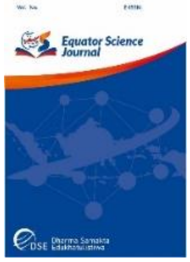
EQUATOR SCIENCE JOURNAL (ESJ) e-ISSN: 2988-3881
Volume 2, Issue 2 (2024) 39-48

EQUATOR SCIENCE JOURNAL (ESJ)
e-ISSN: 2988-3881
Journal homepage:
https://ejournal.edukhatulistiwa.com/index.php/ESJ



Profile of Science Practicum Course, Logical Thinking Ability, and Systems Thinking for Prospective Science Teacher Students in Sorong Regency

Febrian Andi Hidayat [1*], Isnawati Isnawati[2], Lisa Dewi Ramadany[3]
[1]Department of Science Education, Universitas Pendidikan Muhammadiyah Sorong, Sorong,
[2]Department of Science Education, Universitas Pendidikan Indonesia, Bandung
[3]Post Graduate of Basic Education Program, Universitas Pendidikan Indonesia, Bandung,

Received: February 6th, 2024. Revised: March 11th, 2024. Accepted: March 30th, 2024
DOI: 10.61142/esj.v2i2.114

Corresponding author: fabrianandi@unimudasorong.ac.id

Keywords: Science Practicum Course, Logical Thinking, Systems Thinking, Science Teacher

ABSTRACT
This research aims to determine the profile of science practicum lectures, logical thinking abilities, and systems thinking skills of prospective science teacher students in Sorong Regency. This research is a case study with pre-research, implementation, and final/post-research stages. The subjects of this research were students who were or had contracted for science practicum course. The instruments used are analysis lists, logical thinking test instruments, systems thinking scales, and systems thinking skills tests. Interviews were also conducted to support the data that had been obtained. The research results show that (1) the practicum activities that have been running so far have only trained skills in collecting, processing, and analyzing scientific research data. (2) The contents of the practicum instructions do not train students' thinking skills, such as critical thinking, systems, or problem-solving. (3) Students' logical thinking abilities are relatively evenly distributed at proportional, correlational, and combinatorial reasoning levels; however, the majority of students have reasoning in the transitional category, and there is quite a high level of concrete reasoning. (4) Students' systems thinking skills are relatively low, especially forest thinking skills. Different and innovative practicum lecture approaches need to be developed to improve logical thinking and systems thinking skills for prospective science teacher students in Sorong Regency. Low levels of logical thinking

and systems thinking skills will have implications for achieving skills at the next level, such as the skills needed today, namely 21st-century skills.

INTRODUCTION

Higher education has a goal set out in Law No. 12 Tahun 2012: to develop students' potential to be faithful and devoted to God Almighty, noble, knowledgeable, capable, creative, independent, qualified, competent, and educated. Another goal is to produce graduates with qualified science and technology skills. Laboratory practice lectures are one of the activities that can support achieving the objectives as mandated in the Law, where practicum activities allow students to develop basic skills in conducting experiments and become a vehicle for implementing the theory that has been learned (Hofstein & Lunetta, 2004). Laboratory and hands-on activities are important and an integrated part of science learning (Millar & Abrahams, 2009). Hands-on activities combine hands-on activities with the thinking process so that learners have the opportunity to directly observe, explore, and understand the object of study of the science being studied.

Optimization of science practicum lecture programs in higher education is very important as a form of aligning learning outcomes with the demands of competencies that are increasingly developing along with the development of Science and Technology (Desi et al., 2023). The competencies expected in the current learning process require the achievement of 21st-century skills, namely communication, collaboration, critical thinking, and creativity, where these skills are accommodated in laboratory practice activities (Hofstein & Lunetta, 2004; Yuniar et al., 2024).). The demand for the expected competence is a challenge for educators always to prepare as well as possible for the planning of science practicum lectures that will be carried out (Muzdalifah & Ismail, 2023).

