The role of STEM-DSLM in facilitating students’ conceptual change and preventing misconception in life sciences

N Y Rustaman
Biology Education Department, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Jl. Dr. Setia Budhi No. 229, Bandung 40154, Indonesia

Corresponding author’s email: nuryanirustaman@upi.edu

Abstract. Effort to overcome misconception had been conducted mostly using CRI and remedial teaching after having detected misconceptions and the causes of them. The focus of this study was to analyse the development of strategic teaching and learning in formal education after being detected the most often concepts misconceived by the students. One class of each level of students being engage with STEM-PjBL and DSLM in studying abstract concept in Life Sciences (Organization of Living system, Fungi, Evolution). Certainty Response Index (CRI) and Test of Logical thinking (TOLT) were used in data collection. In analysing data, the results of pre-test and post-test were analysed. It was found that nearly no misconception was found as very little students change into negative or disorientation, while students with change into positive was higher in percentage. Additionally, construction is very rare among the students, as they have learnt all the concept before. From these findings, it can be concluded that STEM-PjBL can prevent permanent misconception. Additionally, at college level Dual Situated Learning Model (DSLM) can be used in facing conflict situation to students as requirement for conceptual change to occur.

1. Introduction
Concept has some meaning that cannot describe shortly, can be component of the constituent parts or common attributes by which groups or classes can be distinguished [1], as prior knowledge possesses by learner [2], abstraction based on experience [3]. After having learning experience learner will change their conception into new concept. Meanwhile conception has different meaning with concept. Many obstacles can sometimes cause the process of transforming knowledge, so conception related to its meaning “to conceive”, means the way to receive [4, 3]. Inaccurate understanding of concepts that students understand before or after learning are interpreted as misconceptions. Misconception is interpreted as a cognitive structure that is rooted in students' thinking but deviates from the conception described by experts in their field [5]. Educated learners will replace their misconceptions with the correct concept if they meet the four criteria, that is dissatisfaction (dissatisfied) with the understanding they have, and new concepts are intelligible, plausible, and fruitful [6].

Recent research results found that educators also experienced misconceptions similar to the learners [7], and that teachers sometimes do not understand the material as a whole or have difficulty translating concretely of abstract concepts because of lack of understanding on the previous education level [8]. Certain essential concepts are mandated by Biological Consortium standards as part of the courses that must be taught in biology education and pure biology department at level 6 (KOBI, 2016).
Certainty of Response Index (CRI), proposed by Hasan, Bagayoko & Kelley [9] is used to identify the degree of misconception on a concept. This method can also separate between the criteria of “understands” the concept (U) and “doesn’t understand the concept (DU) based on the answers given. The response given will prove whether a concept is really understood or it is known through memorizing only [10]. In general, difficulties in understanding certain concept are usually seen from the tendency of the results of answers that are based on environmental factors [11]. Nevertheless, difficulties also can be found in the learners themselves. Abstract concept usually difficult understood by concrete operational thinker [12].

New tools and emerging new sciences are expanding what is possible. Foundational technologies, engineered biological systems, systems biology, and computational biology are needed as well as synthetic biology [13]. Cross-cutting technologies and foundational life sciences are needed to educate the new biologist. The new biology represents an integrated, problem-focused approach to science that is entirely consistent with research on how students learn best. High visibility projects using biology to solve important problems as challenges could provide a platform to engage all students in the process of science, and illustrate the excitement and benefits of using science and engineering to solve problems. Therefore, all of these factors-increasing integration within the life sciences and between life sciences and other disciplines, a deep pool of detailed knowledge of biological components and processes, previous investment in the generation of shared data resources, stunning technological innovations, and cross cutting sciences that are foundational across many applications have put life sciences unremarkably on course to a major acceleration of discovery and innovation.

STEM-Project based learning is one of the innovation and dynamic model of conceptual change [14, 15] that can challenge students to solve problem they face. Dual situated learning model (DSLM) in university level has also been proposed to be used in confronted student to conflict situation [16; 17]. As they are in the condition of conflict cognitive, when they are given test that challenge them to determine how sure they are (individually) when they choose the option(s), then they become used to become individual learner.

This study was conducted to investigate how STEM-Project based Learning and Dual situated learning model can facilitate conceptual change which change into positive for the students in each group of learning live science concepts. The use of those learning models can reduce the misconception with the help of CRI or other instruments.

