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# Measuring Visual Literacy Skills on Students' Concept Understanding of Genetic Transfer Material

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**Abstract**. Visualization is an important skill for all students majoring in natural sciences. Also, the visual literacy skills (VLS) are essential for Microbiology learning. The lecturer can use the external representations (ERs) to visualize the microorganisms and its microenvironment. One of learning materials which are rather difficult to interpret in microbiology is genetic transfer. In this study, we measure the VLS on students' concept understanding of genetic transfer material using a simple test. The tests were held before and after the lecture on this topic employing a combination of talking drawing with picture and picture model. The results show that in the beginning, students showed their poor visual literacy. After the lecture, students were able to draw their understanding on the genetic transfer in bacteria. Most students' visual literacy ability improves in the level of acceptable. In conclusion, the students' ability was improved in the average amount of conceptual knowledge. This result reveals that some students comprehend in the correct level of ability, meaning that they have a high degree of conceptual (propositional) and visual knowledge.

## 1. Introduction

Microbiology is a discipline which studies all microscopic organisms in the form of unicellular, multicellular or acellular such as bacteria, microfungi, mold, microalgae, protozoa, and archaea [1]. In Indonesia, microbiology began to be introduced in the middle school and is a compulsory subject for higher level students of biology, chemistry, integrated science, pharmaceutical, food, health, medicine and the environment [2]. Nowadays, mastering microbiology by natural sciences students is important since it is directly related to everyday life and can be associated with life skills aspects [3]. In microbiology learning, students are required to translate the microscopic form of microorganisms and its environment in their mind, something that is hard and confusing for them. In fact, the biologists use the visualization tools for understanding and researching the molecular and cellular biosciences. The visualization tools by some psychologists are called by external representatives (ERs); for example: molecular models, photographs, micrographs, pictures, diagrams, illustrations, drawings, images, analogical representations, maps, symbolic pathways, genomic representations, graphs, icons, static visuals, dynamic visuals, animated visuals, multimedia, and virtual reality environments [4]. The use of external representations (ERs) such as diagrams and animations in science education, particularly in microbiology has rapidly increased over the past decades.

In addition, the best way to learn microbiology is by conducting the practicum and a direct observation under the microscope. However, not all schools and faculties have the facilities to support this activity. Therefore, teachers and lecturers can simply construct the picture and picture model in an

attempt to explain the abstract phenomena. This model is effective for understanding theories and concepts of biology, biotechnology, and microbiology by visualization. Picture and picture learning model uses the pictures which are paired or sorted into a logical sequence. One of microbiology materials is genetic transfer mechanism of bacteria. Even though the undergraduate students have directly observed the form of bacterial cells in microbiology practicum; however, most of them have not observed the genetic materials inside the cells due to the limitation of microscope resolution capacity. Therefore, this material of study is rather difficult for students to interpret if only taught in a common lecture without any learning model application. In regards to this issue, the implementation of picture and picture model is promising to facilitate students to imagine the process of genetic transfer process in the simplest way. This particular ER is suitable for achieving desired learning outcomes. Moreover, it is also important for lecturers to teach students the visualization skills to interpret ER to ensure that the students are capable of visual literacy skills. Thus, we conducted a research on the undergraduate students in microbiology subject to measure their ability in visual literacy skills. The aims of this study are to discuss the use of picture and picture model in developing students' visual literacy skills, to measure the level of students' visual literacy skills and minimize visualization difficulties as well as enhancing the general literacy of future students.

## 2. Methods

The study was conducted in the Department of Integrated Science, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang. The population of this study was 46 undergraduate students who registered in Microbiology subject (Course Code: D0014037). The students were taught the genetic transfer learning material in the 12$^{th}$ meeting using the combination of talking drawing with picture and picture (P&P) model [5]. The course was designed to help students comprehending the material by training their visual literacy because learning biology is considered difficult, especially in some areas like cell division, genetics, and hormones [6]. The course design is presented in Table 1.

**Table 1**. Course Design

| Step | Action |
|---|---|
| 1 | Select the concept, topic, or object |
| 2 | Measure initial ability |
| 3 | Introduce the materials through picture |
| 4 | Invite students to share and discuss their work with their classmates in group |
| 5 | Instruct in a concept, topic or object selected |
| 6 | Encourage students to create another drawing based on the instruction |
| 7 | Facilitate discussion among students comparing and contrasting their drawing |
| 8 | Assess their concept mastery through drawing |

The course design focuses on developing students' visual literacy through drawing since biology is the most visual of all sciences and has a long history of the use of imagery to define and link concepts in living systems [7]. The P&P strategy was used to train students to help them formulating the concept of material. The example of learning material is presented in Figure 1.

