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Implementation of jigsaw cooperative learning to improve students’ analyze competency of metabolism concept

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Abstract. The aim of this study is to improve analyse competency of students through the implementation of cooperative learning jigsaw on metabolism concepts. The cooperative learning jigsaw began with information collecting about the materials assigned to each member of the jigsaw groups, and then each expert gathered in expert groups to discuss the same material and agree on it, ending with sharing among all team members in the jigsaw group. This study used a pre-experimental design pre-test and post-tests group. The metabolism concepts consist of cell respiration and photosynthesis. The results showed that by cooperative learning jigsaw implementation the students analyse competency on metabolism concepts can increase significantly, although this competency is still low. There are increasing team recognition from the good and very good teams, becoming very good and super teams. Thus the implementation of jigsaw cooperative learning can increase metabolism concept analyse of students and team recognition. One of the weaknesses of students is metabolism concepts mastery is less detailed and less integrate concepts each other. It takes a long time in carry out the cooperative learning jigsaw. All students prefer jigsaw cooperative learning.

1. Introduction
Because of plant physiology included difficult biological material [1,2,3,4], so biological education researchers tried to work through various improvements in learning [5,6,7,8] and development of teaching materials [9]. Of all these studies, no one has revealed about the implementation of jigsaw cooperative learning to improve analyze competency, especially on metabolism concepts. Cooperative Jigsaw learning itself is defined as the distribution of material, resources or tasks so that group work is not done by one or a small number of group members but each member of the group has an important and necessary part of the whole group [10]. Therefore each member of the group is responsible for the task or specific part that must be shared with his group's friends.

The jigsaw cooperative learning has been proven to improve the learning outcomes of students and the quality of learning at various levels of education from elementary school [11,12], junior high school [13,14,15], senior high school and equal [16,17,18] and in college [5,19,20,21,7] on various learning materials. Analysis is one of the higher-order thinking skills [22,23]. The facts show that Indonesian students' high order thinking is still low [24]. The application of cooperative learning can improve students' high order thinking and able to align lower academic students with upper academic [25]. Based on the successful of cooperative jigsaw implementation on students' high order thinking, then the implementation of this learning model is also expected to improve the analyse competency of biology student on Plant Physiology lecture, especially on metabolism concepts.
In general the purpose of this study is to improve the learning quality of Plant Physiology lecture and the learning outcomes of students about metabolism concepts (consist of cell respiration and photosynthesis) especially in analysis competency. In addition, the other objective is to find out students’ responses to the learning model. It is expected that the benefits of this study can improve the quality of other lectures and improve students’ learning outcomes in high order thinking.

2. Method
The method used in this study is pre experimental pre-test and post-test design. Independent variable is jigsaw cooperative learning in Plant Physiology lecture which is done in two cycles, cycle I about cell respiration concepts and cycle II about photosynthesis concepts. The dependent variables are the analysis competency about cell respiration and photosynthesis of the students of Department of Biology Education before and after implementing jigsaw cooperative learning. Lecture content of Plant Physiology in cycle I of jigsaw cooperative learning include glycolysis, citric acid cycle, oxidative phosphorylation, alcohol fermentation and lactic acid fermentation, concerning the place of occurrence, input, process and its output. The places of occurrence, inputs, processes and outputs of light reactions, Calvin cycle reactions, photosynthesis of C4 plants, photosynthesis of CAM plants, and sucrose and starch formation are explored in cycle II.

The research instrument consisted of student work sheet for cycle I, student work sheet for cycle II, six essay items about cell respiration and four essay items about photosynthesis for collecting pretest and posttest data, observation sheet, and questionnaire to reveal response students on learning. Student worksheets and items refer to the course goals of Plant Physiology and contain level of thinking analysis and synthesis. Respondents of this study were 34 Biology students of Department of Biology Education Indonesia Education University of year 2016 who were contracting course of Plant Physiology in first semester of academic year 2017/2018. Research planning stage includes: (1) Literature study about jigsaw cooperative learning, cell respiration and photosynthesis. (2) Preparation of jigsaw cooperative learning plan and its follow-up. (3) Preparation about research instruments.

Research execution stage includes: (1) Socialization of the jigsaw cooperative learning and its assignment to the students. (2) Implementation of cooperative jigsaw learning cycle I includes: (a) Pretest about cell respiration. (b) Grouping students heterogeneously and encoding each member of the jigsaw group. (c) Collection assignment of each member of the experts group for material preparing about the place of occurrence, input, process and its output of glycolysis, citric acid cycle, oxidative phosphorylation, alcohol fermentation and lactic acid fermentation. (d) Discussion in expert groups to reach agreement about answers on the student worksheet. (e) Sharing in the jigsaw group to complete the answers on the student worksheet. (f) Reinforcement concepts by the lecturer. (g) Posttest. (h) Reflection and team recognition. (3) Implementation of cooperative jigsaw learning cycle II almost same as cycle I, but the material learning is photosynthesis. At the end of the lesson, the questionnaires were distributed to obtain students’ responses to the learning model.

