Equipping students’ research skills and logical thinking through practical work on algae topic

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Abstract. This research was initiated by biology students’ that have difficulties in writing scientific papers so as to reduce the quality of students’ research and facilitate them to make proposals for students’ creativity program conducted by kemenristek dikt as Tridharma forms of higher education. A research using pre-experimental method was conducted to equip research skills and improve students’ logical thinking. The initial development of the practicum program was based on a preliminary study at one state university in Bandung, West Java. The study was conducted from February to April 2019 and involved 38 second semester biology students’. Data were collected through: tasks and rubrics (for reviewing articles, proposal outlines, pre-proposals, and final proposals), and TOLT. Research skills used at the scaffolded research. Data were quantitatively analyzed and qualitatively as well. The results show that the cryptogamae botany practicum program could improve students’ moderate research skills and logical thinking. In addition, it was also found that students who are in formal operation category tend to increase their research skills higher compared to those of the transitional and concrete operation categories.

1. Introduction
Research skills are one of the skills developed in biology learning in Indonesia. This is in accordance with the Tridharma of Higher Education which has an obligation to carry out education, research, and community service. Tridharma of Higher Education as a basic reference for developing students’ creativity. Efforts to foster student creativity and innovation are an integral part of research skills as students. The Student Creativity Program is the implementation of the Tridharma of Higher Education [1]. As a biology student in fulfilling the obligations of the Tridharma of Higher Education there are a number of things that need to be done, namely: (1) understanding and mastering skills related to his/her field of expertise (2) researching, developing and solving problems using an interdisciplinary approach and research results related to his/her field of expertise. The skill of writing scientific papers is also important for the academic community in higher education to develop the scientific field for students’ [2]. In this regard, the Research Skill Development (RSD) is present in the midst of students’ to facilitate students’ who have difficulties in writing scientific works such as articles in journal and assessment matrix in biology project [3][4]. Research Skill Development (RSD) facilitates educators to conceptualize of student research skills in a systematic with flexible manner, characteristics
combined to allow a coherent approach, both in courses, and university education [5]. RSD is very important in learning at the University level as it can help improve the teaching skills of lecturers in teaching content to students because of the academic process in terms of aspects and levels of autonomy is very high. This framework has a process of thinking and flexibility for each researcher because it has a degree of autonomy where level 1 is a very determined end, and level 5 is a very autonomous end [6].

RSD helps facilitate students’ in carrying out their duties, namely making algae lab reports. The practicum of cryptogamae botany is a course that discusses classification, dichotomy key and identifying abilities. This course is very close to the student environment because it is easy to find algae species. The characteristics of this course help students think logically. The algae material used in this study was microscopic and macroscopic algae consisting of Cyanophyta, Chlorophyta, Crysophyta, Phaeophyta, and Rhodophyta [7].

The fundamental aspects related to student research skills: (1) writing as an aspect of language skills, (2) students as “producers” of scientific papers, (3) problems in writing scientific papers. Some of the solutions offered include: (a) a sense of laziness can be overcome by building self-motivation, increasing association with the author and changing the picnic pattern; (b) ideas can be overcome by reading references from various journals that are liked and participating in many national or international seminars; (c) not mastering the topic overcome by rising to advance by motivating themselves by reading and searching for research ideas from various references; (d) difficulty starting writing above by making an outline and doing free writing. To be able to do a good research, students’ must have good research skills, because good or bad research results depend on the research skills of the researcher. Students’ who have good research skills are also expected to have good logical thinking skills so that they have the potency to have problem solving skills, strong inquiry and the ability to compile scientific papers [8]. The ability to think logically consists of formal, transition and concrete operation in reasoning abilities. The ability to think logically is used as a feature of someone who reaches the level of formal thinker in the form of logical reasoning [9]. The characteristics of biology content enough abstract are very much needed by formal thinking categories for students’ to be active in each type of learning and able to solve problems independently.

