Connecting qualitative observation and quantitative measurement for enhancing quantitative literacy in plant anatomy course

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Abstract. Forming of cognitive schemes of plant anatomy concepts is performed by processing of qualitative and quantitative data obtained from microscopic observations. To enhancing student’s quantitative literacy, strategy of plant anatomy course was modified by adding the task to analyze quantitative data produced by quantitative measurement of plant anatomy guided by material course. Participant in this study was 24 biology students and 35 biology education students. Quantitative Literacy test, complex thinking in plant anatomy test and questioner used to evaluate the course. Quantitative literacy capability data was collected by quantitative literacy test with the rubric from the Association of American Colleges and Universities, Complex thinking in plant anatomy test according to Marzano and questioner. Quantitative literacy data are categorized according to modified Rhodes and Finley categories. The results showed that quantitative literacy of biology education students is better than biology students.

1. Introduction
New findings and facts in biology are presented in qualitative and quantitative data. Technological advances have also led to a change in the trend of object studies from the macro to the micro and nano study. Universities should be able to prepare learners to understand qualitative and quantitative data and study biology studies on macro and nano scale [1]. explained that obtaining quantitative data through measurement is the first step in developing the ability to understand numbers, to criticize, and use them to solve problems in real situations (quantitative literacy).

Quantitative literacy is the ability to understand numbers, criticize and use them to solve problems in real situations encountered in everyday life, both in the world of work and in lectures [2,3]. For prospective biology scientists, this ability needs to be developed in order to communicate scientifically with various scientists. A scientist needs to apply qualitative and quantitative approaches to develop problem formulation, research questions, analysis and interpretation of data, and draw conclusions. For students, they also need to be trained as a scientist. The responsibility for the development of quantitative literacy in schools is teacher’s responsibility [4]. Therefore, the development of QL in prospective teachers is important.

Quantitative literacy indicator according to the Association of American Colleges and Universities is interpretations, representations, calculations, assumptions, applications, and communications [5]. Quantitative reasoning is one of the several general-purpose of the lectures at Michigan State University.
This college measures the scientific skills and quantitative reasoning of all students at the beginning and end of the lecture program. Although some universities already have quantitative skills programs and assessments, most universities have not explicitly established a clear program [3].

Over thirty years of quantitative literacy are a big concern to both national and international levels [2,6,7]. Several studies suggest that this quantitative literacy is a skill that becomes an essential requirement for the individual [8 - 10]. However, students of biology and biology education in Indonesia have low quantitative literacy skills [11].

Plants Anatomy Course traditionally focus on plant anatomical content through qualitative observation of microscopic objects, only a few quantitative aspects are observed in observing plant anatomy [11]. The scope of matter in the study of plant anatomy includes cells, tissues, and organs. Structure of cells, tissues, and organs can be observed from both qualitative and quantitative aspects. From the qualitative aspects of cells, tissues, or organs can be distinguished from the form and its constituent components, while the quantitative aspects are distinguished from their size, thickness, distribution, and cell density. Various attributes of cells, tissues, and organs can be accurately measured using a micrometer scale mounted on the ocular lens of the microscope. Thus, the microscopic representation formed becomes more accurate and proportional. While the distribution, density, and arrangement of cells or tissues in the organs can be determined by the technique of sampling, counting, and mathematical calculations. Connecting qualitative observations and quantitative measurements in this course can train the ability to study the structure of microscopic images in three-dimensional form with appropriate proportions and scales, spatial abilities, and a sense of scale for microscopic concepts.

In this article, we describe how the team connects qualitative observation and quantitative measurement of plant cells and tissues to develop quantitative literacy in the course of plant anatomy. Interventions focused on basic quantitative literacy include calculation, representation, analysis, and interpretation.

2. Methods
The study was conducted across 9 meetings. Participants in this study were 24 biology students (2nd semester) and 35 biology education students (4th semester). Students joined plants anatomy lecture program courses that are intervened with quantitative aspects to develop quantitative literacy in each class. During the first phase of the lectures for 3 weeks, students practice making microscopic preparations and microscopic measurements. The second phase of the lectures students find and understand the concept of plants’ cell and tissue, and train quantitative literation through microscopic observation and measurement (6 weeks), the goal of phase 1 is to develop representational capability in table form, calculate average cell size, cell magnification and determine result scaled ocular lens calibration at 40X, 100X and 400X magnification, performs interpretation of cell size calculations at different magnifications and analyzes the effect of magnification of lens on cell size. The lectures are guided by the teaching materials as shown in Figure 1.
In the second phase of the lecture, students doing observation and measurement of the object then using the qualitative and quantitative data to understand the concept of plant anatomy. The development of quantitative interpretation and analytical capabilities is guided by questions in teaching materials such as 1) How does the shape and size of colenchymal cells in each organ observed? Compare to surrounding parenchymal cells, does it have the same shape and size? How is the size of sclerenchyma cells in young and old coconut endocarp? Are the cells still alive? What qualitative and quantitative evidence that supports your answer? The ability of quantitative representation is guided by the command to create two-dimensional and three-dimensional images of cells and tissues using the quantitative and qualitative data obtained. On each phase of the lectures, calculation abilities developed by calculating the average size of the cells, calculating the size of the cell to calculate stomatal density by counting the number of pores per leaf surface area [12]. In the teaching materials are written in the form of equations as in equation (1).