| Posttest Scores         | Progress Points | Average Team Progress Points | Recognition Team |
|------------------------|-----------------|-----------------------------|-----------------|
| 5-1 points below pretest | 1               | 1 – 10                      | Moderate Team   |
| 0-10 points above pretest | 5              |                             |                 |
| More than 10-20 points above pretest | 10            |                             |                 |
| More than 20-30 points above pretest | 15 | 11 – 15                    | Good Team       |
| More than 30-40 points above pretest | 20            | 16 – 20                     | Very Good Team  |
| More than 40-50 points above pretest | 25            |                             |                 |
| More than 50-60 points above pretest | 30            | 20 >                        | Super Team      |
| More than 60-70 points above pretest | 35            |                             |                 |
| More than 70 points above pretest | 40            |                             |                 |

To reveal the improvement of analysis competency of Biology students, then calculated Normalized-gain (N-gain) and its categorical level by using the Hake formula [26]. The progress points of each
individual either from pretest to posttest in cycle I and cycle II are calculated and converted (Table 1). To determine the category of team achievement used the modification of team recognition rules according to [27].

3. Result and discussion

Table 2 shows that the original Biology students had very low analysis on cell respiration concepts, the average only 13.6%. The highest analysis competency of this cellular respiration pre-test is in the glycolysis sub-concept (53.7%), while the lowest competency is in the oxidative phosphorylation sub concept (1.5%). This shows that although each student has been assigned to find information according to their individual assignment in their group, the most of students more mastered sub concept of glycolysis than other sub concept.

From the pretest answer, almost half the number of students stated that in glycolysis to break down 1 molecule of glucose uses 2 molecules of ATP, whereas glycolysis produces 2 ATP (generated 4 ATP and minus 2 ATP used) [28,29]. It seems that when students work individually, the competency of the cell respiration analyze of students is very low.

After discussion in expert group by filling out the worksheet in cycle I, the average mastery of cell respiration concepts is 85.1% which is high (Table 2). The cognitive level contained in the worksheet is the synthesis of search results related to the assigned sub concepts. The most high concept mastery in this cell respiration worksheet is the sub concepts of citric acid cycle, glycolysis and alcohol fermentation, while the lowest mastery of the concepts is in the oxidative phosphorylation sub-concept. The oxidative phosphorylation inputs are 10 molecules of NADH and 2 FADH molecules [28,30]. Generally students wrote the oxidative phosphorylation inputs only NADH and FADH alone without the number of molecules.

### Table 2. Analyze competency of average Biology student about cell respiration.

| No. | Sub Concept                  | Average Student Mastery       |
|-----|------------------------------|-------------------------------|
|     |                              | Pretest (%) | Worksheet (%) | Posttest (%) | N-Gain |
| 1.  | Glycolysis                   | 53.7        | 95.8          | 77.2         | 0.4    |
| 2.  | Citric acid cycle            | 2.9         | 100.0         | 15.4         | 0.1    |
| 3.  | Oxidative phosphorylation    | 1.5         | 66.7          | 1.5          | 0.0    |
| 4.  | The amount of energy         | 7.8         | -             | 52.9         | 0.5    |
| 5.  | Lactic acid fermentation     | 11.8        | 68.7          | 52.2         | 0.5    |
| 6.  | Alcohol fermentation         | 8.8         | 91.2          | 36.3         | 0.3    |
|     | Average                      | 13.6        | 85.1          | 40.0         | 0.3    |

---: No Data

After peer teaching in the jigsaw group is carried out analysis competency of the cell respiration concept increased to an average 40.0% with a low N-gain value of 0.3. Glycolysis is a sub-concept of the most mastered students on posttest. Although it has been confirmed by the lecturer in the reflection of cycle I but there are still students who stated that in glycolysis to break down 1 molecule of glucose uses 2 molecules of ATP.

In posttest, there is no improvement in students' analyze competencies in the sub-concept of oxidative phosphorylation compared to pretest. This shows that although there has been sharing among members of jigsaw group and even confirmed by lecturers, Biology students have not been able to analyze where electron transport chain occurs and differentiate it from chemiosmosis. According to student opinions the transport electrons on oxidative phosphorylation occurs along the inner membrane of the mitochondria until ATP is formed through a channel in the complex protein ATP synthase. The transport electrons occurs along the inner membrane of the mitochondria until the electrons reach oxygen (1/2 O₂ + 2H⁺ forming H₂O, whereas ATP is formed when the ion H⁺ from inter membrane space enters into mitochondrial matrix through the complex protein ATP synthase [28, 30].
As well as cycle I, in cycle II the Biology students in the jigsaw group have the analyze competency of photosynthetic concept very low, that is average only 6.9% (Table 3). The lowest analyzing competence in the pretest of photosynthesis is in the C4 photosynthesis sub concept. According to a small number of students C4 plants can bind more CO$_2$ than O$_2$ so that C4 plants are predicted to be more survive than C3 plants in the future without connecting to the state of the environment and the concept of photorespiration. With the increase of earth temperature which one of them is caused by the abundance of CO$_2$, CO$_2$ fixation in C3 plants will be inhibited because of photorespiration. In Plant C4, photorespiration can be avoided, because of the PEPCase enzyme that fixes CO$_2$ to PEP to form 1 molecule C4 that is oxaloacetate in mesophyll cells [30]. PEPCase has advantages over RuBP carboxylase, RuBP carboxylase catalyzes the reaction between O$_2$ with RuBP rather than CO$_2$ when the stomata are closed and the concentration of O$_2$ increases [29].

