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PROMOTING STUDENTS' CONCEPTUAL CHANGE ON THE CONCEPT OF ECOSYSTEM THROUGH PDEODE (PREDICT-DISCUSS-OBSERVE-EXPLAIN-DISCUSS-EXPLAIN) TEACHING STRATEGY

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ABSTRAK

Penelitian ini menyelidiki perubahan konseptual pada pemahaman siswa tentang konsep ekosistem.Variasi dari strategi pengajaran POE (*Predict-Discuss-Explain*) yakni PDEODE (*Predict-Discuss-Explain-Observe-Discuss-Explain*) diterapkan selama penelitian ini. Sampel penelitian adalah 28 siswa di salah satu Sekolah Menengah Atas di Bandung. Ide-ide siswa tentang konsep ekosistem diungkap dengan menggunakan ujian 10 soal yang disebut sebagai ECT (*Ecosystem Conceptual Test*). Perubahan konseptual siswa dalam hal pemahaman tentang konsep ekosistem dievaluasi dengan ECT pada pretes, postes, dan *delayed posttest.* Hasil uji ANOVA satu arah menunjukkan nilai ketiga tes berbeda signifikan ($p<0,05$) yang menunjukkan bahwa PDEODE membantu siswa untuk memperoleh pemahaman yang lebih baik. Selain itu, tidak adanya perbedaan yang signifikan antara postes dan *delayed posttest* mengindikasikan bahwa strategi pengajaran ini dapat membantu siswa untuk mempertahankan pemahaman baru mereka.

Kata kunci: Perubahan Konseptual, Konsep Ekosistem, Strategi Pengajaran PDEODE

ABSTRACT

This study investigated conceptual change in students' understanding of ecosystem concept. The PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) teaching strategy, a variant of classical POE (Predict-Discuss-Explain) was implemented during the study. Sample was 28 senior high school students in one of senior high school in Bandung. Students' ideas about ecosystem concept were revealed by a ten questions-test called ECT (Ecosystem Conceptual Test). Conceptual change in student's understanding of ecosystem concept was evaluated by administering ECT in pretest, posttest, and delayed posttest.Tests' score were then analyzed quantitatively and qualitatively. One-way ANOVA test result showed statistically significant score difference ($p<0.05$) in each test which suggested PDEODE helped the students to achieve better understanding. Moreover, no statistically significant differences were found between posttest and delayed posttest scores, indicating that the teaching strategy helped the student to retain their new conceptions.

Keywords: Conceptual Change, Ecosystem Concept, PDEODE Teaching Strategy

INTRODUCTION

Misconception is one of the challenges for both teachers and students during instruction process in school. It happens because some concepts in science are something deemed abstract by the students. Students entering the classroom with their own conceptions and science concepts that they got from their daily activities (Costu, 2008), and most of the time those conceptions fall into incorrect conceptions in science (Cetin, 2003). Those existing conceptions should be the concern of teachers in teaching science because alternative conceptions are strongly rooted in students understanding (Pfundt and Duit, 2000).

Most of the time teachers thought that students entering the classroom as an empty bottle or in condition called "*clean mental states*" and teachers teach only to fulfill those empty bottles (Marionni, 1989). The problems come when the bottles are not empty anymore; it has been filled with many alternative conceptions that come from daily activities or other experiences. For example, when a student saw a farmer gave fertilizer to the plant, the student then thought that fertilizer was food for plant and plant took up the food by using their roots. It can also happen

when a student interacts with the environment; they naturally will construct and search explanation for their experiences. When the student got the explanation for certain scientific phenomenon, they may have an alternative conception.

As science subject, biology consists of many abstract concepts. Ecosystem is one of concept deemed abstract for senior high school students even though they have learned it since elementary level or even when some students thought that the concept is not difficult to learn, misconceptions about this concept still occurs. Ecosystem is central concept in ecology and involved three functional process, i.e. photosynthesis, matter cycle and energy transfer (Cokadar and Yilmaz, 2010).