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\text{Stomatal Density} = \frac{\text{Amount of Stomata}}{\text{Leaf Surface Area}}
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Quantitative literacy capability data collection was conducted using the quantitative literacy test method with the rubric from the Association of American Colleges and Universities [5]. Complex thinking in plant anatomy test according to [13] and questioner used to evaluate the course. Data is analyzed descriptively. Quantitative literacy data are categorized according to modified Rhodes and Finley categories [14]. Benchmarks (1 <2), Milestone (2 ≤ 3), and Capstone (3-4).

3. Result and Discussion

Figure 1. The addition of quantitative aspects in the teaching materials of plant anatomy lectures
achieved in the indicator analysis. The greatest quantitative literacy achievement was achieved in phase 1 of representation and phase 2 of calculation.

Figure 2. Quantitative Literacy of Biology Education Students

The students' quantitative literacy in the indicators of representation, calculation, analysis, and interpretation of biology students are presented in Figure 3. Figure 3 shows that analytical and interpretation ability decreased achievement in phase 2 of the lecture. The significant decrease experienced by students on the indicator analysis. The calculation is the lowest achieved indicator by biology students in phase 1 (1.73).

Figure 3. Quantitative Literacy of Biology Students

Figures 2 and 3 show that adding quantitative aspects into the lectures of plant anatomy successfully developed the student's quantitative literacy. At the end of the lecture, biology education students have higher quantitative literacy compared to biology students. At the end of lecture implementation of biology education students reach capstone category on three indicators, whereas in biology students only 1 indicator. Quantitative measurements on microscopic observations of plant anatomy can produce quantitative data that can be calculated, analyzed, represented in the form of tables, two-dimensional images and three-dimensional images and can be interpreted meaningfully. This means that the addition of quantitative aspects through microscopic measurements can train students to develop their quantitative literacy skills.
Implementation of the strategy to train students to produce the data can be started by giving knowledge of procedural and declarative knowledge in an integrated manner [11]. In the first phase, students exercise to calculating the real cell size, calculating the average cell size, and calculating the ratio of cell enlargement. The data are presented in tabular form so it is easy to read. Interpretation and analysis is done when students process the measurement data using several lenses with different magnification. Some groups can draw the correct conclusions as student A’s statement "so ... regardless of lens magnification used, cell size does not change". According to Table 2, the findings in this study differ from the previous findings. According to [3] the highest ability is controlled by the students is Calculation. The ability of Calculation of biology students is lower than that of biological education and the lowest among other quantitative literacy skills in phase 1.

Phase 2 students linked qualitative and quantitative measurements to build cognitive schemes of plant anatomy concepts. The results of interviews on biology education students are known that they understand the relationship of cell wall thickness of parenchyma with cell age. Meanwhile, according to biology students understand the role of aerenchyme is known from the size of the space between cells. The formation of cognitive schemes of plant anatomy concepts is done through interpretation and analysis of the quantitative data obtained. The attributes of the concept of plant anatomy are consistent with the findings of the quantitative data of the students so that the students can easily understand and master the concept of plant anatomy. Quantitative interpretation focuses on data as the center [2] to find the relationship between the variables [1].

The ability of students in connecting qualitative observation and quantitative measurement to construct cognitive schemes of plant anatomy concepts can be seen in the dimension model made by the students at the end of phase 2 (Figure 2). The three-dimensional model of aerenchyme tissue in Canna sp. flower shows that students observe the attributes of aerenchyme concept in detail. Crystal Druz is depicted in plant cells, polygonal cell shape, and cellular arrangement such as the framework of a building with intercellular space built by many cells. Quantitative measurements are expressed in terms of size on the model side. A proportional model shows that students understand the magnification scale. The number and size of the aerenchymas constituent cell and the appropriate space between cells as presented in the real photograph.

**Figure 4. Three-Dimensional Model of Aerenchyme Cell**

4. Conclusion
Quantitative measurement and detailed observation of the concept attributes is an important step in the development of quantitative data-based literacy. Quantification action requires proper observation and measurement of concept attributes. The clarity of the observed object can affect the accuracy of the quantitative data obtained. Quantitative literacy and the establishment of cognitive schemes can be developed in an integrated and meaningful manner through activities involving students in the acquisition and processing of data based on hands-on.
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