Science practicum lectures are compulsory courses that must be completed by prospective teacher students of the Science Education Study Programme at one of the Universities in Sorong Regency. This science practicum course weighs two credits and is in the fifth semester. Science practicum in the curriculum structure of the Science Education study program is unrelated to theoretical lectures. Still, there are several topics related to the Integrated Science course in the previous semester. Topics in science practicum courses refer to the content taught in junior high schools. Student completeness in this science practicum course is determined by the assessment of pre and post-tests, practicum reports, midterm exams, semester final exams, activeness in groups, and attendance during the lecture process both in preparation and implementation of practicum. The graduate learning outcomes imposed on science practicum courses in the curriculum structure of the Science Education Study Program are 12 learning outcomes divided into groups of attitudes, general skills, special skills, and mastery of knowledge. Science practicum lectures utilize indoor laboratories in the form of integrated laboratories and outdoor laboratories with direct observation in designated places.

The laboratory is one of the places that supports students to practice the science process (Hofstein & Lunetta, 2004). Activities in the laboratory allow students to interact with the objects being studied directly, either through direct observation or an experiment. Through the guidance of educators, learners in laboratory activities, both individually and with their groups, practice actively and intensively by involving all five senses, thoughts, and energy to solve various problems encountered and then discuss the results of their analysis to gain knowledge. Science practicum lectures have topics consisting of three fields of science, namely Chemistry, Physics, and Biology where to be able to do and understand the process requires students' thinking skills. System thinking skills need to be owned and trained in science practicum lectures to support students in constructing knowledge and solving problems encountered through practicum activities.

Systems thinking is based on the 21st century competency framework created by *Partnership for 21st Century Skills*, (2015) is part of critical thinking skills as one of the skills developed in the 21st century. Logical thinking has five formal intellectual reasoning for learners: proportional thinking, variable control, probability, correlation, and combinational thinking (Tobin & Capie, 1978). The five formal reasoning abilities in logical thinking are divided into three categories: concrete thinking, transitional thinking, and formal reasoning. Learners with formal reasoning ability demonstrate that these learners have good logical thinking ability.

The science practicum has a strategic role and potential as an effort to prepare students who are able to face the era of industrialization and globalisation. The role of practicum in this effort can be realised if its implementation is able to equip students with the ability to think logically, think critically, think systems, solve problems creatively, master technology, and be adaptive to the times. Systems thinking skills become a tool for the scientific process, especially in the analysis and synthesis process (Boersma et al., 2011). The provision of systems thinking skills in science practicum activities can be done by linking the topics in science practicum lectures with real problems and understanding students relationship to the complexity of the environment around them. This biological complexity can be realised at various levels of living organisms, from the molecular level to the ecosystem (Boersma et al., 2011). Some theories that can be used in systems thinking skills are general systems theory, cybernetics, and dynamic systems (Hester & Adams, 2014).

Observations conducted at one of the higher education institutions in Sorong Regency obtained information that science practicum activities have not run optimally. Practical activities in the process are carried out conventionally and in the form of a verification practicum. The topics in science practicum lectures are also not associated with real problems such as the destruction of mangrove ecosystems, the lack of clean water needs, environmental pollution, the decline in certain animal populations, global warming, and other social problems. Lecture activities, as mentioned above, result in less than optimal quality of the learning process, which results in the ability to think logically and systemically of prospective science teacher students being low.

Science practicum lecture activities that are less varied are the cause of students' inability to study in depth and utilise the results of their studies to solve problems faced in everyday life. These conventional practicum activities also do not support students understanding of the concepts being studied and do not support the achievement of higher-order thinking skills (Sutarno, 2018). The lack of information in conventional practicum activities is the cause of the difficulty students have in constructing their own knowledge learned through science practicum. Based on the description above, the author is interested in conducting a field study related to the implementation of science practicum, logical thinking skills, and system thinking of prospective science teacher students.