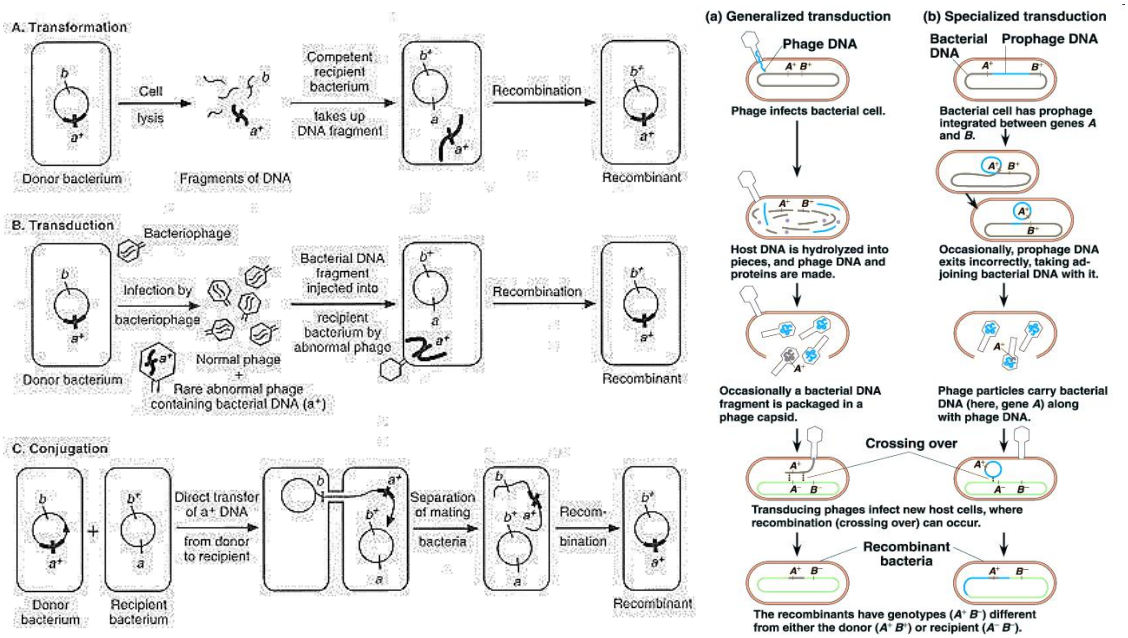


**Figure 1.** The example of genetic transfer external representation

After the implementation of P&P model, a test was conducted to measure the students' visual literacy skills. In this regard, their reasoning skills (R), conceptual knowledge (C), and mode of representation (M) were determined. These three areas were measured based on their response to the questions related with ER. Students were asked to re-draw the transformation, transduction, and conjugation method of genetic transfer in bacteria and explain it in words. The score on their answer was ranged from 0-3 on a 4-point Likert scale as shown in Table 2.

**Table 2.** Scoring guideline using 4-point Likert scale to measure the students' visual literacy skills

| Grading | Score | Definition |
|---|---|---|
| Correct | 3 | High degree of conceptual (propositional) and visual knowledge used to provide a relevant response with a high amount of detail i.e. C – R – M. |
| Acceptable | 2 | An average amount of conceptual (propositional) knowledge, where one uses mainly conceptual knowledge and ER based knowledge to respond to the probe i.e. C – M, with little evidence of in-depth reasoning e.g. student regurgitate answers from conceptual knowledge. |
| Partially correct | 1 | Response based on reasoning with ER, little or no evidence of conceptual understanding i.e. R – M, or response based on reasoning only with regard to conceptual knowledge and no evidence of ER-based reasoning i.e. R – C. (i.e. R-M or R-C, not both) |
| Incorrect | 0 | No response or incorrect response based on lack of, or incorrect conceptual knowledge and/or reasoning ability in relation to the ER |

## 3. Results and Discussion

*Results*

In the preliminary investigation, students showed their poor visual literacy where they exhibited the evidence of visualization difficulties that affect their ability to interpret and learn from external representation (ER). Figure 2 presents the comprehension level before they get material training, most of the students are at the level of little or no evidence of conceptual understanding and No response or incorrect response based on lack of, or incorrect conceptual knowledge and/or reasoning ability in relation to the ER. After an explanation by using picture and picture (P&P) model, students were able to draw their understanding on the genetic transfer in bacteria.