2. Methods
This pre-experimental research was conducted to equip research skills and logical thinking of students’ on the concept of algae. This study involved 38 second semester biology students. The study was conducted from February to April 2019. Data was collected through several instruments in the form of: tasks and rubrics in reviewing articles, proposals outlines, pre-proposals, final proposals, and test of logical thinking (TOLT). Research skills used at the scaffolded research level in facets of research consist of: (1) embark on inquiry and so determine a need for knowledge,(2) find/generate needed data using appropriate methodology, (3) critically evaluate data and the process to find/generate this data,(4) organise information collected/generated,(5) synthesise and analyse and apply new knowledge,(6) communicate knowledge and the processes used to generate it, with an awareness of ethical, social and cultural issues[10]. Research skills data screening is carried out during 6 weeks of meetings [meeting 1: students’ were given direction related to cryptogamae botany course, giving guidebooks, sample journals; in the 2nd to 6th meeting, students were given a questionnaire to review articles]. The ability to study articles in the net was seen based on the range of scores as follows; high 75-100; being 50-74; low <49. Research skills in the net are seen based on the range of scores as follows; high 70-100; currently 40-70; low <40. Data were analyzed qualitatively and quantitatively [11]. The logical thinking ability measured was reasoning ability in the form of logical conclusions based on accurate facts. Reasoning ability was detected in test of logical thinking (TOLT) which includes five reasons including: proportional, control variables, probability, correlational, combinatorial, each of which is represented by two test items. TOLT results were then grouped into
concrete (0-1), transitional (2-3) and formal (4-10) operational stages. Measurement of logical thinking skills was carried out before and after the cryptogamae botany practical learning.

3. Result and Discussion

3.1 Reviewing articles during practical work on algae topic

Table 1. Data below show the ability of students to study articles

| No  | Highlighted aspects                                                                 | 2nd to 4th week | Student Perception | 5th to 6th week |  |
|-----|-------------------------------------------------------------------------------------|-----------------|--------------------|-----------------|---|
|     |                                                                                     | Difficult       | Convenient        | Difficult       | Convenient |
| 1   | The problem                                                                         | -               | 100               | -               | 100         |
| 2   | Factual                                                                             | -               | 100               | 2.64            | 97.36       |
| 3   | Basic problem                                                                       | 5.26            | 94.73             | 5.27            | 94.73       |
| 4   | Temporary conjecture                                                                | 39.5            | 60.5              | 50              | 50          |
| 5   | Findings of scientific research                                                     | 39.5            | 60.5              | 42.11           | 57.89       |
| 6   | Conclusion                                                                          | 2.6             | 97.3              | 5.27            | 94.73       |
| 7   | Essential concept                                                                   | 18.5            | 81.5              | 39.5            | 60.5        |
| 8   | Research variable                                                                   | 18.5            | 81.5              | 15.79           | 84.21       |
| 9   | Parameters measured                                                                 | 21              | 79                | 23.69           | 76.31       |
| 10  | Data processing                                                                     | 100             | -                 | 39.5            | 60.5        |
| 11  | Controlling variables                                                               | 76.3            | 23.7              | 63.16           | 36.84       |
| 12  | Finding the reason for the emergence of facts                                       | 55.3            | 44.7              | 44.74           | 55.26       |
| 13  | Find a developing problem                                                           | 71.06           | 28.94             | 63.16           | 36.84       |
| 14  | Criticize the article                                                               | 65.79           | 34.21             | 50              | 50          |
| 15  | Exploring other referential grounds                                                  | 81.58           | 18.42             | 55.3            | 44.7        |

Data in table 1 show the ability of students’ to study articles. At the 2nd-4th weeks students’ experience easy in reviewing articles at the core points of the problem, objectives, background, conclusions, research variables, parameters measured but on the other hand they also have difficulty finding hypotheses, finding scientific facts, essential concepts, processing data, controlling variables, discovering the reasons for the emergence of facts, capturing developing problems, criticizing articles exploring other referential grounds. Meanwhile at the meeting of 5-6 students’ understanding in studying articles has increased on certain points (hypotheses, finding scientific facts, essential concepts, processing data, finding the reason for the emergence of facts). The difficulty of students in the 5-6 meeting is controlling variables, detecting developing problems, criticizing articles, exploring other referential bases. This happens because students’ are still in semester 2 and they did not have many experiences related to reviewing articles. On one side of the point revealed by researchers based on their references, not based on what the researchers said. The interview results in information that for this time students have difficulties in reviewing and compiling scientific articles in the form of scientific papers or journals because students’ are also not used to reading scientific papers.
3.2 Implementation of Practical Work on Algae Topic to Improve Students’ Logical Thinking.
Measurement of logical thinking was carried out based on the categories of logical thinking: proportional, controlling variables, probabilities, correlational and combinatorial reasoning [12]. The measurement results show that the practicum program implemented can facilitate students’ logical thinking patterns from concrete operation to transitional, from concrete operation to formal operation, and from transitional to formal operation. Changes in student logical thinking can also be seen from the increase in the percentage of questions in each category of logical thinking that was answered correctly by students. The categories of reasoning that are seen: combinatorial reasoning > proportional reasoning, correlational reasoning, probability reasoning, and controlling control reasoning [13].

