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IMPROVING STUDENTS WITH INTELLECTUAL DISABILITIES SCIENCE PROCESS SKILLS THROUGH PHOTOSYNTHESIS EXPERIMENT IN ENHANCING CLIMATE CHANGE AWARENESS

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Abstract

This research focused on improving students with intellectual disabilities science process skills through photosynthesis experiments using various light intensities in enhancing climate change awareness. The research was conducted in one of *Sekolah Luar Biasa* in Bandung, Jawa Barat Indonesia to six students with intellectual disabilities with IQ below 65. The experiments were conducted using *Hydrilla Verticillata* and treated using sunlight, 50-watt light, indoor light, and coloured plastic sheet. The research found that students with intellectual disabilities could learn the topic. In so doing, the preparation stage plays an important role to design the tools and materials needed for the activities. Students' abilities should be scrutinized, and the learning objectives should be adapted based on their actual condition. Besides, giving them a challenging question is also suggested to build their understanding and to develop their analytical abilities. As part of society, students with intellectual disabilities also play an essential role in taking care of the environment. Teacher's knowledge and understanding of the scientific topic are definitely indispensable so students' needs can be accommodated and their knowledge on the topic improves which eventually helps to build their better life.

Keywords: Climate change, Photosynthesis experiment, Science process skills, Student with intellectual disabilities.

1. Introduction

Science has a key role to play in developing skills of communication, critical thinking and problem-solving, and the ability to use and evaluate evidence [1]. Science is stimulating and exciting and it also has the potential to engage learners at every level using the latest technological simulations, explaining everyday phenomena [2]. Therefore, science education has become an important area for educating students who are scientifically literate regardless of their disabilities. Science learning is a subject that is included in the curriculum for students with intellectual disabilities in Indonesia. One of the science topics that students with intellectual disabilities study when they are at the higher secondary level is the photosynthesis.

All food is produced directly and indirectly by photosynthesis [3]. As the world is facing climate change, the growing number of people, and the need for food supply, educating students regarding the importance of the photosynthesis process on plants is a must. It was ascertained that plant productivity greatly depends on the speed and efficiency of photosynthesis, specific environmental conditions, and nutrients essential for plant growth [4].

In Southeast Asia, the terms and concepts generally used to refer to intellectual disability include mental retardation, mental handicap learning disabilities, mental deficiency, and mental sub normality [5]. In Indonesia, those with intellectual disabilities are doubly disabled by the social relations of ableism [6]. Thus, the perspectives towards students with intellectual disabilities hinder them to get the full advantages of education compared to students who are not categorized as students with intellectual disabilities.

Generally, there are four challenges that students mostly encountered while learning about photosynthesis [7]. It includes the concept of food, energy, the nature of matter, and the functional nature of scientific explanations. However, in science, effective learning for students with special needs appears to be hindered partly because of issues related to teachers' experience or ability to make appropriate modifications based upon the needs of the student, and also in part because of the instructional methodologies and resources used in most general education classrooms [8].

Teaching and learning photosynthesis to students have been started since the secondary level in Indonesia. Many research has been conducted in finding more updated information and knowledge regarding photosynthesis such as research on student assessment and misconceptions of photosynthesis [9], Experienced biology teachers' pedagogical content knowledge (PCK) on photosynthesis [10], compare the past misconception problems in photosynthesis and respiration topics with the present cases in Indonesia [11], misconceptions on photosynthesis and plant respiration topics based on thinking styles [12], and how to improve the mastery of students' concept on photosynthesis topic [13]. However, studies on photosynthesis to students with intellectual disabilities particularly in Indonesia are limited. Therefore, this study conducted to fill in the research gap and to find deeper insights into the science process skills of students with intellectual disabilities.