METHOD

This research was conducted at the Science Education Study Program, Faculty of Teacher Training and Education, Universitas Pendidikan Muhammadiyah (UNIMUDA) Sorong, for students in semesters V and VII who had contracted science practicum courses. For participants who took the logical thinking test, there were 19 students, while for the system thinking test, there were 14 students. In addition to students, the subjects of this study were assistants and lecturers teaching science practicum courses. This research was conducted in December 2022.

Data collection in this case study was obtained by: (a) conducting document studies in the form of course analyses in the curriculum and semester learning plans for science practicum courses at the Science Education Study Program, Faculty of Teacher Training and Education, UNIMUDA Sorong, and comparing them with 4 other campuses. In addition, other documents analysed were the science practicum instructions used at UNIMUDA Sorong. (b) measuring the logical thinking ability, perception, and system thinking ability of science teacher candidates. Logical thinking ability is measured using an instrument by (Tobin & Capie, 1978). Perceptions of systems thinking were measured using the systems thinking scale developed by (Dolansky et al., 2020). Students' systems thinking skills were measured using a test developed by the Ministry of Education (Dorani et al., 2015). (c) Interviews with practicum assistants and lecturers teaching ecology practicum courses were conducted to explore information about the implementation of science practicum lectures. Semi-structured interviews were conducted according to interview guidelines.

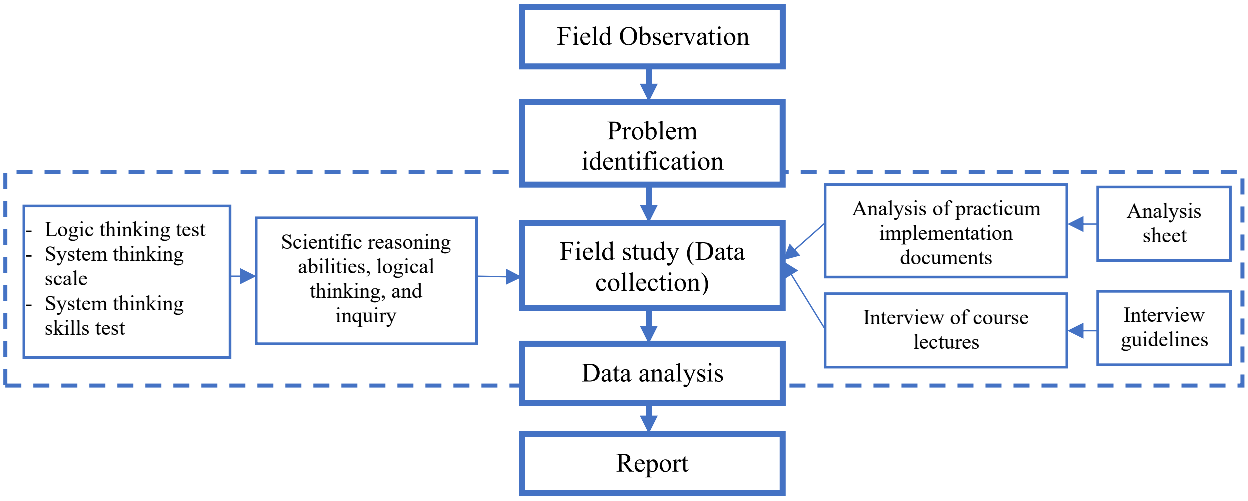


Fig 1. Field Study Research Flow Chart

RESULTS AND DISCUSSIONS

Description of Science Practicum Course

A science practicum course is a course that must be followed by prospective teacher students in the Natural Science Education Study Program at one of the universities in Sorong Regency. Science practicum courses are given in the sixth semester with a weight of two credits. The science practicum course is a compulsory course and is a separate course from the theory course. The completeness of science practicum lectures is determined by the assessment of pretests, posttests, practicum reports, midterm exams, and attendance during lectures and practicum implementation.

In the study programme curriculum document, there are 12 study programme learning outcomes (SPLO) that are imposed on science practicum courses. The 12 SPLO are then elaborated into 4 Science Practicum Course Learning Outcomes (CLO). From the 4 CLO, practicum lectures were conducted with a total of 10 practicum topics for one semester.

