Concept map and problem-based learning

F Fitrianingsih, S Widoretno*, R M Probosari, S Dwiastuti and Sajidan
Biology Education, FKIP, Sebelas Maret University, Surakarta, Indonesia

*Corresponding author: sriwidoretno@staff.uns.ac.id

Abstract. The research aims to calculate the increase of student’s Concept Map (CM) scores through the implementation of Problem-Based Learning (PBL). The research is a classroom action. Research procedures include planning, observation, implementation, and reflection. The subjects were 34 X grade students. The data were collected by observation, assessment, interviews, and documentation. CM scores were calculated as a percentage based on expert CM. The research data consisted of the percentage of students' CM scores, performance assessment, the implementation of PBL syntax, interviews, and documentation of the learning process. The validity test used data triangulation. The analysis techniques are through reduction, data presentation, and drawing conclusions. The results show that the percentage of CM scores in the pre-cycle, cycle I, and cycle II, respectively have a range of values of 4.62-20.80%; 11.56-24.25%; and 12.14-30.86% with an average increase in the first cycle is 10.96%, and the second cycle is 4.06%. The increase in the average percentage of CM score is supported by the linear increase in the average components of H, P, B, and E, thus the application of PBL is able to increase the percentage of CM scores based on the linear increase in the average components of H, P, B, and E.

1. Introduction

Concept Map (CM) is a graphic visualizing the inter-concept relations [1] and represents knowledge [2]. CM is used as an instructional tool and assessment [3]. As an assessment, CM can visualize and evaluate students’ knowledge [4]. A Concept Map consists of hierarchy, valid relationship, branching, crosslink, specific example, and pattern [5]. The CM observation results show that in conventional learning, 26.47% of the students give no example; 14.70% of the concept is not linked by lines; 17.64% of valid relationship is not correct, and 91.17% has no cross-link. Thus, the CM constructed by students has not described all the CM components. An example is the missing-component, while the example emphasizes the meaning of concept [2]. Therefore, students have not been able to make specific objects or phenomena that clarify the meaning of concept. An incorrect valid relationship is indicated by the absence of connecting lines. In addition, linking words as conjunctions [6] are considered as concepts. Based on these facts, the result of CM illustrates that students are unable to find and connect concepts.

Finding and connecting concepts help students find a way to solve problems [6]. The results of problem solving can be in the form of concepts of knowledge made by students [7]. Students should have concept integration to help solving the problems that require more than one real solution and have inter-concept relations [8]. Ill structure problem is a problem which concepts need to be integrated due to their complex and unstructured nature [9]. Ill structure problem accommodates students to participate in the discussion to define the problems, collect information and skills needed, and synthesize understanding to solve problems. [10] Ill structure is a real life problem that makes...
students more able to connect concepts and solve problems [11]. The learning model that helps students to connect concepts for solving ill structure problem Problem Based Learning/PBL [9].

PBL has five stages: Meeting the Problem, Problem Analysis and Learning Issue, Discovery and Reporting, Solution Presentation and Reflection, and Overview, Integration, and Evaluation [12]. The stage of meeting the problem facilitates to discover the main problem, namely the ill-structured problem that becomes the focus to get knowledge [13]. An ill-structure problem creates many perspectives and ideas to understand problems [14]. General and complex ideas are needed to create the CM [15], visualized in a more complex CM structure [16]. Problem analysis and learning issue covers the process of identifying problems and determining issues[12]. The stage of problem analysis is important to help building and understanding concepts based on relevant problems [17], so the ability to make connections is needed to identify problems [14]. Connection-making in the form of integration between concepts is visualized through CM and important links [18]. The discovery and reporting stage involves finding and presenting a problem-solving plan[12], which requires analysis, assessing and linking information to arrange the problem-solving plan [14]. Analyzing and linking information at the discovery and reporting stage accommodate the formation of meaningful statements consisting of several concepts connected to CM [16]. The solution presentation and reflection stage include the results presentation and evaluation of problem solving process [12] that accommodates the application of cross-fields knowledge integration [13]. The activities at this stage are able to stimulate new insights and ideas from the audience, which are then analyzed and evaluated by all students [14]. New integrated ideas are knowledge found to accommodate students build more complex connections in CM [18].