2. Logical Framework

Photosynthesis is a process by which green plants synthesize carbohydrates from water and carbon dioxide [14]. Photosynthesis helps to keep the earth cool because

it removes carbon dioxide from the atmosphere, therefore, it is vital to life on earth. The photosynthesis process can only occur if there is light and through the intermediate green pigment chlorophyll in the cytoplasmic organelles namely chloroplasts. Moreover, chlorophyll, light, and carbon dioxide should exist. Therefore, sunlight plays an essential role during photosynthesis because it provides energy. Most plants obtain energy through photosynthesis using the green pigment chlorophyll.

The primary reactions of photosynthesis are mediated by a series of photosynthetic complexes associated with or embedded in the photosynthetic membranes. The first step in the process of photosynthesis is the absorption of light photons by an array of antenna pigment-protein complexes, termed light-harvesting complexes (LHCs) [15]. Photosynthesis is a complex process by which carbon dioxide is converted to carbohydrate (Fig. 1) and is converted to many other compounds. The carbon of carbon dioxide is reduced during photosynthesis and the energy is supplied to it and converting it into carbohydrate.

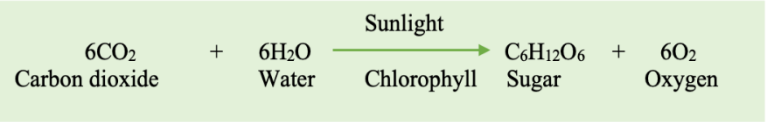

Fig. 1. The raw materials and products of photosynthesis.

The converting process involves endergonic reactions driven by adenosine triphosphate (ATP) and requiring new bonding orbitals filled by electrons carried to the reaction by reduced nicotinamide adenine dinucleotide phosphate (NADPH). Before this can happen, ATP and NADPH themselves must be formed in highly endergonic reactions driven by light energy [16]. One of the photosynthesis processes involves Photosystem II that its reaction produces oxygen that we breathe. Photosynthesis starts with the absorption of a photon that activates specialized chlorophyll, P680, leading to the ejection of a P680 electron. This electron is transported via the photosynthetic electron transport chain to the final electron acceptor (NADP+) through a series of redox reactions, including the absorption of the second photon by the photosystem I antenna system, which creates the NADPH reductive. A proton gradient is generated across the thylakoid membrane along the way, and this gradient generates ATP via ATP synthase [17].

During this study, we used the water thyme plants; *Hydrilla Verticillata*. *Hydrilla Verticillata* is also familiar to the students because it is often used as aquatic plants. *Hydrilla Verticillata* is found in freshwater and also grows in various types of aquatic habitats (such as lakes, rivers, and ponds) from tropical to temperate regions [18]. *The Hydrilla Verticilata* is placed inside a glass funnel and put inside a beaker filled with water. The energy from the sun uses for the process of water molecule breakdown into hydrogen and oxygen under the influence of light during the light reaction of photosynthesis. During this process water (H2O), the solar energy used to produce hydrogen ions (H +) and O2. The hydrogen ion will be combined with CO2 to form sugar (CH2O) n, while the O2 will be released in the form of a bubble. The resulting bubble is oxygen gas which is formed due to the breakdown process when water is broken down into oxygen gas as shown in Eq. (1).

$$2H_2O \longrightarrow 4H^+ + O_2 \quad (1)$$

Furthermore, the photosynthesis process is also affected by light. The difference in the light colour also affects the number of bubbles produced. Sunlight comes from white light that can be broken down into components of colour because the wavelengths of light vary for each hue Fig. 2. Most of us can see all the wavelengths from red (760 nm) through orange, yellow, green, blue, indigo, to violet (390 nm) [19].

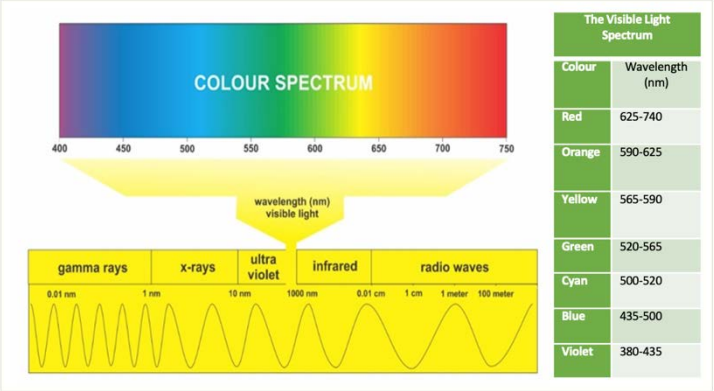

Fig. 2. Light spectrum wavelength and the visible light spectrum (inserted).