Further analysis was carried out on the science practicum instructions that had been used. The analysis process focused on the topics or lab chapters provided in the lab manual. Based on the results of the analysis of the practicum instructions, it can be concluded that the practicum instructions present a prescription or verification method of work to be followed by students. There are no practicum instructions that train inquiry, critical thinking, systems thinking, problem solving, or project-based thinking.

Logic Thinking Ability of Science Teacher Candidate Students

Students' logical thinking ability was measured through the TOLT logical thinking test developed by (Tobin & Capie, 1978). Formal reasoning that can be measured in this study includes all reasoning. This test instrument can also categorise students' scientific reasoning with concrete operations, transitional operations, and formal operations. The level of logical thinking ability possessed by prospective science teacher students who are and have contracted science practicum courses is presented in Figure 2.

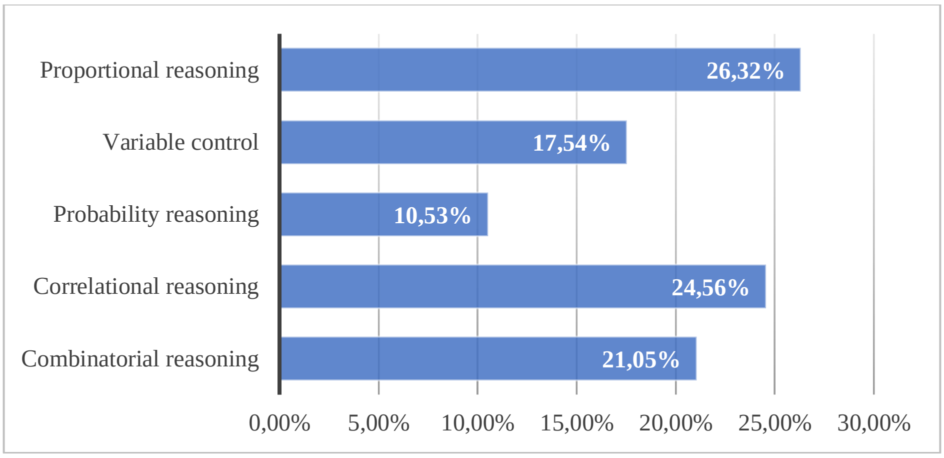


Fig 2. Percentage of Students' Logical Thinking Ability Level

The logical thinking skills shown in Figure 2 have different percentages at each level. Proportional reasoning obtained the highest percentage (26.32%), while probability reasoning obtained the lowest percentage (10.53%).

Data on the category of students' scientific reasoning is also obtained from the results of the logical thinking test conducted, where students' scientific reasoning is grouped into concrete operational, transitional, and formal operational categories presented in Figure 3 below.

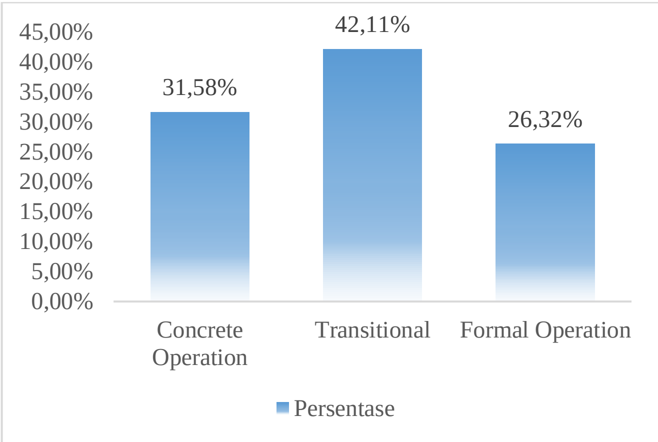


Fig 3. Percentage of Students' Scientific Reasoning Category

Figure 3 shows that most students are still in transitional reasoning (42.11%). Students who belong to formal operational reasoning have the lowest percentage (26.32%). And there are still students in the category of concrete operational reasoning with a fairly high percentage (31.58%).