The last PBL stage is overview, integration and evaluation, this is a stage where students and their teacher evaluate and review the learning process, and reflect new knowledge as a result of problem-solving [12]. The activities of reviewing concepts that are found in the problem-solving process, and responding to feedback [10], are able to accommodate the students to evaluate the results and process of problem solving, are visualized in the form of concept failures and the relations made [18]. PBL has five stages which sequentially play a role in solving problems [12], providing opportunities for students to improve their ability to find and connect concepts that are constructed in the form of CM at the end of learning.

2. Methods
This is a class-action research that consists of pre-cycle, cycle I, and cycle II. The research subjects were 34 students of 10th grade. The research procedures included planning, acting, observing, and reflecting. Research in cycle I and II applies PBL learning followed by assessment in the form of CM at the end of learning, as well as student and teacher interviews.

The results of the CM score analysis underlied the actions for the next cycle. The research data were the percentage of students’ total CM scores based on expert CM in each cycle; the percentage of PBL learning syntax implementation in cycle I and II; and observation data of students' performance during PBL learning. The supporting data were in the form of the students and teacher’s open interview results, photos, and videos of PBL learning. The percentage of CM scores and CM component scores were calculated using a percentage based on expert CM in each cycle. The percentage of total CM scores was calculated based on students' CM scores and the expert CM scores in pre-cycle, cycle I, and cycle II. The calculation of the percentage of students’ total CM score in each cycle is illustrated in table 1.

| Table 1. Calculation of the percentage of total CM scores in pre-cycle, cycle I, and cycle II. |
|---------------------------------------------------------------|
| Treatment   | Total expert CM score | Calculation                  |
| Pre-cycle   | 173                    | Students CM score/173 x 100%  |
| Cycle I     | 268                    | Students CM score/268 x 100%  |
| Cycle II    | 162                    | Students CM score/162 x 100%  |
The percentage of component CM scores was calculated based on students' component CM scores and the expert component CM scores in pre-cycle, cycle I, and cycle II. The calculation of the percentage of students' component CM scores in each cycle is illustrated in table 2.

### Table 2. Calculation of the percentage of component CM scores in pre-cycle, cycle I, and cycle II.

| Component CM | Score | Expert Component CM score | % of component CM score |
|--------------|-------|----------------------------|-------------------------|
| Valid Relationship | 1 point | 49 | 71 | 49 | Component CM score |
| Hierarchy | 5 point | 25 | 25 | 15 | component CM score x 100% |
| Pattern | Max 5 point | 5 | 5 | 5 | score/expert |
| Branching | 1st level : 1 point | 13 | 13 | 7 | |
| | 2nd-5th level : 3 point | | | | |
| Example | 1 point | 31 | 44 | 16 | |
| Cross-link | 10 point | 50 | 110 | 70 | |

The students’ CM score validity test was carried out using data triangulation technique that includes CM scores, interview, and documentation. The data were analyzed qualitatively included data reduction, data presentation and conclusion. The research achievement indicators were based on the increase of percentage of students’ CM scores which were calculated based on expert CM.

### 3. Results and Discussion

The average percentage of students’ CM scores experience a linear increase from pre-cycle to cycle II are shown in Figure 1.

![Figure 1](image)

**Figure 1.** shows the students’ concept map scores in pre-cycle to cycle II.

The average percentage of students’ CM scores each cycle are 6.87%; 17.83%; and 21.89% consecutively. In cycle I increases by 10.96%, while in cycle II increases by 4.06%. Thus, the average percentage of the total students’ CM scores increases from pre-cycle to cycle II. The average percentage of CM component in pre-cycle cycle I, and cycle II are shown in Figure 2.

The average VR percentage in pre-cycle, cycle I, and cycle II are 5.46%, 18.80%, and 18.18%. Thus, there is a fluctuating change in the average VR percentage from pre-cycle to cycle II. The average H percentage in pre-cycle, cycle I, and cycle II are 20.58%, 42.35%, and 54.90%. The average P percentage in pre-cycle, cycle I, and cycle II are 20.58%, 42.35%, and 54.90%. The average B percentage in pre-cycle, cycle I, and cycle II are 8.37%, 33.48%, and 42.01%. The average E percentage in pre-cycle, cycle I, and cycle II are 3.60%, 37.96%, and 86.58%. Thus, there are a linear increase in the average of H, P, B, and E percentage. The cross-link (CL) from pre-cycle to cycle II has a percentage of 0%, so there is no increase or decrease in the average CL percentage. Based on the average CM percentage, the components that experience a linear increase are H, P, B, E. This supports the increase in the average percentage of the total CM.
The linearly-increasing average percentage of CM scores is supported by the linear increase of H, P, B, and E percentages. The average percentage of H and P in pre-cycle, cycle I, and cycle II have increased linearly. The linear increase of H and P average percentage show that the students’ capability in organizing concepts with specific concept patterns in the bottom order has improved. The students can organize concepts that are hierarchically and strongly integrated after being able to connect old with new concepts [19]. The ability to connect concepts hierarchically and in complex connections are accommodated by the PBL in the stages of solution presentation and reflection through analysis and evaluation of new ideas that are integrated to find knowledge [14].