| No. | Category of Reasoning | Percentage of logical thinking Pretest | Postest |
|-----|-----------------------|--------------------------------------|---------|
| 1   | Proportional reasoning (number 1-2) | 27 | 10 |
| 2   | Controlling variable (number 3-4) | 2 | 3 |
| 3   | Probability reasoning (number 5-6) | 8 | 10 |
| 4   | Correlational reasoning (number 7-8) | 15 | 19 |
| 5   | Combinatorial reasoning (number 9-10) | 26 | 33 |

Table 2. Shows changes in students’ logical thinking in each category of reasoning. Changes with the greatest percentage found in combinatorial reasoning. The lowest change occurs in variable control reasoning. The improvement in each logical thinking category shows that the Cryptogamae Botany practicum program implemented can improve students’ reasoning.

3.3 Implementation of Practical Work on Algae Topic to Improve Students’ Research skills

Table 3. Data below show the ability of research skills based on test of logical thinking (TOLT)

| TOLT value category | Pretest (%) | Postest (%) | TOLT value category | Pretest (%) | Postest (%) |
|---------------------|-------------|-------------|---------------------|-------------|-------------|
| Concrete            | 32          | 10          | Transitional        | 42          | 47          |
| Transitional        | 26          | 43          | Formal              | 45          | 45          |
|                     |             |             |                     |             |             |
| Embark & Clarify    | 8           | 25          | Find & generate     | 10          | 12          |
| Evaluate & reflect  | 48          | 35          | Organize & Manage   | 44          | 44          |
| Analyze, synthesize and apply | 44 | 47 | Communicate and apply | 45 | 45 |
| Communicate and apply | 44 | 47 | Organize & Manage   | 44          | 44          |
|                     | 46          | 46          | Find & generate     | 46          | 46          |
|                     |             |             | Evaluate & reflect  |             |             |
|                     |             |             | Analyze, synthesize and apply |     |             |
|                     |             |             | Communicate and apply |     |             |

(a) Pre-proposals  Scaffolded research in Facets of research

| TOLT value category | Embark&clarify | Find & generate | Evaluate & reflect | Organize & Manage | Analyze, synthesize and apply | Communicate and apply |
|---------------------|----------------|-----------------|-------------------|------------------|------------------------------|-----------------------|
| Concrete            | 10             | 11              | 10                | 12               | 11                           | 10                    |
| Transitional        | 45             | 44              | 39                | 41               | 47                           | 45                    |
| Formal              | 45             | 45              | 51                | 47               | 42                           | 45                    |

(b) Final proposals  Scaffolded Research in Facets of Research

| TOLT value category | Embark&clarify | Find & generate | Evaluate & reflect | Organize & Manage | Analyze, synthesize and apply | Communicate and apply |
|---------------------|----------------|-----------------|-------------------|------------------|------------------------------|-----------------------|
| Concrete            | 10             | 10              | 10                | 10               | 10                           | 10                    |
| Transitional        | 44             | 44              | 44                | 44               | 45                           | 44                    |
| Formal              | 46             | 46              | 46                | 46               | 45                           | 46                    |
Data in Table 3 show the ability of research skills based on test of logical thinking (TOLT). The results of the students' research skills based on TOLT as can be seen from the outline show that the students’ develop the embark and clarify phase, and “find and generate” phase. The outline component consists of: title, background, literature study and method [14]. Pre-proposals research skills that develop the embark and clarify on inquiry, find/generate appropriate methodology, evaluate and reflect data critically phases, communicate, but not to analyze, synthesize and apply. The final research skills in pre-proposals have developed overall facets of research. Overall developing facets are students who are formal thinkers and are in the moderate category. The facets of research application by students at the proposals outlines stage puts the theme of research independently then proceeds to the pre-proposals. The idea that has been written on the chosen proposals outlines is in the group that will be used in the plan for making algae products. After completing the production of algae products students submitted the final algae proposals. Some of the products processed by algae are from macroscopic algae including such as (powder milk made from *Eucheuma cottoni*), (ice cream, masks and antipyretic made from *Sargassum sp*), (chips, nori and “cireng” made from *ulva lactuca*), (made from *Sargassum sp*), (syrup made from *gracillaria sp*).

4. Conclusion
The results show that the Cryptogamae botany practicum program could improve students’ moderate research skills and logical thinking. In addition, it was also found that students who have a formal score of TOLT category tend to increase their research skills higher compared to those of the transitional and concrete score categories.

5. References
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