Systems Thinking Scale

There are 20 statement items given and answered by students in measuring the system thinking scale. The system thinking scale used has four options, namely never, rarely, often, and always. The focus of the system thinking scale used on the interdependence system indicators developed by (Dolansky et al., 2020). The student answers are presented in Table 1.

Table 1. Systems Thinking Scale for Prospective Science Teacher Students

No	*When I want to make repairs,….*	*Percentage*
1	I asked everyone in the group for their views on the situation.	82.14%
2	I look for the root of the incident to determine the cause of the problem	85.71%
3	I think it is very important to understand how the chain of events occurred	87.50%
4	I involve my group members to find solutions	83.93%
5	I think recurring patterns are more important than one particular event	78.57%
6	I consider existing problems as a series of interconnected problems	71.43%
7	I consider the causes and effects that occur in a situation	82.14%
8	I consider the relationships between group members	91.07%
9	I think that the system keeps changing	71.43%
10	I propose solutions that affect the classroom environment, not specific individuals	82.14%
11	I remember that the proposed changes could affect the entire system	71.43%
12	I think to be successful requires more than one or two people	76.79%
13	I always remember the mission and goals of the group	83.93%
14	I think small changes can produce important results	83.93%
15	I consider many changes affecting each other	87.50%
16	I think about how different group members might be affected by the improvements	67.86%
17	I try strategies that don't rely on people's memories	69.64%
18	I am aware of system problems influenced by past events	73.21%
19	I consider past history and culture	76.79%
20	I assume that the same action can have different effects over time, depending on the state of the system	76.79%
	Average	**79.20%**

The systems thinking scale is intended to measure how often students are involved in activities that constitute systems thinking activities. Categorization in the systems thinking scale is divided into four groups, namely never, rarely (26-50%), often (51-75%), and always (76-100%). The measurement results show that science education students are included in the frequent category (79.20%).

Systems Thinking Ability of Prospective Science Teacher Students

Systems thinking skills are measured using a description test based on the systems thinking classification developed by (Dorani et al., 2015), where the classification is divided into six complementary skills, namely: 1) Dynamic thinking, 2) System-as-Cause Thinking, 3) Cause effect Thinking, 4) Forest thinking, 5)Closed-Loop Thinking, 6) Stock and Flow Thinking. Based on the measurement results, the data obtained is presented in Figure 4.

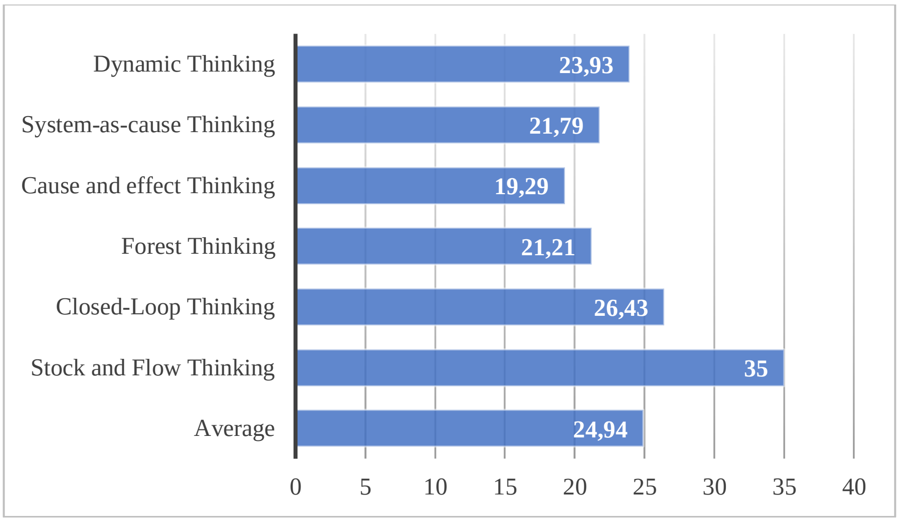


Fig 4. Systems Thinking Score Results per Indicator

In general, the systems thinking skills of science education students are still low, with an average score of 24.94. The stock and flow thinking indicator has the highest value at 35.00. Meanwhile, the lowest value lies in the causal thinking indicator of 19.29.