There are at least 21 alternative conceptions and two common difficulties that most students have concerning ecosystem central concepts. Some alternative conceptions related with those three functional functions are: *plants feed by absorbing food through their roots* (Bell, 1985; Smith and Anderson, 1984; Berthelsen, 1999), *water, carbon dioxide and minerals from ground water are food for plant* (Berthelsen, 1999), *sunlight is a food for plant* (Berthelsen, 1999), *varying the population size of an organism will affect all other organisms to the same degree* (Munson, 1991), *varying the population size of a species may not affect an ecosystem, because some organisms are not important* (Munson, 1991), *varying the population size of a species will only affect the others that are directly connected through a food chain* (Griffiths and Grant, 1985; Munson, 1991), *energy is not lost in tropic transfer* (D'Avanzo, 2003), *some ecosystems are limitless resources and provide an opportunity for limitless growth of a population* (Munson, 1991), *populations increase until limits are reached, then they crash and go extinct* (McComas, 2002), *populations higher on a food web increase in size, because they deplete those lower in the web* (Munson 1991; 1994), *populations exist in states of either constant growth or decline depending upon their position in a food chain* (Munson, 1991), *plants obtain their energy directly from the sun* (Berthelsen, 1999), *plants use heat from the sun as a source of energy for photosynthesis* (Berthelsen, 1999), *sunlight helps plants grow by keeping them warm* (Fries-Gaither, 2009), *sunlight is not part of ecosystem and not helpful for animal survival*; *sunlight is not abiotic component* (Fries-Gaither, 2009), s*unlight is helpful for plant survival but not critical in ecosystem* (Fries-Gaither, 2009), *photosynthesis occurs in plants and respiration occurs in animals* (Lavoie, 1997), *respiration is the reverse of photosynthesis* (Lavoie, 1997), *the process of photosynthesis provides plants with their energy* (Lavoie, 1997), *carbon dioxide is a source of energy for plants* (Lavoie, 1997), *ecosystems change little over time* (D'Avanzo, 2003; NRC, 1996). Besides alternative conceptions, there are also two common difficulties that most of the students have which are: *unable to link the abiotic and biotic components of the ecosystem correctly* (Morholt et al., 1958) and *not understand the concept of ecosystem comprehensively* (Sharma, 1981).

Teaching activity must concern on student alternative conceptions because students come to the classroom with their own alternative conceptions. By knowing student's alternative conceptt-ion, the teachers could prepare their teaching intervention to promote conceptual change, from alternative conceptions into scientifically accept-ed concepts. Many educational researchers saw that learning is the process of conceptual change which comes from constructivist pers-pective (Dykstra et al., 1992; Posner et al., 1982). According to constructivist learning theory, learning is process to construct mental model to accommodate experiences. Learning is the result of mental construction, knowledge construction, and the learner socially or individually constructs the meaning when learning (Kolari et al., 2005).

PDEODE is called as teaching strategy because it involved variety teaching methods. Costu (2008) stated that PDEODE is an important learning strategy because it provides the atmosphere to support discussion of various perspectives (Costu, 2008). This strategy is effective strategy to replace students' alternative conceptions with scientific conceptions in order to facilitate conceptual change (Costu et al., 2010). Costu et al. (2010) noted that PDEODE is the development and modification of POE (Predict-Observe-Explain) propose by Gunstone in the early 90s with some addition to enrich the patterns. Key modifications distinguish PDEODE from POE are the discussion and explain steps. Discussion is inserted in between Predict-Observe-Explain stage whereas explain is carried out twice so that it resulted in Predict-Discuss-Explain-Observe-Discuss-Explain (PDEODE). It

is expected that while going through these steps, the students will begin to resolve the contradictions that may exist between their beliefs, and adopt a new concept that is compatible with the scientific concept.

The purpose of this study was to develop a PDEODE teaching strategy that can facilitate conceptual change, and investigate its effectiveness on student understanding of Ecosystem concept. The following research questions were addressed: 1) Do PDEODE teaching activities help students to change their alternative conceptions towards more scientific ones?, and 2) Do PDEODE teaching activities enable students to store their new conceptions in long-term memory?

