Student conception and misconception in drawing phosphorus cycle based on worked example learning

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Abstract. The phosphorus cycle is still unfamiliar for students in the biogeochemical cycle. When worked example provides an opportunity for students to be able to learn from existing examples, this study seek to uncover the conceptions and misconceptions about the phosphorus cycle that carried out in the implementation of worked example learning. This research was conducted in the form of descriptive research by analyzing the diagram made by students and interviews conducted on some students whose diagram indicated contain misconception. Results showed that worked examples can help students to get a conception of the phosphorus cycle through the identification of the components involved in the phosphorus cycle, the relationships between components, and training students to trace phosphorus atoms. Misconception occurred only in a small proportion of students (10.58%) due to students’ limitations in understanding the concepts of chemical molecules and plant physiology. It also influenced by the presented examples during classwork.

1. Introduction

The biogeochemical cycle discusses the trace of the elements in the reservoir through the environment and organisms, how they are transformed, transported, and reused [1]. The Material about the environment relating to the biogeochemical cycle that has started since the level of primary and junior secondary education is certainly not as complicated as the discussion at the secondary level. The first element cycle and it commonly known by students since the level of basic education is the water cycle. This is because the water cycle is so contextual with students' lives. Almost all the mechanisms in the water cycle can be observed directly. However, it does not guarantee that student's understanding of the water cycle is correct. The results of the research have revealed that there are still students' misconceptions about the water cycle [2], [3]. The same thing happened in other cycles, such as students' misconceptions about the carbon cycle [4]–[6] even though carbon is very closely related to the organism's respiration activity and plant photosynthesis. This is possible because so far they do not realize that the knowledge they have is wrong [7].

Amid in the unfolding of the conception of students in both element cycles that are very 'close' to students 'daily lives, it is also necessary to reveal how students' conceptions of element cycles that sound unfamiliar, for example, the phosphorus (P) cycle. The results of interviews with students in the research class showed that they had only heard about the P cycle and had not mastered the facts about it. They only know the water cycle and the carbon cycle. Although the P cycle is unfamiliar to them, it is
important to note that P is an essential nutrient for organisms [8] and plays a role in the formation of nucleic acids [9]. Moreover, the P cycle is one of the subjects according to the X high school syllabus with the water, carbon, nitrogen, and sulfur cycles. Is like the carbon cycle that requires understanding interconnection between trophic levels and carbon flow between various sources, understanding physiological processes, and connecting different levels of biological organization hierarchy [4], the P cycle has the same challenges.

When previously they did not know the facts about the P cycle after this learning hopefully there will be a conception that is successfully mastered. The expected conception in this study is that they can master a collection of facts that are interconnected and bound in the correct inferential relationships [10] related to the P cycle. However, some may encounter an alternative conception in the form of the misconception that can present a serious obstacle to learning in biology and disrupting subsequent lessons [6]. In this case, the teacher is important in helping them build new knowledge on top of misconceptions that students may have [11]. Therefore, it will be very important for the teacher to identify the extent of conception and misconception in class.

Considering the background and recommendations for using teaching strategies that trace the presence of atoms [4] students need to be introduced the ways to trace the presence of atoms in the biogeochemical cycle to gain a comprehensive understanding of the transformation, transport, and use of these elements by organisms until they return to the environment. However, the opportunities for the misconception that cannot be overcome if you rely on students just by reading the text [7]. In this section, worked examples expected to facilitate them to get an explanation of the steps of solving through existing examples [12] in tracing the presence of atoms/elements in cycles. At the end of learning, students can independently solve problems related to tracing the flow of P elements in the biogeochemical cycle. The conception and misconception revealed in the implementation of this learning as an evaluation.

