 4.  | Number 4 | 21             | 2     | 23    | 28        | 0          | 6          | 8          |
| 5.  | Number 5 | 37             | 5     | 5     | 25        | 2          | 10         | 0          |

Table 2 shows the data on students’ abilities at the pre-test and post-test. There is a good change in the categories achieved by students at post-test when compared to the pre-test. Tacit is the lowest level of metacognitive abilities that students are not aware of their metacognitive knowledge. Students only receive the information and did not think about specific strategies. One of the examples is the item number 4.

“Explain! What do you have and have not understood about environmental changes”.

Some students answered
“not yet understood besides environmental pollution”.

This category is also show in the answers of number 5 that asked
“can you describe waste decomposition projects? If the answer is yes, make a plan for implementing the project”.

In this question, students who were given an introduction about the project only answered that they could not do it, even though some answered it could. The aware category shows that students know several types of thoughts and produce ideas, but the way of thinking is not always used in a planned manner. This is shown as the student’s answer:
“The project separates organic and inorganic waste. The aim is that waste is easily selected when it is decomposed and recycled. Something that is needed is the knowledge about the type of waste, determining the material tools, and how to work”.

In the item number 1, the students are asked to write down the type of project, the purpose, and the things needed to do the project about waste.

Strategic categories show students have been able to organize their thinking using problem solving strategies and they apply the strategies that help them to learn. The answer in this category as in the below:
“I will make a schedule, make a picture before doing the research, and use my time as well as possible. I will divide the group fairly and match it with expertise of each member”.

These three categories are found in the answers of 44 students who were the subjects of the study. However, the last category, Reflective, is not found in the student’s answer at the time of the pre-test. After carrying out the waste decomposition project, the distribution of categories at the posttest was dominated by the aware and strategic categories. In the posttest, the reflective category was found in the answer to question items 4 and 5.

Furthermore, another kind of analysis that has been done in this research is measuring the value of effect size. This approach has been carried out by researchers to see how much effect the learning based on organic waste decomposition has on metacognitive abilities. Based on the calculation, the values of effect size is 1.33. The Cohen's d value obtained in this calculation shows the effect of project on decomposing organic waste into very strong categories. This refers to the effect size category compiled by Cohen [11].
4. Conclusion
The project of decomposing organic waste using BSF larvae has been introduced with a simple design in Biology learning. The instrument used as a tool for identifying students strategic abilities (metacognitive abilities) in the project can be used. So that the final result are in the form of categorizing students’ metacognitive abilities. This study shows that students’ metacognitive abilities have mainly developed in three metacognitive categories namely Tacit, Aware and Strategic, while the Reflective category only appears slightly. It is still dominated in the Aware and Strategic categories, although they have carried out a waste decomposition project using BSF larvae. Moreover, it can be concluded that the effect of project on decomposing organic waste into very strong categories.

5. References
[1] Solovjeva TP, Minakova LY 2015 Implementation of ecological education in a higher school Procedia-Social and Behavioral Sciences 200 453-9.
[2] Onder R, Kocaeren AA 2015 Analysis of science teacher candidates’ environmental knowledge, environmental behaviorand self-efficacy through a project called “Environment and energy with professional science education” Procedia-Social and Behavioral Sciences 186 105-12.
[3] Dortmans BM, Diener S, Verstappen BM, Zurbrügg C 2017 Black Soldier Fly Biowaste Processing-A Step-by-Step Guide Eawag: Swiss Federal Institute of Aquatic Science and Technology. Dübendorf, Switzerland
[4] Li Q, Zheng L, Qiu N, Cai H, Tomberlin JK, Yu Z 2011 Bioconversion of dairy manure by black soldier fly (Diptera: Stratiomyidae) for biodiesel and sugar production Waste management 31 6 1316-20.
[5] Llander C, Senecal J, Calvo MG, Ahrens L, Josefsson S, Wiberg K, Vinneräs B 2016 Fate of pharmaceuticals and pesticides in fly larvae composting Science of the Total Environment 565 279-86.
[6] Lai ER, Viering M 2012 Assessing 21st Century Skills: Integrating Research Findings Pearson
[7] Sart G 2014 The effects of the development of metacognition on project-based learning Procedia-Social and Behavioral Sciences 152 131-6.
[8] Arifin MS, Siti Z, Susriyati M 2013 Hubungan Antara Keterampilan Metakognitif terhadap Hasil Belajar Biologi dan Retensi Siswa Kelas X dengan Strategi Reciprocal Teaching di SMA Negeri 1 Lawang. Skripsi tidak diterbitkan. Malang: Universitas Negeri Malang
[9] Sholihah M, Zubaaidah S, Mahanal S 2015 Keterampilan Metakognitif Siswa SMA Negeri Batu pada Mata Pelajaran Biologi. InSeminar Nasional Biologi/IPA & Pembelajarannya
[10] Cambridge Assessment International Education 2017 Metacognition
[11] Cohen J 2013 Statistical power analysis for the behavioral sciences Academic press

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