Using concept maps to describe undergraduate students’ mental model in microbiology course

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Abstract. The purpose of this research was to describe students’ mental model in a mental model based-microbiology course using concept map as assessment tool. Respondents were 5th semester of undergraduate students of Biology Education of Universitas Pendidikan Indonesia. The mental modelling instrument used was concept maps. Data were taken on Bacteria subject. A concept map rubric was subsequently developed with a maximum score of 4. Quantitative data was converted into a qualitative one to determine mental model level, namely: emergent = score 1, transitional = score 2, close to extended = score 3, and extended = score 4. The results showed that mental model level on bacteria subject before the implementation of mental model based-microbiology course was at the transitional level. After implementation of mental model based-microbiology course, mental model was at transitional level, close to extended, and extended. This indicated an increase in the level of students’ mental model after the implementation of mental model based-microbiology course using concept map as assessment tool.

1. Introduction
Concept map was introduced by Joseph Novak as a way of assessing children's understanding of science with graphical tools to organize and represent knowledge [1]. Concept maps are used to express meaningful relationships between concepts in the form of propositions. Propositions are two or more concepts connected by words in a semantic unit. Concept map is a top-down diagram showing relationships between concepts, including cross-links between concepts and examples, and demonstrating systematic relationships among related sub-concepts [2]. Kinchin [3] states that concept maps are a very useful way of gathering information, and because concept maps are flexible, concept maps can be adapted for use in different groups of learners.

Concept maps have several advantages for learners, including developing a well-integrated cognitive structure, which will subsequently facilitate learning. According to Eppler [2] concept maps can be used as learning support tools for students, that is, to summarize key topics or clarify elements and examples of abstract concepts.

Byrne & Grace [4] developed a concept map technique using photo associations (CoMPAT). This technique can express ideas that the students have about microorganisms’ activity. The resulting concept maps show that some students have a more complex conceptual framework about microbial activity than some other students.
The target of a concept map is to measure cognitive aspect. Other than used in teaching and learning process, concept maps can be applied for various purposes such as in: a) investigating what students already know (as prior knowledge), b) learning how to learn, c) uncovering misconceptions and, d) as an evaluation tool [5].

There are three forms of concept map patterns and each pattern shows the level / linking level and monitoring, wherein the net pattern has a more complex hierarchical pattern than the chain and spoke patterns, in which each category indicates the level of complexity of someone’s mental model[6].

The mental model is a depiction, personal ideas, or an individual's internal representation of a phenomenon, a collection of ideas or concepts. By visualizing concepts and processes in the mind, mental models are generated. Mental models are personal, internal, and inconsistent with scientific explanations [7]. Knowing one's mental model is something that is difficult to do, therefore an expressed model is needed to reveal learner's mental model, i.e through the concept map [7]. Thus, the concept map is one technique for external representation.

Changes in the complexity of a person's mental model can be analyzed through a particular learning model. In this article, the authors applied mental model based-microbiology course using concept map as assessment tool, so it can give description of mental model development before and after the program implementation.

2. Methods
Respondents in this study consisted of 39 undergraduate students of 5th semester Biology Education Department of Universitas Pendidikan Indonesia. Data were taken before and after the implementation of mental model based-microbiology course. The microbiology course subject matter is limited to bacteria sub subject. In the program, students were divided into 13 small groups (2-3 group members). Group divisions were based on initial ability test results. There are 4 lower academic groups, 5 moderate academic groups, and 4 high academic groups. Before mental model based-microbiology course began, students were assigned to create concept maps based on the knowledge they already had about bacteria.

Students participated in mental model based-microbiology course that consisting of several stages (syntax). Mental model based-microbiology course begin with pre conception exploration to find out students' comprehension on microorganisms concept. Concept restructuring was carried out subsequently. At this stage, students were guided to achieve a target mental model or achieve a higher mental model level. Then, the students were asked to apply the new concept. The mental model-based microbiology course ends with reviewing and evaluating the new ideas whether they fit or not with the targeted mental model. Furthermore, based on the learning experience that students got during the course, students were asked to revise the initial concept map. Revised concept maps were also based on learning resources used in the form of text books and teaching materials in the form of power points [8].

The initial concept maps and revisions were analyzed based on the Novak and Gowin scoring techniques [1]. The concept map assessment refers to the concept reference map. Concept map rubric with a maximum score of 4 (Table 1) was subsequently developed. The quantitative data was converted into a qualitative one to determine the level of mental model (Byrne with modification [9]), namely: emergent = score 1, transitional = score 2, close to extended = score 3, and extended = score 4.

| Score | Description |
|-------|-------------|
| 1     | Less than 25% of the essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and cross-links are also appropriate. |
| 2     | Only 25-50% of the essential concepts are raised, the relationships between |
Score | Description
--- | ---
3 | Only 51-75% of the essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and cross-links are also appropriate.
4 | More than 75% essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and cross-links are also appropriate.