METHODS

Participant in this study initially comprise of 34 tenth grader students (11 boys and 23 girls, whose age were ranged from 14-16 years old) at a senior high school in Bandung, but six students could not finish the study sequences completely. Therefore only 28 students become full participant in this study. To assess students' conceptual change before and subsequent to intervention, an Ecosystem Conceptual Test (ECT) consisting of ten questions was developed based on 21 alternative conceptions and two common difficulties (Bell, 1985; Smith and Anderson, 1984; Berthelsen, 1999; Munson, 1991, 1994; Griffiths and Grant, 1985; D'Avanzo, 2003; McComas, 2002; Fries-Gaither, 2009; Lavoie, 1997; NRC, 1996; Morholt et al., 1958; Sharma, 1981)

The items were devised in three types of formats, of which two were multiple choice test one-tier items, five true/false two-tier test items and two open-ended test items. Reliability coefficient was found to be 0.66 (modest but acceptable). The test was validated by a panel of three biology teachers and two teacher educators. The final form of the test was administered to the students six weeks before (pretest), after the intervention (posttest), and six weeks after posttest (delayed posttest) in identical form. It is assumed that the time intervals is sufficient for students to forget the test items. An example of each type of test item is presented in Figure 1.

Sample items

- *Where do plants get their food?*
  a. They make their own food internally, mainly from a gas and water.
  b. They absorb it from the soil via the roots.
  c. They get it from ground water.
  d. Sunlight consumed as a food for plant.

Because,.....

- *Plants obtain their energy directly from the sun.*

True **False**

Because,

a. Plants use heat from the sun as a source of energy for photosynthesis.
b. Sunlight helps plants grow by keeping them warm.
c. Energy from the sun allows the plants to carry out photosynthesis and produce sugars.
d. Sunlight is a food and consumed in photosynthesis
e. .....

- *A test tube filled with water. Inside this tube live a snail, small fish and an aquatic plant. They do not eat each other's. This tube is tightly closed to prevent air circulation and placed in a place with enough sunlight. Could we call the test tube with those conditions as an ECOSYSTEM? Yes or Not? Why? Explain your reason?*
  .....
  .....

Figure 1. Examples of ECT (Ecosystem Conceptual Test) Questions Evaluating Students' Alternative Conceptions in Ecosystem

Taking into account the variation of students' performance in the pretest, conceptual change was determined from (1) the gain in answer scores, (2) the changes in the responses from pretest to post- or delayed posttest and (3) the changes in students' alternative conceptions from pretest to posttest and delayed posttest.

The treatment that had been conducted was laboratory experiment which allows the students to follow the PDEODE teaching strategy. The procedure that they need to conduct based on the teaching strategy was observing the mini aquarium experiment (Figure 2) guided by open ended question provided in the worksheet.

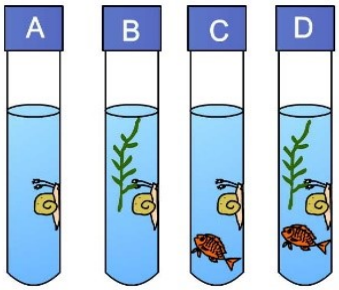

Figure 2. The mini aquarium as the phenomena during student's laboratory activity.

In order to analyze the test items, two criteria were used to classify and to mark the students' responses to different test type items. In analyzing two-tier test items and multiple choice test items with explanation, students' responses were analyzed with criteria proposed by Costu et al. (2010).

In analyzing open-ended test items in the test, firstly students' responses were examined thematically and the following criteria (Costu et al., 2010) were used to classify the responses: *Sound Understanding,* SU (3 points); *Partial Understanding,* PU (2 points); *Specific Misconception,* SM (1 point); *No Understanding,* NU (0 point); and *No Response,* and NR (0 point) and the detailed criteria can be seen in table 3. To provide the validity of categorization, students' responses to open-ended items (Items 9 and 10) were classified into categories by tracking the following steps.

