Impact of quantitative literacy on student reasoning in plant anatomy course

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Abstract. Research about the impact of quantitative literacy on prospective student reasoning on Plant Anatomy Course has been done. This study implemented lectures program that develop quantitative literacy and analysed its impact on student reasoning. Participants were 24 Biology students and 35 Biology Education students. The development of quantitative literacy in the lectures was done through the activity of quantification of plant anatomical variables through observation. Students observed quantitative aspects including cell size, cell ratio with organelles and crystals, intercellular space size, density and stomatal index. Observation activities continued with discussion based on data obtained. At the end of the lecture the students tested their conceptual reasoning with the instrument of multiple choice questions referring to Marzano indicators and Quantitative literacy. A Correlational analysis indicates that the quantitative literacy of students correlates positively and significantly to the reasoning of plant anatomical concepts.

1. Introduction

Quantitative literacy is the capability to understand, to criticize and to use numbers to solve problems in real situations in the world of work and in lectures [1, 2]. For prospective biology scientists and prospective teachers, this ability needs to be developed in order to communicate scientifically with various experts. They need to apply qualitative and quantitative approaches to develop problem formulation, research questions, analysis and interpretation of data, and draw conclusions as a scientist or as educators. However, students of biology and biology education in Indonesia have low quantitative literacy skills [3].

Plant anatomy is one of the compulsory courses for Biology Education student and biology students. However, the mastery of the student's plant anatomy concept is still low [4, 5, 6]. The low understanding of the concept of plant anatomy is due to low skills using microscopes and microscopic observation [5, 7] low representation and microscopic transformation [6]. Furthermore [4] describe various problems to understanding plant anatomy through practicum learning. Student hard to reconstruct the meaning of descriptive messages, to explain the characteristics of the plant tissue using words and to organize information, to connect the anatomical structure with its function and to draw relationship between the observed structure and the new situation encountered [4]. Therefore mastering skills using microscopes in the observation and reasoning to understand the concept of plant anatomy through the processing of observation data needs to be improved.
The capability to make microscopic preparations and to do microscopic observation accurately is the main keys to representing microscopic object of plant anatomy correctly. The accuracy of the data from observation is greatly influence microscopic representation capability. These capability can be reinforced by quantification of data from microscopic observation [8] Furthermore [9] states that the implementation of learning strategies that accommodate procedural and declarative knowledge in an integrated manner is a good step to obtain and process quantitative data on the structure of plant anatomy to practice quantitative skills. Inquiry laboratory learning improved the quantitative information processing with relatively-low mental efforts. The determination of quantitative variables by the students, continued by measuring and analyzing quantitative data develop student quantitative literacy [10].

Infusing quantitative literacy with peer tutor in plant anatomy course has been done by [8]. The result showed that peer tutoring with combination of three teaching methods of demonstration, laboratory work, and discussion improved student laboratory skill performance of plant anatomy including making fresh preparations, using a microscope, and measuring the cell indicators. The research examined the function of the lecture program of Plant Anatomy developed based on instructional framework of learning dimension on developing quantitative literacy of biology students also has been done by [9]. This course program was accommodated procedural and declarative knowledge. According to [11] the use of instructional frameworks based on learning dimensions on the structure and function of plants lecturer enhance students' reasoning on abstract and microscopic concepts. However, research that applies the framework of learning dimensions in the plant anatomy course to develop quantitative literacy has not been assessed for its impact on students' anatomical reasoning of plants.

2. Method
Participants were 24 Biology students and 35 Biology Education students. The study was conducted across 14 meetings. The first phase of the course for 3 weeks student practices making microscopic preparations and microscopic measurements with peer tutor [8]. All classes implemented three teaching methods of demonstration, laboratory work, and discussion. Peer tutoring was employed in both classes particularly when the students do laboratory work. Tutors were taken from their own group. The class was reinforced with task to stimulating student prior knowledge. The tutors had two main tasks, to guide the students to master their three laboratory skills and to provide feedback on student performance of laboratory work. The second phase and third phase course instructional framework of learning dimension was implemented according to [9].