2. Method
This research was using a descriptive research design that tried to examine the situation through the collection of analyzed data [13]. The data analyzed using a descriptive-quantitative analysis of the primary data obtained from the research subjects. The study conducted in three X classes in three high schools in Bandung (N = 85) which is a group of students who for the first time used working examples in Biology and had never learned about the P cycle. Primary data used in this study are in the form of diagrams made by students with the consideration of drawing methods that have been widely used by previous researchers [2], [14]–[18] to identify common misconceptions and conceptual weaknesses about concepts abstract [19] and rated effective [20]. The drawing created was a diagnostic task in the form of a P cycle diagram even the diagram itself is part of a worked example learning series. First, the analysis of the diagram in the form of absolute numbers for the types of list components, the interrelationships of components, and students trace atoms by categories formed inductively and deductively [4]. In the coding for the components listed by students in the picture nine categories: plants, rocks, animals, soil, water flow, feces, humans, decomposers, and sediments. The same coding scheme also used in the interrelation of components. There are seven categories in the form of the interrelation of components: consumption, absorption, weathering, decomposition, defecation, death, and deposition/formation of sedimentary rocks. There are two categories to classify the way students trace P atoms: trace P atoms exclusively at the organism level and trace carbon atoms at the level of biological organizations. Following [4], the category label that traces P atoms exclusively at the organism level appears when students only show the transfer of P from one organism to the next without explaining the transformation process of any P compound and without making a single, correct relationship between organism level and organizational level other biological. The category label traces P at the biological organization level appears when at least once students show that they have traced P atoms to the molecular level by linking products from the transformation process of P compounds to subsequent components. For example, in the case of synthesis of organic P compounds in plants, students must identify PO₄³⁻ as inorganic compounds that are absorbed by plants through roots and nucleic acid, amino
acid/protein, or ATP compounds as organic compounds that contain P. Second, diagram analysis in the form of misconception identification confirmed through interviews to ensure the interpretation of diagram from researchers to the misconception that occurs when students make a diagram of the P cycle.

The worked example learning series in this study consist of four-phase. First, the phase of the students exploring in the biogeochemical cycle video in general and the water cycle diagram to reduce students' cognitive load. Second, the student is given a worked example in the form of videos and a nitrogen cycle diagram then answers several prompting questions related to the steps of tracing the nitrogen atom in the cycle. Third, the phase of students working independently based on worked examples by answering prompting questions on worksheets provided to help students make the P cycle diagram. Fourth, students individually and independently create a diagram of the P cycle.

3. Result and Discussion
The results of this study presented in table 1 in the form of absolute numbers based on the types of components, the interrelationship of components, and type way of atomic tracing in the drawing students have made. Table 1 showed that no member of the component category was successfully made by all students (100%). Based on categorization [21] the most components made by almost all students (>75%) are plants, rocks, animals, and soil while the sediment component identified by a small proportion of students (<25%). In the category of the interrelation of components, consumption, absorption, weathering, and decomposition are controlled by almost all students (>75%) while sedimentation/rock formation was only successfully understood by a small proportion of students (<25%). Based on the type of trace P atoms, most of the students (>50%) traced P atoms exclusively at the organism level while the other traced P at all levels of biological organizations.

Table 1. Absolute numbers of types of components, interrelation of components, and the ways how students trace P atom

| Category                          | n  | %     |
|----------------------------------|----|-------|
| **Components created**           |    |       |
| Plant                            | 84 | 98.82 |
| Rock                             | 81 | 95.29 |
| Animal                           | 81 | 95.29 |
| Soil                             | 69 | 81.18 |
| Water / water flow               | 61 | 71.76 |
| Feces                            | 54 | 63.53 |
| Human                            | 46 | 54.12 |
| Decomposer                       | 42 | 49.41 |
| Sediment                         | 10 | 11.76 |
| **Interrelation of components**  |    |       |
| Consumption                      | 72 | 84.71 |
| Absorption                       | 71 | 83.53 |
| Weathering                       | 69 | 81.18 |
| Decomposition                    | 68 | 80    |
| Defecation                       | 59 | 69.41 |
| Dead                             | 55 | 64.71 |
| Sedimentation / formation of sedimentary rocks | 13  | 15.29 |
| **Trace phosphorus atoms**       |    |       |
| Traces phosphorus atoms exclusively at the organism level | 56  | 65.88 |
| Trace phosphorus at all levels of biological organization | 28  | 32.94 |

Based on these data shows that worked example has helped students to identify the components in the P cycle both biotic and abiotic. The mechanism worked example can support because there is a clear structure in the steps shown as an example to get students actively involved [22]. More than half of the
students identified all components in the P cycle except the decomposer and sediment components. As a result, they were less able to identify possible interrelation from sedimentary rock formation so that the P cycle appears to stop in this section. On the other hand, almost all students (81.18%) managed to identify weathering as an important mechanism that occurs so that can release \( \text{PO}_4^{3-} \) so that plants can make absorption (83.53%) which will channel through consumption (84.71%) in the food chain. As for the way students trace P atoms, nearly half the students (32.94%) have begun to explore P at all levels of biological organizations by being able to demonstrate the process of transformation of inorganic P compounds into organic P compounds in plants. Nevertheless, it is undeniable that most students (65.88%) still have difficulty tracing the presence of organic P atoms as well as the results of research [4] that show that they also have difficulty in identifying the transformation of organic carbon compounds that have to do with physiological knowledge, biochemistry, and ecology. As a sample, a diagram of the P cycle made by students presented in Figure 1.