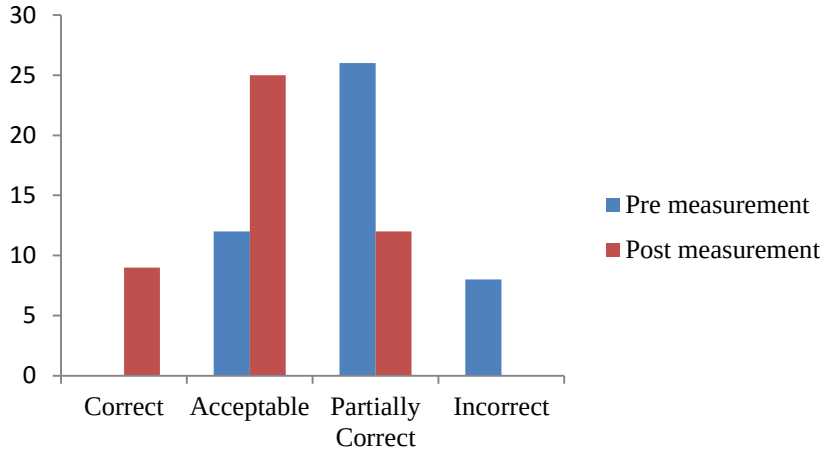


**Figure 2.** Students' Ability Level of visual literacy

From the figure 2, we can see that most students' visual literacy ability improves in the level of acceptable. It means that their ability is in the range of the average amount of conceptual (propositional) knowledge. In fact, some of the students comprehend in the correct level of ability, meaning that they have a high degree of conceptual (propositional) and visual knowledge used to provide a relevant response related to materials.

*Discussion*

In this study, we did indirect training on visual information interpretation and drawing. In fact, drawing is a powerful tool for thinking and communicating, regardless of the discipline. Also, drawing is a skilled process integrated into the practice of science, used in the generation of hypotheses, the design of experiments, the visualization and interpretation of data, and the communication of results [8]. Drawing has always helped artists to observe and reflect on their ideas; however, using drawing as a tool to help students to develop and document more complex understandings is not often used in science instruction. Images that have been made by a student was different from the other students, this issue has happened because the differences in the imagination, creativity, and ability to draw. Therefore, in one class, there was a variation of drawing results. However, their drawing explanation could reveal their understanding on the ER in this study.

The learning model by drawing is declared can improve long-term memory due to several reasons. One of them is citing the theory of "dual coding" initiated by [9]. In his theory, the memory consists of two separate theory systems. The first system is the Verbal System used to represent thinking with the language. The second system is a Non-Verbal System to represent and think of non-verbal information, such as images. When some information is received, one or both of these systems can be activated. An information form as sentences or words that entered will be stored in the memory system of verbal or non-verbal, or both. If memory can be encoded properly in both of the systems of verbal and non-verbal, the possibility that information stored in long-term memory will increase. In this study, the genetic transfer ER as visual literacy can provide information that cannot be given thoroughly only with words. When the students see the pictures, the students are more interested in learning, whereas the ability to draw an object can enhance students' understanding of the object and improve the memory of students as they "make" the object themselves.

Learning by a common lecture method that usually applied by teachers will indirectly impact the declining ability of scientific-creative thinking. Surveys of teachers and students indicate when students drew to explore understandings in science, they were more motivated to learn than conventional teaching and drawing activity seem like play can stimulate students' interests of to explore their scientific interests. To stimulate an interest in science is important if students are to be motivated to engage in scientific research in the long term [8] [10]. The use of drawing to individual learner differences is shaped by the learner's current or emerging ideas and knowledge of visual conventions [8].

Drawing can function as a communication tool even in non-interactive social contexts. For example, generating an explanation of a concept can have the effect of inducing deeper conceptual understanding in the explainer as well as the explainee [11]. By drawing, students can expand expression and imagination without limits. In this process, the child can develop ideas, channeling his emotions, foster interest in art and creativity. Students can show their skills, express their ideas, experiences, observations into a scratch line, shape, color, according to tools they use images that make students more creative [12]. Moreover, drawing can improve motoric ability, the premise is that drawing focuses on effective coordination of mind and muscle to culminate in the production of swift and meaningful patterns of movement that has to be learned [13].

In studying visual literacy, we need to understand what it meant. There are numerous definitions of visual literacy, each emphasizing various unique characteristics [14]. Research and studies on visual literacy began to be developed after Debes introduce visual literacy in 1969. Visual Literacy refers to a group of vision-competencies a human being that can develop by seeing and at the same time having and integrating other sensory experiences. The development of these competencies is fundamental to normal human learning. When it is developed, they enable a visually literate person to discriminate and interpret the visible actions, objects, symbols, natural or man-made, that he encounters in his environment. Through the creative use of these competencies, he can communicate with others. Through the appreciative use of these competencies, he can comprehend and enjoy the masterworks of visual communication [8].