Firstly, students' responses in Item 9 and Item 10 were classified by the two biology teacher as SU, PU, SM or NU. Secondly, in each of the two items, the two biology teachers agreed of the classifications. Finally, all differences or disagreements were resolved by discussion.

For two-tier test items, since each question and reason had one correct answer and the others had alternative conceptions, students' responses were also analyzed in order to define their conceptions based on pre-, post- and delayed posttest. Moreover, changes of their conceptions were presented in tables to observe students' conceptual changes after the teaching. Besides qualitative analyses, quantitative analyses were utilized. Total number of points for each student was analyzed by ANOVA for repeated measures to make statistical comparisons.

RESULTS AND DISCUSSIONS

Major alternative conceptions that were found in this study mainly related to plant, photosynthesis, and energy used by plant. This doesn't mean the plant concept more dominant than ecosystem concept; because the concepts related to plant energy conversion is the subordinate concept from ecosystem concept. According to Lawson (1995) concept is not stand alone, but interacted to make meaningful system that can be found in hierarchy from subordinate to superordinate concept. The interrelated concepts are called conceptual system. Ecosystem is conceptual system because every concept from plant, sunlight, producer, food webs, communities and environmental factor integrated into a system called as Ecosystem.

Students' answers were analyzed to determine Student Alternative Conceptions (SAC) and Students' Common Difficulties (SCD) based on *pretest, posttest,* and *delayed posttest.* Result in Table 1 showed that conceptual changes happen for almost all SAC and SCD. This can be seen from decreasing number of SAC and SCD after teaching intervention. For example, the percentage of the SAC No. 12 decreased from 82.14% in pretest to 17.86% in posttest and 3.57% in delayed posttests (+64.28% conceptual changes occurred). Additionally, it was possible to see whether conceptual change was retained or not. If the percentage of the SAC in the delayed posttest was less than that in the posttest or equal to each test, conceptual change in the SAC was considered to have been retained.

Table 1. Conceptual changes and retentions in students' alternative conceptions (SAC) and common difficulties (SCD) through each test

No.	Alternative conceptions and difficulties	*Pretest* (%)	*Posttest* (%)	Conceptual Change (%)	*Delayed Posttest* (%)	Retention
1.	*Plants feed by absorbing food through their roots.*	17.86	0	+17.86	0	R
2.	*Water, carbon dioxide and minerals from ground water are food for plant.*	7.14	0	+7.14	0	R
3.	*Sunlight is a food for plant.*	10.71	0	+10.71	0	R
4.	*Varying the population size of an organism will affect all other organisms to the same degree.*	0	0	-	3.57	-
5.	*Varying the population size of a species may not affect an ecosystem, because some organisms are not important.*	0	3.57	-	0	-
6.	*Varying the population size of a species will only affect the others that are directly connected through a food chain.*	17.86	0	+17.86	3.57	R
7.	*Energy is not lost in tropic transfer.*	0	0	-	0	-
8.	*Some ecosystems are limitless resources and provide an opportunity for limitless growth of a population.*	21.42	3.57	+17.85	10.71	R
9.	*Populations increase until limits are reached, then they crash and go extinct.*	7.14	3.57	+3.57	3.57	R
10.	*Populations higher on a food web increase in size, because they deplete those lower in the web.*	17.86	0	+17.86	0	R
11.	*Populations exist in states of either constant growth or decline depending upon their position in a food chain.*	28.57	25	+3.57	17.86	R
12.	*Plants obtain their energy directly from the sun.*	82.14	17.86	+64.28	3.57	R
13.	*Plants use heat from the sun as a source of energy for photosynthesis.*	50	14.28	+35.72	14.28	R
14.	*Sunlight helps plants grow by keeping them warm.*	0	0		0	-