2. Method
This study was conducted at three different class level (Junior High school, 7th grade: Organization of living system; Senior high school, 10th grade: Fungi; College level, 6th semester: Evolution) and one science teacher, one prospective Biology teacher, and one science teacher educator. Two types of instrument were used to detect the misconception in abstract biology concepts at each level, namely: Certainty response index (Organization of living system, Fungi, and Evolution), and Test of Logical thinking (TOLT) which are content free.

Participants: 34 students of 7th graders, 25 students of 10th graders, and 33 students of 6th semester biology students taken as convenience sampling. One science teacher from certain junior high school, one prospective biology teacher who is "teaching practice" in one public senior high school, and one science teacher educator are involved as model teachers. They have created their own CRI tests and have validated them accordingly. CRI test were used firstly to detect misconception in each level.

Test of Logical Thinking was administered first to identify which students are in certain level of thinking (concrete operation, transitional, and formal operation). This test can be used for junior high school up to doctorate candidates [18]. Then CRI results were used to determine the strategy to deliver for those “concepts”. For junior and senior high schools it was determine STEM-project based learning as instructional model, while for university level, dual situated learning model (DSLM) was used for three meetings (three weeks: three topics) in Evolution course [19; 20]. Part of the CRI was used for high school students, meanwhile additional test consisted of 5 simple essay test was used as pre-test and post-test for Evolution. Even though there are the three composition of the three groups...
(Table 1, it is clear that the higher group level the more number of formal operational thinker. It can be stated too that even in university level, there still can be found concrete operational thinkers.

From Table 2 it can be interpreted that the most expected is type I, and then type III. The most unexpected is type IV which meant misconception. Different result can be interpreted when we used essay test to detect conceptual change as well as misconception, as it can be seen in Table 3.

**Table 1** Results of Test of Logical Thinking for each group of Participants

| Groups of Participant         | Concrete Operation (%) | Transitional (%) | Formal Operation (%) |
|------------------------------|------------------------|------------------|---------------------|
| 1 Junior High School (7th grade) | 73.5                   | 23.5             | 2.9                 |
| 2 Senior High School (10th grade) | 36.0                   | 28.0             | 36.0                |
| 3 College (6th semester)      | 18.2                   | 30.3             | 51.5                |

**Table 2.** Type of Category based on four type Pattern [21]

| No | Pair of Conception (x, y) | Pattern | Category                  | Interpretation               |
|----|---------------------------|---------|---------------------------|-------------------------------|
| 1  | Negative → Positive (+, +) | I       | Change into Positive      | Construction                  |
| 2  | Negative → Negative (-, -) | II      | Remain negative           | Static negative               |
| 3  | Positive → Positive (+, +) | III     | Remain positive           | Static positive               |
| 4  | Positive → Negative (+, -) | IV      | Change into negative      | Misconception                |

**Table 3.** Category of Conceptual Changes based on Response Category

| No | Pair of Conception         | Pattern | Category   | Type of Conceptual change |
|----|---------------------------|---------|------------|---------------------------|
| 1  | No Response → Complete     | I       | Construction | Construction            |
| 2  | No response → Incorrect    | II      | Revision    | Revision                  |
| 3  | No Response → In complete  | II      | Revision    | Revision                  |
| 4  | Incorrect → In complete    | II      | Revision    | Revision                  |
| 5  | Incorrect → Complete       | II      | Revision    | Revision                  |
| 6  | In complete → Complete     | III     | Complementation | Complementation        |
| 7  | No response → No response  | IV      | Static      | Static                    |
| 8  | Incorrect → In correct     | IV      | Static      | Static                    |
| 9  | In complete → In complete  | IV      | Static      | Static                    |
| 10 | Complete → Complete        | IV      | Static      | Static                    |
| 11 | Incorrect → No Response    | V       | Disorientation | Disorientation      |
| 12 | Incomplete → No response   | V       | Disorientation | Disorientation      |
| 13 | In complete → In correct   | V       | Disorientation | Disorientation      |
| 14 | Complete → No response     | V       | Disorientation | Disorientation      |
| 15 | Complete → In correct      | V       | Disorientation | Disorientation      |
| 16 | Complete → In complete     | V       | Disorientation | Disorientation      |