![Figure 1. Phosphorus cycle diagram sample](image)

Figure 1 shows that students have been able to identify the results of rocks that have been weathered, exposed to the flow of rainwater to form \( \text{PO}_4^{3-} \) which dissolves into the soil so that it can be absorbed by producers, follow the path of the food chain until finally returning to the environment through decomposition after organism death. Analysis of the results of the identification showed that students have found an interrelation between living things with inanimate objects. This is progress in student achievement when previous research showed that there are still students who believe that organisms do not interact with inanimate objects [6]. However, when analyzing the level of complexity of the components it seems that students have not been able to explain the mechanism of the P cycle. Students drew waters with fish in them without describing the process that occurred whereas the phosphorus cycle in these waters was interesting to reveal because it had to do with eutrophication events in water bodies [8] that could be one of the environmental problems. Even though students are aware of these environmental problems, they lack scientific information so they have a weak structure about ecological concepts [23]. Besides, students also experience a lack of information on the mechanism of sedimentary
rock formation. Students did not provide information that the rock formed dissolved P that undergoes sedimentation. If this information is lost then the cycle stopped at this stage.

Based on the content analysis of diagrams, some diagrams have indicated a misconception in students. The results of misconception identification in the P cycle presented in Table 2 that contains the statement of interpretation of the diagram confirmed through interviews with the students concerned.

Table 2. Misconceptions about the phosphorus cycle based on diagrams

| Misconceptions                                                                 | n | %   |
|-------------------------------------------------------------------------------|---|-----|
| 1. Phosphate is present in the atmosphere and is absorbed by plants through leaf organs | 2 | 2.35|
| 2. Phosphorus undergoes a process with the water cycle: evaporation-condensation-precipitation | 2 | 2.35|
| 3. Inorganic phosphate PO$_4^{3-}$ absorbed by plants does not undergo transformation into organic compounds | 2 | 2.35|
| 4. The phosphorus cycle does not involve animals and humans in the food chain | 2 | 2.35|
| 5. Organic phosphate compounds consumed by animals undergo transformation back into inorganic phosphate (PO$_4^{3-}$) in the animal's body | 1 | 1.18|
| Total                                                                         | 9 | 10.58|

In the table 2 showed that overall misconception occurred in a small proportion of students (<25%) at 10.58% (n = 9) students. The data in the table shows that at most only 2.35% (n = 2) students have a misconception of each type of misconception identified. Examples of student images that indicate the existence of the misconception showed in Figure 2 and Figure 3.

Figure 2. Sample of a phosphorus cycle diagram containing misconceptions 1 & 2

Figure 2 shows that students understood the P in the form of PO$_4^{3-}$ dissolved in water released into the atmosphere. Based on the students' acknowledgment, he got this understanding from the exploration phase of the water cycle and worked examples that presented in the form of the nitrogen cycle. When students knew that PO$_4^{3-}$ can be found in water, students conclude that the compound will evaporate
with the water. This reinforced when students get information in worked examples that nitrogen can be in the form of gases in the atmosphere so that students conclude that P compounds can be gaseous in the atmosphere so that leaf organs in plants can absorb then synthesized into organic P compounds. The truth is P can be found in the atmosphere but not in a gaseous form but very small particles so that the atmosphere is not a reservoir for P [24]. The analysis indicates that students have limitations in understanding the concept of molecules in chemistry. The next fact, leaf organs in plants are not able to circulate gases to and from the atmosphere other than carbon dioxide and oxygen so that when students assume that P is absorbed by leaf indicates that students do not master plant physiology. However, misconceptions will not occur if students master all important information and related factual knowledge relationships [25].

Figure 3. Sample of a phosphorus cycle diagram containing misconceptions 3

Figure 3 shows that students understood that P is always in the form of PO$_4^{3-}$ and cannot undergo transformation into other compounds but only undergoes displacement in the components that are traversed during the cycle. Based on interviews students think so because of the example of the water cycle in various forms whether liquid, gas, or solid. In this case, students fail to trace P atoms at all levels of biological organization in the form of the transformation of inorganic P compounds (PO$_4^{3-}$) into organic P compounds in organisms in the form of phospholipids, nucleic acids, amino acids or other organic compounds [26].

4. Conclusion
The findings show that worked examples succeeded in helping students identify the components involved, the interrelations of components, and practice to trace phosphorus atoms at all levels of biological organizations in the P cycle. Misconception occurred only in a small number of students because of the limitations of students in understanding the concepts of chemical molecules and plant physiology. It also influenced by the water cycle exploration and the nitrogen cycle worked example during classwork.

5. References
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