The average percentage of B in pre-cycle, cycle I, and cycle II increases linearly. The increase shows that the students are able to create new concepts and links at a hierarchical level, so that heterogeneous concept divisions are formed. This ability can increase due to the wide perspective on a valid problem space [20], It is accommodated at the meeting the problem stage, thus increasing the average B percentage after PBL implementation.

The average percentage of E in pre-cycle, cycle I, and cycle II increases linearly. The increase illustrates that the students have inter-disciplines understanding, so they are able to provide examples in real situations in the form of specific objects or events [21]. At the meeting the problem stage, the students carry out observations within the environment directly. This makes the students able to make more examples of objects or events related to the concept.

The fluctuating changes in VR and the 0% CL percentage stimulate the decrease in the average percentage of CM scores. The average percentage of VR fluctuates and increases in cycle I and decreases in cycle II. The increase of average VR score percentage in the pre-cycle, shows that the students are able to connect previous concepts with the new concepts. The connections are visualized in a valid inter-concepts relation. The ability to connect new and old concepts is the result of searching information that is more related to the topic, and making meaningful information [20]. The formation of meaningful information is accommodated at the discovery and reporting stage in information analysis and linking activities [19] and the ability to connect concepts is accommodated in the problem identification process that exists within the stage of problem analyze and learning issue [14]. So, the students’ ability to connect valid concepts increases after PBL implementation. The decrease in the average VR percentage in cycle II is shown by the invalid concepts made by the students. Invalid concepts relation indicates less optimal understanding of the main concepts [22].

The average CL score percentage in pre-cycle, cycle I, and cycle II is 0%. It shows that the students have not been able to integrate the concepts by using new ideas that they obtain. The ability to integrate new ideas may improve knowledge that accommodates the making of a complex CM [18]. The complexity of a CM can be identified from the existence of CL [23]. The making of CL is accommodated by the solution presentation and reflection stage. However, making CL requires HOTS
and an optimal percentage of performance assessment. Optimization of performance assessment at the solution presentation and reflection stage can help students to find integrated concepts between disciplines as a result of problem solving. By discovering integrated concepts, students can make a CL in CM easily. Thus, making CL in CM requires optimal performance assessment at the solution presentation and reflection stage, and HOTS.

A linear increase in the CM score percentage is followed by a linear increase in the average percentage of performance assessment scores. The average percentage of performance assessment scores in pre-cycle, cycle I, and cycle II can be observed in Figure 3.

![Figure 3. Average percentage of performance assessment score](image)

The average percentage of performance group work in pre-cycle, cycle I, and cycle II are 74.91%; 82.02%; and 83.25%. The average percentage of oral presentation in pre-cycle, cycle I, and cycle II are 50.88%; 55.98%; and 57.10%. The average percentage of performance making observation and inference in pre-cycle, cycle I and cycle II are 30.33%; 35.45% and 38.99%. The average percentage of pre-cycle, cycle I, and cycle II shows that all performance increases linearly after PBL implementation. The linearly-increasing average percentage of CM components is supported by an increase in the average percentage of performance assessment scores. The average percentage of performance group work increases linearly from pre-cycle to cycle II. The linearly-increasing average percentage of performance group work shows that the performance is better when the members/students work in a group that involves discussion and sharing information. Group members with heterogeneous academic abilities maximize information exchange [24]. The activity of exchanging information adds new information, thus accommodating students to analyze information to synthesize new knowledge and evaluate the existing and new concepts [25][26]. New knowledge-synthesis and activities of evaluating existing concepts with new concepts make the students easier to understand the material.