3. Result and Discussion

3.1. Results in Junior and Senior High Schools

Based on the data in Table 4, it shows that most junior high school like to learn new things such as prokaryotic cells. The examples for those cells among others are bacteria and blue green algae. Even it was not easy to see those organisms under the microscope. As they have to plan and make cell models (animal and plant cells for each group) they enjoyed learning in STEM-project based learning (STEM-PjBL). They got the opportunity to operate objects and learn invisible concepts, by generalizing. They were happy too that they had learnt a lot about variety of cells. From their real experience they learn that organism can be one cell (unicellular) or many cells (multicellular).
Most senior high school students and first two-year university students have limited knowledge about animal and plant cells, as they learn imaginative cells (reconstructed ones) from the picture in their textbook. They do not have direct experience in recognizing variety type of cells in animal and plant. They usually draw oval shape for animal cell and rectangular shape for plant cell. Actually the way students learn about cell will influence how well they understand [22]. Ignoring our student in learning abstract concepts by just telling them will lead them to misconception. They should learn the cell and its characteristic meaningfully. Without understanding about cell well, the students will have difficulty in understanding other related concepts, included learning cell and fungi [23; 24].

Table 4. Distribution of Conceptual Change pattern in Organization of Living System

| No | Topic (average) | Subtopic                                      | Pattern of Conceptual change (%) |
|----|-----------------|-----------------------------------------------|---------------------------------|
| 1  | Cell [22.0 → 59.9] | Characteristic of cell                         | I  | II  | III | IV  |
|    |                 | Prokaryote and Eukaryote cells *               | 32.4 | 20.6 | 38.2 | 8.8 |
|    |                 | Unicellular and multicellular organisms        | 47.1 | 7.4  | 45.6 | 0.0 |
|    |                 | Cell structure and Role of cell parts         | 57.4 | 19.1 | 19.1 | 4.4 |
|    |                 | Structure of Animal and Plant cells           | 40.2 | 25.5 | 24.5 | 9.8 |
|    |                 |                                              | 42.4 | 18.4 | 31.6 | 7.8 |
| 2  | Tissue [6.0 → 54.5] | Characteristic of Tissue                      | 47.1 | 0.0  | 47.1 | 5.9 |
|    |                 | Plant tissue                                  | 43.2 | 2.5  | 53.5 | 1.0 |
|    |                 | Plant tissue system *                         | 50.0 | 0.0  | 50.0 | 0.0 |
|    |                 | Animal tissue                                 | 64.7 | 11.8 | 20.6 | 3.0 |
| 3  | Organ [22.5 → 52.0] | Characteristic of organ                       | 32.4 | 8.9  | 53.0 | 5.9 |
|    |                 | Organs in Plant                               | 29.4 | 11.8 | 54.4 | 4.4 |
|    |                 | Organs in Animal and Human                    | 41.2 | 32.4 | 22.1 | 4.4 |
| 4  | Organ System [31.4 → 57.8] | Characteristic of Organ System | 29.4 | 5.9  | 58.8 | 5.9 |
|    |                 | Organ System in Animal and Human              | 44.1 | 17.7 | 26.5 | 11.8 |
|    |                 | Organ System in Plant                         | 41.2 | 35.3 | 5.9  | 17.6 |
| 5  | Organism [16.2 → 55.9] | Organism                                      | 45.6 | 10.3 | 38.3 | 5.9 |

*new concept for junior high school

From Table 5 it is shown that the percentage of first indicator/topic for misconception is the highest, as it is difficult to get clear and good object for microscopic fungi, especially when the practical work was conducted in the afternoon. Meanwhile the percentage for second topic/indicator about reproduction in Fungi is the lowest for understanding concept (42%), as there are variety of spore in fungi (sporangiospore, conidiospore, basidiospore, ascospore, etc.) based on vegetatively or generatively formed. It is very complicated event for university students. It is unfortunately found that student concept mastery on fungi is low [25], and very little percentage achieve by the senior high school students about fungi role as decomposer. Without their contribution our beloved planet will very rapidly full and crowed.

When we compare the results of junior high school students’ achievement to senior high school students’ achievement it is clear that young students have high spirits in learning new things, while older students have less eagerness to maintain the cultivation of fungi due to be managed outside the school schedule. Nevertheless, STEM-Project based learning is good to be implemented at high school level. Their practical work, planning and re-planning ability can be improved, and most prestigious is useful for them to be life-long learners in facing rapid changes during the Industrial Revolution (IR) 4.0. It is their own duty to improve themselves in order to be survive for their carrier and equipped them with competencies needed in their generation and next generations [26].
3.2. Result in University Level
After joining Evolution course (Theoretical) for at least three meetings using “Dual situated learning model” or DSLM, the results show that nearly very little “construction category” occurred, as most of the concept had been learnt during school years and in some previous semesters. For radiation of human and Primate evolution most of the students’ conception is in revision category. It means that they have tried to change their conception into more positive one. For the other two topics mostly in Static categories, and very little found in disorientation category. It is very hard to teach human evolution to religion based high schools which focusing on certain religion [27]. They often confronted the concepts with their beliefs.