Student quantitative literacy was measured by six indicators rubric developed by AACU [12] i.e interpretation, representation, calculation, assumption, application, and communication Quantitative literacy data was collected through written test. Written test was taken at the end of each lecture phase using a description item that measures six quantitative literacy indicators. The written test instrument used has a reliability of 0.71 for Phase 1 and Phase 3, and 0.91 for Phase 2. The reasoning ability indicator modify from [13] The tests for measuring reasoning abilities in plant anatomy concepts consist of direct observation tests, multiple choice written tests. The question of direct observation is used to measure the indicators of acquiring knowledge and integrating knowledge, whereas multiple-choice written tests are used to measure indicators of comparing, classifying, induction, deduction, and constructing support, and definitional investigation.

Data obtained were analyzed using SPSS 21. To determine effect of framework of learning dimensions in the plant anatomy course on quantitative literacy and reasoning was used one sample t test with standard score 60 [14]. To determine impact quantitative literacy on student reasoning were used Pearson correlation.
3. Result and discussion

3.1. Student reasoning and quantitative literacy
The result of descriptive statistic test and significance test toward the mean of total students' reasoning and quantitative literacy is shown in Table 1 and Table 2.

| Variable                  | Class            | N  | Mean  | Std. deviation | Std. error mean |
|---------------------------|------------------|----|-------|----------------|-----------------|
| Reasoning                 | Biology          | 24 | 64.32 | 5.30           | 1.08            |
|                           | Biology Education| 35 | 68.27 | 5.65           | 0.95            |
| Quantitative Literacy     | Biology          | 24 | 73.76 | 5.38           | 1.10            |
|                           | Biology Education| 35 | 80.73 | 5.43           | 0.92            |

The Data in Table 1 shows that biology students have lower reasoning scores (64.32 ± 5.30) than Biology Education students (68.27 ± 5.65). The mean total quantitative literacy of biology student is lower than biology education student. Biology student score is 73.76 ± 5.38 and biology education 80.72 ± 5.43. Based on the mean score of students in general (score C = 60), the score of reasoning and quantitative literacy is higher. The result of significance test of reasoning score used t tested one sample shown in Table 2.

| Variable                  | Class            | T    | Df    | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval |
|---------------------------|------------------|------|-------|-----------------|-----------------|-------------------------|
| Reasoning                 | Biology          | 4.001| 23    | .001            | 4.32            | 2.09 - 6.56             |
|                           | Biology Education| 8.663| 34    | .000            | 8.27            | 6.33 - 10.21            |
| Quantitative Literacy     | Biology          | 12.524| 23    | .000            | 13.76           | 11.49 - 16.03           |
|                           | Biology Education| 22.581| 34    | .000            | 20.73           | 18.86 - 22.59           |

Test Value = 60

Based on the mean score of students' reasoning ability in plant anatomy in both classes, the average of Biology student's reasoning ability and Biology education student in plant anatomy is significantly greater than the normal value. The result of t test one sample to the reasoning is obtained t (23) = 4.001 p = 0.001 for Biology and t (34) = 8.663 p = 0.000 for Biology Education, while the analysis of Biological grade quantitative literacy ability is obtained t (23) = 12.524 p = 0.000 and Biology Education t (34) = 22.581 p = 0.000.

3.2. Impact quantitative literacy on student reasoning
To determine impact quantitative literacy on student reasoning were used Pearson correlation. The result of prerequisite test for correlation test is normality test presented in Table 3. Based on Table 3 the variables tested have a normal distribution so that the correlation test conducted is Pearson correlation test.

| Variable                  | Biology | Biology education |
|---------------------------|---------|--------------------|
|                           | sig.    | summary            |
| Quantitative literacy     | 0.979   | Normal             |
| Reasoning                 | 0.994   | Normal             |

The results of the correlation test are shown in Table 4. According to Table 4 it can be seen that in both classes found a positive and significant correlation between quantitative literacy and reasoning. In the
Biology class there was a strong positive correlation between quantitative literacy and reasoning with \( r(24) = 0.619, p < 0.05 \). In the Biology Education class there was a positive correlation between quantitative literacy and reasoning with \( r(24) = 0.501, p < 0.05 \).