The environment is going through a period of rapid change globally as can be seen from the elevated CO2, ocean acidification, temperature rises, and increased UV radiation and a pace of which is unprecedented in our geological history [20]. Although the planet has undergone very large fluctuations in climate in the geological past, the pace at which current changes are occurring is extraordinary [21]. The climate change is a change that is significant and permanent and an objective transition of a sample climate over a period ranging from decades to several years [22]. Climate change has made the planet earth warmer, drier, and wetter depends on the areas. When the temperature is warmer, the plant may lose its water through wide openings of stomata in hot regions [23].

3. Research Method

3.1. Research subject

This study used single-subject research towards six students with mild intellectual disability with IQ below 65. The participants were six students at the secondary high school given initials A, B, C, D, E, and F, in Bandung, Indonesia. There are four male students and two female students. All students study at SLB-C which is a special school for students with intellectual disabilities.

3.2. Teaching analysis

To find out a comprehensive profile of participants, we collected data subject by using data from an identification book and interview with the homeroom teacher. Demographic data and academic learning outcomes were collected through interviews with teachers. The collected data were the students' communication methods, literacy skills, numeracy skills, reasoning ability, and memory. To simplify the data, all information is scaled from 1-4 where 4 (very good), 3 (good), 2 (quite good), 1 (needed support), 0 (know nothing), and presented in Fig. 3. The

gathered data then used to develop research instruments. From the interviews, it is found that students have poor reading, writing, and numeracy abilities although students age ranges from 16-7 years old. Generally, all students understood simple and short instruction, and three students could understand long sentences. One student only produces single words in daily communication. Three students have another disability causing some limited physical movement and unclear utterances.

3.3. Materials and tools for the photosynthesis experiment

To experiment with the students, we used water thyme or *Hydrilla Verticillata*, 1000 mL-beaker glass, 70mm- glass funnel, 16 mm-tube glass, four S-shaped wires to hold the glass funnel, a 50-watt light blue plastic sheet, green plastic sheet, yellow plastic sheet, red plastic sheet, tube, and water. The worksheet was made in two different types based on the analysis of students' abilities.

3.4. Photosynthesis phenomena

$C_6H_{12}O_6$ (glucose) and oxygen (O_2) are formed by CO_2 (carbon dioxide) and H_2O (water) when exposed to the sunlight. We counted the number of oxygen bubbles that formed, and the results were compared to predict the converted CO_2.

4. Results and Discussion

4.1. Student demographics

The subjects for this study were six students with intellectual disabilities who study at the secondary high special school. All the students had an IQ below 65. Two students have very good communication skills, one has good communication skills, and the rest still needs help in their communication methods. Mostly students' literacy skills are quite good, and two students have very good literacy skills. Two of the students have very good literacy skills which means they can express their opinions and ideas using long sentences and complex sentences. They also can write and read long sentences. All the students have average numeracy skills. Although two students have very good numeracy it is limited to knowing numbers 1-100. Students 'reasoning ability is quite low and also their memory as can be seen in Fig. 3.