No.	Alternative conceptions and difficulties	*Pretest* (%)	*Posttest* (%)	Conceptual Change (%)	*Delayed Posttest* (%)	Retention
15.	*Sunlight is not part of ecosystem and not helpful for animal survival. (Sunlight is not abiotic component).*	0	0		0	-
16.	*Sunlight is helpful for plant survival but not critical in ecosystem.*	3.57	7.14	-	0	-
17.	*Photosynthesis occurs in plants and respiration occurs in animals.*	60.71	28.57	+32.14	25	R
18.	*Respiration is the reverse of photosynthesis.*	3.57	3.57	0	3.57	-
19.	*The process of photosynthesis provides plants with their energy.*	17.86	0	+17.86	7.14	R
20.	*Carbon dioxide is a source of energy for plants.*	39.28	10.71	+28.57	14.28	R
21.	*Ecosystems change little over time.*	32.14	21.42	+10.72	25	R
22.	*Unable to link the abiotic and biotic components of the ecosystem correctly.*	53.57	0	+53.57	0	R
23.	*Not understand the concept of ecosystem comprehensively.*	96.42	3.57	+92.85	0	R

From 21 students' alternative conceptions (SAC) and two Students' Common Difficulties (SCD) in understanding the concept of ecosystem, 17 SAC and two SCD were found in the pretest, in which more than 30% students have SAC No. 12, 13, 17, 20, 21 and SCD No. 22 and 23.

In SAC No. 13, students' belief that the plants use heat from the sun as a source of energy for photosynthesis decreased from 50% in pretest to 14.28% in posttest, which indicated a positive conceptual change (+35.72). Students maintained positive conceptual change until delayed posttest. In SAC No. 17, students' belief that photosynthesis occurs in plants and respiration occurs in animal, decreased from 60.71% to 28.57% in posttest and decreased further to 25% in the delayed posttest.

In SAC No. 20, students' belief that *carbon dioxide is a source of energy for plants* decreased from 39.28% to 10.71%, a positive conceptual change (+28.57%). One student goes back to this conception in the delayed posttest, whereas in the posttest this student answers correctly. In SAC No. 21, students' belief that *Ecosystems change little over time* decreased from 32.14% to (21.42%), a positive conceptual change (+10.72%). One student goes back to this conception in the delayed posttest whereas in the posttest this student answers correctly. 25 students retain this conception until delayed posttest.

In the difficulties No. 22, 53.57% students could not make connection between abiotic and biotic factors in the ecosystem correctly, but after teaching intervention, SCD decreased to 0% in posttest and delayed posttest. These difficulties occur because the students have partial understanding that interaction between living things to survive is via food chains, and they do not consider abiotic factor contribution in supporting living things survival. In difficulties No. 23, 96.42% students initially didn't understand the ecosystem concepts comprehensively but after teaching intervention, SCD decreased to 3.57% in posttest and 0% in delayed posttest.

Table 2. Possible types of changes in students' alternative conceptions (SAC) and difficulties

Possibility of changes	Pretest	Posttest	Delayed posttest	Student Sample
1	+	+	+	S19 in SAC No. 8
2	+	+	-	S15 in SAC No. 11
3	+	-	-	S2 in SAC No. 1
4	-	-	-	S1 in SAC No. 1
5	-	+	-	S17 in SAC No. 5
6	-	+	+	S17 in SAC No. 11
7	+	-	+	S22 in SAC No. 11
8	-	-	+	S34 in SAC No. 6

Note: (+) : shows that alternative conceptions or difficulties exist in students' minds
(-) **:** shows that alternative conceptions or difficulties do not exist in students' minds

PDEODE could promote eight (8) types of conceptual change (Table 2). Type 3 (alternative conception in pretest, conceptual understanding in posttest and delayed posttest) was the most frequently observed conceptual change type. These findings are consistent with respect to the research literature on conceptual change in various topics (Costu et al., 2008; Costu et al., 2010).

The result showed the differences between the test scores were statistically significant ($p<0.05$). However, multiple comparisons (based on the Tukey post-hoc test) suggest that while there was a statistically significant difference between pretest and posttest scores, and between pretest and delayed posttest scores *($p<0.05$)*, no significant differences were observed between posttest and delayed posttest scores *($p>0.05$)*. These results support the ideas that most conceptual changes in students' alternative conceptions were retained.