In other words, visual literacy is the ability to communicate knowledge through imagery [7] [14]. Different types of mental image and visualization in science can serve different purposes. For example, realistic diagrams (such as an anatomical diagram) highlight the salient features of an object. Schematic diagrams (such as an electrical circuit diagram) illustrate relationships, assist in calculations, or provide descriptions of a phenomenon or process. Other visualizations in science education include photographs, simulations, astrophotography and scale drawings of equipment. Scientific visualizations can offer a means for imagining the unseen (such as the molecular, atomic and subatomic worlds) [15].

To develop visual literacy, students not only see the pictures provided in textbooks as it has been considered by the teacher but also they are guided to visualize concepts into images. Certainly making visualizations is integral to scientific thinking. Scientists do not use words only but rely on diagrams, graphs, videos, photographs, and other images to make discoveries, explain findings, and excite public interest [8]. Visual literacy skills can be learned in ways analogous to textual literacy. Through effective teaching, people can learn to develop the ability to recognize, interpret, and employ the distinct syntax and semantics of different visual forms. Researchers assert that the process of becoming visually literate continues through a lifetime of learning new and more sophisticated ways to produce, analyze, and use images [16].

Because science is so often visual and spatial in nature, drawing is one of the key activities in teaching and learning science, alongside practicum, modeling, role-play, and digital simulation [17]. The effectiveness of drawing and modeling to support rich learning we explain using the notion of affordance as a productive constraint. Drawings and models, because of particular visual spatial requirements, constrain and guide the learner into seeing phenomena in new ways [18].

Effective learning strategies will help learners overcome the limitations of the material presented, organize their knowledge more effectively, and integrate new and existing understanding; ultimately, they can be transformative by generating new inferences [8]. In this study, picture and picture (P&P) model is a strategy in the form of cooperative learning to deliver genetic transfer material through picture logical sequence. In P&P model, the lecturer asks the students to have pre-learning drawing phase. After that, the lecturer presents the learning material by showing the picture (ER) related to the material. Some students are asked to explain by their understanding and interpretation after the lecturers' explanation. After that, the lecturers ask the students to make the group where they have to re-draw the ER in a logical sequence based on their understanding and analyze the drawing results together.

Making visual images within the mind as one reads provide an effective framework for organizing, remembering, and constructing meaning from text [5] [8]. In the pre-learning drawing phase, students are introduced to the topic to be studied, and then the students were directed to share the knowledge

they "think" they have about the learning topics. Before the lecturer explains the topic in expository text, lecturer leads the students to describe their imagination about the topic on a piece of paper through drawing mental images. During the pre and post-learning, students were asked to share their pictures with each other [5]. Their drawing in pre-learning can be different with their drawing in post-learning because students receive new knowledge during the learning process. Thus, the students' understanding can be seen through their drawing in post-learning.

The other way to introduce learning through drawing method is by directing the students to find the topic to be learned from their natural surroundings, books, or another image that can be given by the teacher, like the picture shown on the LCD, preserved animals or organs, artificial sectional, etc. Then the students were asked to draw the topic in detail because the topic drawn is a topic of their choosing, then students will pay more attention to detail of the material [19]. The difference from the strategy of "talking drawing" is students receive apperception and basic materials first and then draw according to their individual creativity, then the teacher guide students to present the results in front of the class to initiate discussions between students. During the discussion, students were asked to correct the image that they have made according to results of the discussion. The practice of this lesson requires a shorter time, and the teacher can control the discussion better. But overall, the two methods of the image has the same main steps, namely: 1) providing information about the material using a picture, (2) guiding students to visualize information by the understanding, imagination and skill of students, and (3) analyzing their drawing image. However, it does not mean drawing for learning is the only method that should be applied, but rather drawing is used to complement the writing and speaking activity [10].

Noteworthy by the teacher is when students share their knowledge through images, is important if the owner of the image is explaining the image he had made by himself rather than asking other students to interpret images owned by somebody else. When the teacher explains the students are drawing or asked the other students to interpret the work of other students, it could be the purpose and the meaning of the images can be extremely different, because every student has the distinction of imagination and their motor abilities [5].

## 4. Conclusion

Based on the analysis it can be concluded that the students' ability in comprehending material improves significantly in the level of the average amount of conceptual (propositional) knowledge. In fact, some of the students comprehend in the correct level of ability, meaning that they have a high degree of conceptual (propositional) and visual knowledge.

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