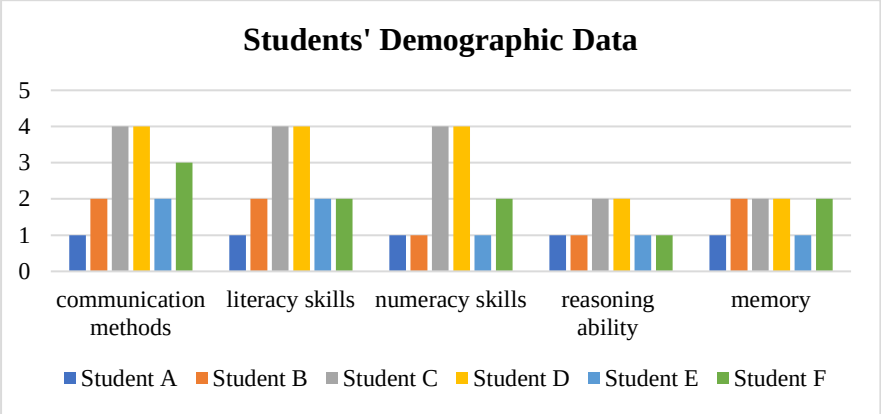

Fig. 3. Students' demographic data on communication methods, literacy skills, numeracy skills, reasoning ability and memory.

4.2. Data analysis of Carbon Dioxide

Analysis of the carbon dioxide don the photosynthesis experiment that we conducted presented in Table 1. $C_6H_{12}O_6$ (glucose) and oxygen (O_2) are formed by CO_2 (carbon dioxide) and H_2O (water) when exposed to the sunlight. The light intensity was measured to find out the amount of CO_2 occurred.

Table 1. Photosynthesis experiment.

No.	Treatment	The amount of CO_2 occurs
1	Inside the classroom	11.78 mL/m^3
2	Outside the classroom (direct sunlight)	45.138 mL/m^3
3	Direct sunlight covered with green plastic	17.66 mL/m^3
4	Direct sunlight covered with yellow plastic sheet	13.74 mL/m^3
5	Direct sunlight covered with red plastic sheet	431.75 mL/m^3
6	Direct sunlight covered with blue plastic sheet	47.1 mL/m^3
7	Exposed to 50-watt light sheet	25.52 mL/m^3

4.3. Phenomena in the learning and teaching process

Before our designed learning, the teacher had taught students basic photosynthesis. The teacher used a conventional approach where the teacher talking time was very high. Students only listened to the teacher and most of the questions given by the teacher were closed-ended questions. As a result, it was challenging to see students' learning outcomes. Before conducting the lessons, researchers and the teacher discussed the lesson plans together. The learning then decided to be conducted two times using the inquiry-based learning approach to create more opportunities for students to create opportunities for students to discover, observe, try, and draw conclusions. The teacher acted as a facilitator and gave a model before started the experiments.

At the beginning of the class, the teacher recalled the previous photosynthesis discussion where the teacher used students' growth to help students getting the idea of growing. The teacher then showed the stages of how to experiment. The glass funnel is placed upside down and supported with three wires to ensure that the glass funnel is slightly lifted, and the resulting bubbles are trapped, then observed properly. The test tube then filled with water so that and placed on the top of the glass funnel and the trapped bubbles could be observed.

The experiment was conducted twice in the classroom and at the school. In the classroom, students experimented using the 50-watt light and the light. Students experimented with pairs and followed the stages that the teacher showed earlier. Then, students asked to compare the Hydrilla Verticillata treated with 50-watt light and with the indoor light. As for the experiment outside the classroom, students experimented using the coloured plastic sheets and covered the beaker glass with the sheets. Students then asked to analyse which treatment produces more bubbles. During the experiment, students were asked questions (Table 2) and after conducting the experiments, students were given different worksheets based on their abilities. Students learning outcomes are based on their comments and answers on the worksheet then analysed as seen in Table 2.

Table 2 shows that the students made progress in understanding photosynthesis. 33% of students were able to recall the things needed for the experiment while 67% of students could name things needed for the experiment with support from the teacher. Additionally, for the abilities to recall the stages for the experiment, 67% of students could name the stages with some help from the teacher and 33% could restate the stages for the experiments. However, when students asked to experiment themselves, all students could do and repeat all the stages.

Table 2. Students learning outcomes on photosynthesis experiment.