### Table 4. Correlation and regression test result.

| Class                  | Pearson test | Regression |            |
|------------------------|--------------|------------|------------|
|                        | R            | Sig        | \( r^2 \)  | contribution |
| Biology                | 0.619**      | 0.001<0.05 | 0.384      | 38.4%        |
| Biology education      | 0.501*       | 0.002<0.005| 0.251      | 25.1%        |

* : significant at \( \alpha = 0.05 \)
** : significant at \( \alpha = 0.01 \)

Based on the data in table 4 in Biology class Quantitative literacy contributes 38.4% to the reasoning of Plant Anatomy. In the Biology Education class the amount of quantitative literacy contribution to the reasoning of Plant Anatomy is 25.1%. The result of correlation and regression test (table 5) shows the same pattern correlation between Biology and Biology Education class. Significant positive relationship between variables found in the study showed that the increase of quantitative literacy score will increase the score of reasoning of Plant Anatomy.

According to table 2, there is a positive effect of framework of learning dimensions in the plant anatomy course on quantitative literacy and reasoning. Implementation of framework of learning dimensions on anatomy course drive student to use their working memory to process all information the first lecture phase strategy succeeds in developing microscopic observation skills that include microscopy skills, focusing observational objects, fresh preparing skills, cell-measuring skills, and microscopic photography. All these skills can be directly used to collect qualitative and quantitative data for processing and transformation of quantitative literacy knowledge and the concept of Plant Anatomy at lecture phase 2 and 3. At lecture phase 1 has also laid a foundation on the concept of cell. The lecture phase 1 provides the basic quantitative literacy required at the lecture 2 and lecture 3 stages. At the lecture phase 2 microscopic observation skills are used meaningfully to produce accurate quantitative and qualitative information. At the lecture phase 3 students use all the prior knowledge that has been obtained in the previous phase to be used in processing and transforming information in understanding organ concepts and conducting research. The lecture phase 3 cannot be exchanged or skipped. The students microscopic photography shown in Figure 1.

![Figure 1. Photo of epidermal tissue taken by student.](image)
of stomata and plant adaptation. Quantification action is an important step in the development of quantitative literacy [15].

The mental activity for information processing begins with quantitative and qualitative information gathering activities. Quantitative information is obtained through a quantification step that includes the identification of the concept attributes and the measurement of the attributes of the concept. Obtaining accurate quantitative information is the key to processing the right information. Quantitative information is compared, as well as with qualitative information, searched for similarity and differences, grouped, generalized, and defined to construct a plant anatomy concept. All mental activity done by students is relevant to [13] opinion which states that the purpose of the learning process emphasizes the process of thinking on constructing meaning, organizing new knowledge, storing knowledge, expressing similarities and differences, grouping by category, formulating principles and evidence, drawing conclusions, supporting a statement, emphasizing the underlying theme, digging information and solving problems. The phase of student reasoning development through quantitative literacy shown in Figure 2.

![Figure 2. Reasoning development through quantitative literacy.](image)

Figure 2 shows that the findings of the research indicate that the application of the Plant Anatomy course program based on the learning dimension can increase the quantitative literacy. This finding is support previous research [16]. The ability of students’ quantitative literacy increases through lectures that provide an opportunity to collect and analyze data through laboratory activities. This finding is relevant with reaseach [17] that quantitative literacy learning will work if quantitative literacy is attached as habit of mind.

4. Conclusion
Based on the results it can be concluded that student quantitative literacy and reasoning improved significantly through lectures based on learning dimensions. Quantification of the plant anatomy concept attributes helps to clarify microscopic representation. Connecting detail microscopic representation and quantitative data of plant anatomy enhance student reasoning. Mastery of quantitative literacy helps student in representing, analyzing, and interpreting quantitative data of plant anatomy. Quantitative literacy helps students to organize information and explain the characteristics of concept.
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