Table 3. Analyze competency of average Biology student about photosynthesis.

| No.  | Sub Concept                        | Pretest (%) | Work Sheet (%) | Posttest (%) | N-Gain |
|------|------------------------------------|-------------|----------------|--------------|--------|
| 1.   | Light reaction & Calvin cycle      | 19.1        | 83.3           | 80.3         | 0.8    |
| 2.   | C4 photosynthesis                  | 3.9         | 44.4           | 26.5         | 0.2    |
| 3.   | CAM photosynthesis                 | 6.9         | 44.4           | 42.7         | 0.4    |
| 4.   | Sucrose and starch formation       | 5.1         | 52.6           | 63.2         | 0.6    |
|      | Average                            | 6.9         | 64.8           | 46.0         | 0.4    |

In the worksheet as the results of the jigsaw group discussion on cycle II, average mastery of photosynthesis concepts is 64.8% which is categorized as moderate (Table 3). The highest concept mastery in photosynthetic worksheets area sub-concepts of light reactions and the Calvin cycle. It may be based on the mastery of these sub-concepts that causes the posttest value of the sub-concepts of light reaction and the Calvin cycle to be high (80.3%) and contributed a high N-gain value as well (0.8) (Table 3).

From the posttest result, there is an increase of photosynthetic analysis to an average of 46.0% with the N-gain value reaching 0.4 which included the medium category improvement. The lowest analyze competency is found in the sub concept of C4 photosynthesis. Students do not link the process of photosynthesis of C4 plants with its superiority compared to C3 plants in deal with the photorespiration and the higher the earth's temperature. This indicates that students are less able to integrate one concept with another concept. Assignment to each member of the group as an expert turned out to be less ensuring mastery of the concept, because it seems that the difficulty level of the concept is more influential. In addition, the information literacy of student is less detailed. This also happened to previous Biology students [7].

Table 4. Average progress points and team recognition of each group.

| Group | Progress point cycle I | Team recognition cycle I                          | Progress point cycle II | Team recognition cycle II |
|-------|------------------------|---------------------------------------------------|-------------------------|--------------------------|
| 1     | 19                     | Very Good Team                                    | 27                      | Super Team               |
| 2     | 15                     | Good Team                                         | 24                      | Super Team               |
| 3     | 14                     | Good Team                                         | 23                      | Super Team               |
| 4     | 14                     | Good Team                                         | 21                      | Super Team               |
| 5     | 19                     | Very Good Team                                    | 20                      | Very Good Team           |
| 6     | 13                     | Good Team                                         | 18                      | Very Good Team           |
| 7     | 19                     | Very Good Team                                    | 25                      | Super Team               |

Based on the average progress points on all origin groups in cycle I, all the jigsaw groups are already in the category of good and excellent team (Table 4). The result of reflection in cycle I, gives the average progress points of the jigsaw group cycle II, so its rate to be a very good and super team. With the increase of team recognition, it shows that through the application of cooperative learning jigsaw
team works are getting better. This is closely related to the development of interpersonal skills [21] and occurs because each student is required to contribute to the success of his group [31]. With increased team work in the group resulted in increased quality of learning and learning outcomes, as well as this learning has also proven to be favored by all students. This is consistent with the results of research which states that jigsaw type cooperative learning can improve quality of learning and student learning outcomes from elementary level [11,12], junior high school [13,14,15], senior high school and equal [16,17,18] and in college [5,7,19,20,21]. As in previous studies [5, 7] the execution of cooperative learning jigsaw takes a long time.

4. Conclusion
Implementation of jigsaw cooperative learning can improve the analyse competency of Biology students in metabolism concepts in Plant Physiology course; improve the quality of learning and teamwork. Analyse competency about concept of cell respiration from pre-test to post-tests increases in the low category and a moderate increase in the concept of photosynthesis.

All students are actively involved and contribute very well to their group, resulting in improved team recognition from good and very good teams to very good and super teams. The results of the questionnaire indicate that all students love the jigsaw cooperative learning in the lecture.

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