No.	Question	Able (3)	Able with help (2)	Unable (0)
1.	What are the things needed for the experiment?	33%	67%	-
2.	What are the stages for the experiment?	33%	67%	-
3.	Why are there oxygen bubbles?	17%	66%	17%
4.	Where are those oxygen bubbles from?	33%	50%	17%
5.	Which experiment has more bubbles? Inside or outside the classroom?	33%	67%	-
6.	Which colour of light determined more oxygen bubbles?	17%	66%	17%

When the students asked questions on the reason why oxygen bubbles appear, 17% of students could identify the appearance of bubbles caused by sunlight. When experimenting, the student was immediately responded based on the direct analysis students conducted. Furthermore, 50% of students could name the cause of the oxygen bubbles with support from the teacher, 33% could name it without help and 17% was unable to answer it although the support had been given.

Students were able to compare the number of bubbles given treatment inside and outside the class (33%), however, 67% of students needed some hints before they could answer. When comparing the light colour which determined the number of oxygen bubbles, students found it was quite challenging, 17% could not answer it, 66% could answer by getting some help from the teacher and only 17% could answer it without any help.

Light intensity affects the process of photosynthesis and that most of us can see all the wavelengths from red to violet through orange, yellow, green, blue, indigo. During the activity, the students observed the *Hydrilla Verticillata* which had been placed inside beaker glasses. The beaker glasses covered with coloured plastic sheets to find which colour produce more bubbles. This experiment conducted outside the classroom to expose the plants to sunlight. After five minutes students started to get distracted since during the experiment there were some students who were having sports. Despite the teacher encouragement and the interesting experiment, only one student was able to focus on the experiment. As a result, when the teacher gave questions, students were barely able to give correct answers.

Although students showed significant progress when they conducted the experiment themselves, however, students could only identify that the bubbles happened due to the sunlight. When asked where plants got food, student A said the *Hydrilla Verticillata* got the food from water which was acceptable but not scientifically correct. Students with special needs are more complicated because the dominance of concrete and objective perception is typical and their logical thinking is closely related to the fact, and even a small generalization from a particular situation is always difficult [24]. The teacher then, explained that the photosynthesis happened during the experiment and resulting the bubbles to appear. On the other hand, when the teacher connected the photosynthesis process on plants almost similar to the process of human getting the food in order to have energy, the students started to grasp the concept of photosynthesis.

As the lesson also aimed to develop students' awareness of climate change, we found that it was challenging for students to learn the climate change at the same time they learn photosynthesis. Since learning for intellectually disabled students is challenged because of their difficulties in generalizing concepts, decision-making, problem-solving and goal-setting, teachers should provide information on small bits [25]. Therefore, students should have been introduced to climate change prior to teaching photosynthesis. Additionally, adaptation focused mainly on strategies to address the needs of students with smaller steps/procedures, the division of tasks between students with different skills, the provision of relevant background knowledge, the provision of suitable resources, and understanding of safety measures is also needed [26].

Students with intellectual disabilities are known to have an IQ that ranges from 50 to 70. We found that all students make progress in understanding photosynthesis and were able to see and know the photosynthesis process by observing the experiments. Although at special school, science subject is not seen as one of the most important subjects, science is often viewed as an unnecessary facet of their education [19], however, our study found that students with intellectual disabilities were able to learn science using the inquiry-based approach.

5. Conclusion

However, the study that we conducted showed that students with intellectual disabilities could learn the topic. In so doing, the preparation stage plays an important role to design the tools and materials needed for the activities. Students' abilities should be scrutinized, and the learning objectives should be adapted based on their actual condition. Besides, giving them a challenging question is also suggested to build their understanding and to develop their analytical abilities. As part of society, students with intellectual disabilities also play an essential role in taking care of the environment. Teacher's knowledge and understanding of the scientific topic are definitely indispensable so students' needs can be accommodated and their knowledge on the topic improves which eventually helps to build their better life. However, limitation to this study should be noted as the study focused on students with intellectual disabilities whose IQ under 65. The fast-changing light intensity indoor and outdoor during the also affected the experiment and the experiment did not focus on the effect of colours during the experiment. Therefore, further study on the previously mentioned should be conducted to examine the experiment.

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