Although in general this strategy has changed SAC into appropriate conception (scientific conception). However, there are also students who maintain an alternative conception after going through treatment (type 1). This condition is consistent with the view of Lawson (1995) as well as Pfundt and Duit (2000) that some alternative conceptions are very deeply rooted and resistant to learning activities. Those unexpected change of the conception may occur due to the interaction of students with students who hold alternative conceptions during group discussions, and class discussion, or because the student is not actively involved in the PDEODE activities (Costu et al, 2010).

The class that was selected in this study were small class, so that the activity of discussion and observation of the student is more conducive in facilitating conceptual change. According to Ruhf (1993) small class setting is the most appropriate setting to facilitate conceptual change. Class with 100 or more number of students will not be conducive to facilitating conceptual change.

In PDEODE teaching strategy, students were divided into six small groups, six or five students per group. It is intended that the activities of the group can be easily controlled and focused. According to Kauchack and Eggen (1989) the number of groups should be limited to six or fewer so that activity in the group can be controlled and focused. In addition, working in small groups facilitate the construction of knowledge through social interaction in the form of discussion. Discussions that occur can stimulate the activity of thinking, challenging attitudes and beliefs, and develop interpersonal skills.

Activity that must be performed early in PDEODE teaching strategy is making prediction. Prediction is very important in this teaching strategy, because the students make a prediction to be curious about the predictive power they have made, so that the student wishes to maintain and prove the predictions. This prediction according to Sinclair (1994) is one of the important stages and has been shown to be effective in learning. The prediction of each student will then be discussed in the discussion which is the next stage of the PDEODE teaching strategy.

Discussion on PDEODE activities is discussing predictions and observations of a phenomenon. In this study the phenomenon under discussion is the relationship between biotic and abiotic components, as the main

concepts (core concept) of ecosystem. Discussion was held on two stages of group discussions and class discussions. At the class discussion, the teacher (researcher) role was to regulate the course of the discussion, to ensure that the interaction between and among students, and that students can convey his message with more regular (stages explain). According to Lang and Evans (2006) when there was a discussion to the whole class, verbal interaction between teachers and students is required, as much knowledge can be gained through creative inquiry and active participation during discussions.

The teaching strategy involves students in hands on activities (observation) to prove the prediction by explaining the phenomena that appear from the observation. It is very good for facilitating conceptual change, because according to Weaver (1998) hands on activities such as observation or laboratory activities can facilitate conceptual change if combined with discussion and reflection. In general, the success of students in changing their SAC conception into appropriate concepts scientifically as because of several reasons. First, when students are engaged in the PDEODE activity, the students already have a prediction and an explanation as prior knowledge, prior knowledge is then discussed in a group or class, during the discussion there is opinion confrontation with a friend or with a group of friends from other groups, at same time, revision and review comprehension going on (Costu et al., 2010). Second, students become dissatisfied with the knowledge that they have and or students acquire new knowledge of the opinion of friends at the time of the discussion, to answer their dissatisfaction and to prove their understanding, the students conduct observations to provide a better explanation of their previous explanation, and finally, students transform their understanding into a more scientific understanding (scientific conception) by once again discussing their predictions with observations and strengthen it with the discussion after the observation. The condition occurs corresponds to the conceptual change model proposed by Posner et al. (1982).

The results obtained in this study indicate that there is no significant difference between the posttest and delayed posttest. It shows that activity in PDEODE teaching strategies can help students to maintain a conception scientifically (Costu et al., 2007; Costu et al., 2010). This strategy is also shown to improve students' scores, making it possible to change the traditional way of learning ecosystem into a student-centered learning (Costu et al., 2010).

CONCLUSION

Predict-Discuss-Explain-Observe-Discuss-Explain (PDEODE) teaching strategy is one of effective teaching strategy for facilitating conceptual change because PDEODE allows the students to countinously resolve contradiction via continous and intensive discussion with their peer and teacher.

In the future, the PDEODE strategy also can be implemented for teaching another science concept, especially certain abstract science concepts which have higher possibility for the students to have many alternative conceptions.

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