Lecturer and Laboratory Assistant Interview Results

Interviews were conducted with lecturers in charge of science practicum courses where descriptions were obtained regarding the implementation of science practicum. The practicum activities analyzed include preparation for practicum learning carried out by the lecturer, stages of implementing practicum learning and evaluations used. The descriptions related to the description of activities for each stage in the learning process are described as follows:

a. Preparation phase

The information obtained based on the interview results is that the lecturer carries out several activities before the face-to-face meeting in the laboratory. These activities include: 1) The lecturer prepares material related to the topic that will be practiced in the laboratory, 2) Lecturers prepare tools and materials for practical activities and discuss materials and activities with laboratory assistants to equalize perceptions between lecturers and laboratory assistants who assist with practical activities.

b. Practical learning implementation stage

Based on interviews conducted, information was obtained that several stages were carried out in the practical implementation, namely: 1) Ask students to collect practical journals related to the topic that will be practiced, 2) Checking student attendance assisted by the laboratory assistant, 3) The lecturer conducts a pretest before starting regarding the topic that will be practiced, 4) The lecturer asks students to explain the objectives and procedures for activities related to the topic that will be practiced, 5) Students carry out practicums and collect data related to the results of observations during practicum activities under the guidance of lecturers and laboratory assistants, 6) Lecturers, assisted by laboratory assistants, assess student activity in practicums, discussions and presentations, 7) The practical instructions lecturers give are still in the form of recipe books and have not developed students' reasoning and systems thinking abilities, 8) Lecturers and students discuss the results of the practicum activities that have been carried out.

c. Evaluation stage

The form of evaluation at the end of science practicum learning is in the form of preparing practicum reports for students in groups and individually, field lecture reports, pretest and posttest scores, and UTS and UAS scores.

The interview data revealed that in preparing practical instructions, the lecturers had not paid attention to the thinking skills that could be trained in students. Apart from that, the regional potential in Sorong Regency to be integrated into science practicum lectures has not been used as an opportunity to develop quality practicum guides. Lecturers selecting and determining practicum topics are still based on the science practicum tools in the University's integrated laboratory. Lecturers in preparing practical instructions also still experience limited knowledge regarding how to train students' thinking skills, such as systems thinking related to science practicum topics.

The results of the analysis of the semester learning plan show that the CLO Science Practicum, the result of elaboration from the Learning Outcome Study Program, has not been fully accommodated by the practicum activities offered. One of them is in CLO3, which states that students can apply critical, logical and analytical thinking to master the skills of collecting, processing and analyzing scientific data or in CLO4, where students can analyze every problem in the field of science to master the skills to solve problems in the field of science and internalize them in grades, norms and ethics have not been fully reflected in the activities offered in the science practicum instructions. Based on the analysis, the practicum instructions provided have only been able to master the skills of collecting, processing, and analyzing ecological data but have not yet trained critical, logical, and analytical thinking skills in solving science problems as required in the SPLO.

There are several formal intellectual reasoning for students in thinking according to Tobin & Capie, (1978) namely the ability to think proportionally, control variables, probability, correlational, and combinatorial. The five formal intellectual reasoning are divided into three categories, namely concrete, transitional and formal reasoning abilities. Based on the results of measuring the ability to think logically, students in Figure 2 have different percentages at each level. Students achieved the highest level of logical thinking ability for the proportional reasoning level (26.32%), followed by correlational reasoning (24.56%) and combinatorial (21.05%), while probability reasoning got the lowest percentage (10.53%). Combinatorial ability is the third largest after proportional and correlational. This ability is the process of analyzing problems combinatorially using various facts from cause-effect relationships or using certain arrangements for objects to form units that meet certain criteria (Lawson, 1978). The combinatorial reasoning level is good for students to practice systems thinking skills.