3. Results and Discussion

The mental model of biology education students on the sub subject of bacteria in a mental model based-microbiology course using concept map as assessment tool are illustrated in Figure 1 and Table 2. In Figure 1, it shows that the concept map scores increase in all academic groups. The highest increase was found in the moderate academic group. Furthermore, concept map scores are categorized into the mental model level as shown in Table 2. No emergent mental model level is found, either in the initial concept map or the revision one, in all academic groups. This shows that students already have prior knowledge. They got their prior knowledge about the bacteria from biology course in junior and senior high school, as well as in college through general biology course. This is in line with Hay et al. (2008) who stated that concept maps can be used for the identification of prior knowledge and prior-knowledge structure among students.

Based on Table 2, there are three lower academic groups with concept map score improvement, from score 2 to 3, from the level of the transitional mental model to the close to extended level. A low academic group still got 2 score on the revised map. Four academic groups showed an improvement in concept map scores, from 2 to 3 with changes in the mental model level from transitional to close to extended category. Concept map score for one particular group remains unchanged (group 7). High academic groups also experienced a change in concept map scores. The initial concept map of all high academic groups received 2 (transitional) score, but after mental model based-microbiology course, the revised concept maps of this group were varied. Transitional, close to extended, and extended mental models level were found in high academic groups after the implementation of mental model based-microbiology course.

![Figure 1](image.jpg)

**Figure 1.** In Initial and Revised Concept Map Score for Bacteria Subject in Low, Moderate, and High Academic Group.
Based on Table 2, 69.23% experienced an increase in mental model level. Only 30.77% remains unchanged. The increase in concept map scores indicates an increase in mental model level, as higher scores indicate mental model's complexity. This is in accordance with the opinion of Kinchin et al. (2000) which states that the net pattern has the most complex hierarchical pattern and indicates complexity level of someone’s mental model. Bacteria concept maps served as an 'expressed model' to investigate students’ mental models regarding bacteria. This is in line with Chang's [7] as stated in his research on externalizing students’ mental models through the concept of maps about homeostasis of blood sugar. The results of this study also show the effectiveness of microbiology-based course on mental models. Results of previous research show that a mental model-based microbiology course can improve students’ mental model level on microorganisms through a drawing and writing test [10].

| No. | Academic Group | Concept Map Score, Mental Model Level, and Students’ Mental Model Change in Mental Model Based-Microbiology Course (Bacteria Sub Subject). |
|-----|----------------|---------------------------------------------------------------------------------------------------------------|
|     |                | Concept Map                                                                                                   |
|     |                | Initial | Revised | Mental Model Change |
|     |                | Score   | Mental Model Level | Score   | Mental Model Level |                         |
| 1.  | G1/low         | 2       | transitional  | 3       | close to extended  | increased               |
| 2.  | G2/low         | 2       | transitional  | 2       | transitional       | unchanged               |
| 3.  | G3/low         | 2       | transitional  | 3       | close to extended  | increased               |
| 4.  | G4/low         | 2       | transitional  | 3       | close to extended  | increased               |
| 5.  | G5/moderate    | 2       | transitional  | 3       | close to extended  | increased               |
| 6.  | G6/ moderate   | 2       | transitional  | 3       | close to extended  | increased               |
| 7.  | G7/ moderate   | 3       | close to extended| 3       | close to extended  | unchanged               |
| 8.  | G8/ moderate   | 2       | transitional  | 3       | close to extended  | increased               |
| 9.  | G9/ moderate   | 2       | transitional  | 3       | close to extended  | increased               |
| 10. | G10/high       | 2       | transitional  | 4       | extended           | increased               |
| 11. | G11/high       | 2       | transitional  | 2       | transitional       | unchanged               |
| 12. | G12/high       | 2       | transitional  | 2       | transitional       | unchanged               |
| 13. | G13/high       | 2       | transitional  | 3       | close to extended  | increase                |

Note: G= group

According to Hay et al. [11] concept mapping can be used to reduce abstract knowledge into a concrete diagrammatic representation. The concept-mapping method can be used as a tool for enhancing teaching quality in higher education. In particular, it describes how concept mapping can be used to transform abstract knowledge and understanding into concrete visual representations that are amenable to comparison and measurement. Therefore, the use of concept maps remains essential in universities, especially for abstract subject such as bacteria in a microbiology course, as has been done.
by Kinchin et al. [12] in the microbiology course. To maximize the use of concept maps, Kinchin et al. [12] gives some suggestions, namely (1) reflect a student centered teaching philosophy; (2) be collaborative; (3) be given sufficient time for reflection and development; (4) avoid appropriate switching between opposing conceptual frameworks.

4. Conclusion
Results showed that the level of initial mental model concept map about bacteria before the implementation of mental model based-microbiology course was at transitional level (concept maps score 2), while after the implementation, the level were transitional (concept maps score 2), close to extended (concept maps score 3) and extended (concept maps score 4). This shows an improvement in the level of students’ mental model in a mental model based-microbiology course using concept map as assessment tool.

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