Table 5. Recapitulation of FUNGI Pre-conception and Concept Mastery based on CRI

| Concept mastery (%) for each Indicator/Topic | PreTest (%) | Post Test (%) |
|---------------------------------------------|-------------|---------------|
|                                             | UC | UH | MC | NUC | UC | UH | MC | NUC |
| 1 Identify morphological structure of microscopic and macroscopic fungi | 11.0 | 6.0 | 42.0 | 40.0 | 48.0 | 8.0 | 29.0 | 15.0 |
| 2 Explain mechanism of fungi reproductive aspect | 6.0 | 11.0 | 21.0 | 59.0 | 42.0 | 16.0 | 22.0 | 20.0 |
| 3 Classify types of fungi based on certain characteristics | 14.0 | 10.0 | 29.0 | 44.0 | 52.0 | 15.0 | 22.0 | 11.0 |
| 4 Explain variety of fungi role in human life | 23.0 | 10.0 | 30.0 | 37.0 | 52.0 | 14.0 | 21.0 | 13.0 |
| 5 Identify factors influencing fungi growth | 12.0 | 18.7 | 21.3 | 48.0 | 54.7 | 14.0 | 14.7 | 16.6 |
| 6 Present project result about fungi growth in the form of graph | 8.0 | 36.0 | 24.0 | 32.0 | 60.0 | 24.0 | 12.0 | 4.0 |

Average 12.9 12.9 27.8 45.2 50.6 13.9 20.7 14.8

Note: UC= Understand Concept; UH= Understand but hesitate; MC= Misconception; NUC= Non understand concept.

As reported by [28], some misconceptions were found, but the high percentage are mainly in those three concepts. In some text books radiation of human and primate evolution there is very little discussion about human and primate evolution. It was found too by Friedrichsen et al [29].

From Table 6 it is shown that very little construction type mostly static and revision. But it shows too, that very little disorientation. Except for the first topic. Combined to previous table (Table 1), it was found too that only below formal operation have the disorientation, no formal operation students have misconception (or in category disorientation).

Table 6. Level Category of Conceptual Change based on each Topic

| Topics on                                             | Cons. | Rev. | Compl. | Stat. | Disor |
|-------------------------------------------------------|-------|------|--------|-------|-------|
| 1st The nature and History of Evolution               | 0.6   | 26.7 | 3.0    | 56.4  | 13.3  |
| 2nd Diversity & Variety of Living Things              | 1.8   | 16.9 | 21.8   | 55.2  | 4.3   |
| 3rd Radiation of Human & Primate Evolution            | 0.5   | 61.1 | 13.9   | 20.5  | 3.0   |

Note: Con: Construction; Rev = Revision; Compl= Complementary; Stat = Static; Disor=Disorientation

4. Conclusion
STEM-project based learning can facilitate for junior and senior high school students to have positive conceptual change (construction) by having direct experience operating objects. And with help of CRI test we can know whether the concepts were too difficult or not for them based on their position in
stages of intellectual development [12, 18]. Dual situated learning model was suitable been used at university level, as it facilitates students to confront them in conflict situation that they have to react and make decision, and try to make relationship for abstract concepts such as radiation of human and primate evolution etc.

For researcher to determine which pattern of conceptual change to choose, it depend on the complexity of the answer towards the test. For essay test, even very simple one, it is better to determine the response first, then decide the type or pattern of conceptual change [30]. By using CRI or two/three/four tier multiple choice test it is enough to choose four pattern (construction, static positive, static negative, misconception [21].

Instead of remediating misconception based on the result what aspect causes the misconceptions, it is more gain time and more powerful to focus the changes using constructivism and conceptual change which challenge the students in dissatisfaction and conflict cognitive. Then when they realized that the new concept is fruitful, intelligible and plausible [30].

Either for high school student or for university students, it will be better when new knowledge delivered in conceptual change pattern, whether through STEM-Project based learning (where they can operate objects to understand more easily, or using Dual Situated Learning model (where they confronted to conflict by using scientific argumentation).

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