The linearly-increasing performance oral presentation illustrates that there is a change in the students’ concept structure. The change in the concept structure supports the formations of H and more complex VR as an indication of integration between concepts [23]. Students who can convey information with good language structure and content indicate that they have an integrated concepts-understanding which facilitate the delivery of information. Good information-delivery will make the audience easy to understand the information [27]. The new information are then analyzed and evaluated with existing concepts, so as to accommodate the students’ concept integration. The performance making observation increases linearly from pre-cycle to cycle II, but the average percentage is low. The low average percentage of performance making observation and inference shows that students have not maximally carried out the observations at the meeting the problem stage. Activities at the meeting the problem stage include environmental observation to find real-world cases to be solved [28]. Observation activities activate the existing and new knowledge, which facilitate
students to accommodate a wide range of disciplines and encourage the identification of specific
elements of the example. The average percentage of performance assessment scores that increase linearly supports the acquisition of the average percentage of CM scores. However, the achievement of the average percentage of performance assessments is still not optimal. It is necessary to optimize performance at the PBL stage to maximize the average increase in the percentage of students’ CM scores.

4. Conclusion
The average percentage of CM pre-cycle, cycle I, and cycle II scores increased linearly after the application of problem-based learning. The linear increase in the average percentage of CM scores is supported by a linear increase in the percentage of components, especially H, P, B, and E, and an increase in the average percentage of performance assessment in the pre-cycle to cycle II. Although the average percentage of CM scores has increased linearly, optimization is needed at all stages of PBL to improve performance to achieve the average maximum CM score percentage.

Acknowledgment
The researcher thanked Allah SWT, thanks to the PDUPT team who have funded the research and those who participated in the study. Hopefully, the research results can be useful to further research.

References
[1] Canas A J, Novak J D, and Reiska P 2015 Knowl. Manag. E-Learning 7 6
[2] Novak J D and Canas A J 2008 Technical Report IHMC Cmap 1 1
[3] Stoddart T, Abrams R, Gasper E, and Canaday D 2000 Int. J. Sci. Educ. 22 1221
[4] Stoddart T 2006 Proceeding of the Second International Conference on ConceptMapping
[5] Novak J D and Gogin D B 1984 Learning How to Learn (Melbourne: Cambridge University Press)
[6] Putra H D, Thahiram N F, Ganiati M, and Nuryana D 2018 J. Ilm. Pendidik. Mat. 6 82
[7] Ge X, Planas L G, and Nelson 2010 Interdiscip. J. Probl. Learn. 4 30
[8] Abdillah and Mastuti A G 2018 J. Mat. dan Pembelajaran 6 48
[9] Tan O S 2009 Problem Based Learning and Creativity (Singapore: Cengage Learning) [10] Chin C and Chia L 2006 Sci. Educ. 90 44
[10] Yager R E and McCormack A J 1989 Assessing teaching/learning success in multiple domain of science and science education. Science Education (New York: Cambridge University Press)
[11] Tan O S 2003 Learning Using Problems to Power Learning in the 21st Century (Singapore:Cengage Learning)
[12] Hmelo-silver C E 2004 Educ. Psychol. Rev. 16 235
[13] Chua B L, Tan O S, and Liu W C 2014 Innov. Educ. Teach. Int. 53 191
[14] Plotnick 1997 Concept Mapping: A Graphical System For Understanding the Relationship Between Concepts (New York: ERIC Clearinghouse on Information and Technology)
[15] Cañas A J, Novak J D, and Reiska P 2015 Knowl. Manag. E-Learning 7 6–19
[16] Zwaal W and Otting H 2012 JPBL 6 104
[17] Vanides J, Yin Y, Tomita M, and Ruiz-Primo M A 2005 Teach. Strateg. 28 27
[18] Reiska P, Soika K, Mölltis A, Rannikmäe M, and Soobard R 2015 Procedia - Soc. Behav. Sci. 77 352
[19] Hung C H and Lin C Y 2015 BMC med. educ. 15 212
[20] Champagne A B 2016 Cross-Disciplinary Concepts and Principles in Science, Assessing Understanding of Science (New York: State University of New York)
[21] Akinsanya C and Williams M 2004 Nurse educ. today 24 41
[22] West D C, Pomeroy J R, Park J K, Gerstenberger E A, and Sandolav J 2000 Am. Med. Assoc. 284 1105
[23] Davies W M 2009 *Higher Education* **58** 563
[24] Azer S A 2008 *Kaohsiung J MEd* **24** 361
[25] Quitadamo I J and Kurtz M J 2007 *CBE-Life Sci. Educ.* **6** 140
[26] Hincks R 2005 *System* **33** 575
[27] Wang P and Chen W 2012 *Online Submiss.* **11** 94