The ability to think logically is a top priority to be developed in education. The ability to think logically has a fundamental role in student academic achievement and in constructing a concept. Students with a high level of logical thinking ability can change their alternative conceptions more easily (Oliva, 2003). Quantitative aspects of chemistry, especially understanding the derivation and use of many functional relationships in chemistry, such as the development and interpretation of data, tabulations, and graphs, require proportional reasoning. Correlational reasoning is important in formulating hypotheses and interpreting data, which requires considering the relationships between variables. The ability to control variables plays a role in planning, implementation and interpretation. Probability reasoning is required to interpret data from findings, observations, or experiments. Combinatorial reasoning occurs in formulating alternative hypotheses to test the effects of selected variables.

Based on the logical thinking test, it also categorizes students' scientific reasoning, which is grouped into concrete operational, transitional, and formal operational. The measurement results show that the majority of students are at the transitional (42.11%) and formal operational (26.32%) levels of reasoning. However, there are still quite a lot of students with concrete operational reasoning (31.58%). A person's cognitive development, when they reach the formal operational level, will make solving problems in the learning process easier. This is because with formal operational thinking you are able to use your mind to solve various concrete and abstract problems logically and systematically.

Several research results show that students' formal reasoning abilities are an indicator of success in the fields of mathematics and science (Cantu & Herron, 1978). Formal thinking skills are really needed by students in various learning processes with demands for student activity in thinking, especially problem solving. As an effort to see students' abilities in learning, knowledge about formal reasoning is very necessary (Rakhmawan & Vitasari, 2016). The systems thinking scale and systems thinking skills test given to science education students showed results as shown that students were included in the category of frequently (79.20%) carrying out systems thinking activities. The results of the systems thinking ability test show data that is the opposite of the results of the systems thinking activity scale, where the average results are still low (24.94).

Systems thinking skills are measured using a description test based on the systems thinking classification presented by Dorani et al. (2015). This classification consists of six complementary skills, namely dynamic thinking, systems thinking as a cause, cause-effect thinking , forest thinking/holistic thinking, closed-loop thinking, and stock and flow thinking. The test results showed the highest value for the stock and flow thinking indicator was 35.00, and the lowest for the forest thinking/holistic thinking indicator was 19.29. Forest thinking is seeing the big picture and how these components relate and interact. The ability to think in the forest will be produced by a system thinking training process, which requires quite a lot of time. Repeated experiences shape a person to have good forest thinking.

There has not been much research on systems thinking skills in Indonesia (Agustina et al., 2019). Systems thinking skills are developed in higher education by developing systems thinking skills instruments on climate change content, which results in students having a positive response and a better understanding of climate change (Agustina et al., 2019). Human physiology lectures show that systems thinking skills have the highest level in identifying reciprocal relationships in a system and recognizing interactions in Human Physiology learning (Nursani, 2014).

The field study carried out produced data that science education students achieved the highest level of logical thinking ability for proportional reasoning (26.32%), as well as combinatorial reasoning in the middle (21.05%) and the lowest for probability reasoning (10.53%). Combinatorial reasoning is the process of analyzing problems combinatorially using various facts from cause-effect relationships or using certain arrangements for objects to form units that meet certain criteria (Lawson, 1978). The level of combinatorial reasoning can be a good provision for students to practice systems thinking skills, which are still very lacking.

Considering the importance of systems thinking skills to understand science practicum topics comprehensively, it is necessary to design a science practicum program that can train the systems thinking skills of prospective science teacher students at the Sorong Muhammadiyah Education University.

CONCLUSION AND SUGGESTION

Based on the analysis of the results of the field study, it can be concluded that practicum activities only train skills in collecting, processing and analyzing science research data. The contents of the practical instructions do not yet train thinking skills such as critical thinking, systems thinking, or problem-solving. In contrast, the practical instructions used are still in the form of recipes and are verification in nature. Students' logical thinking abilities are relatively even at proportional, correlational and combinatorial reasoning levels. Apart from that, the student reasoning category is still dominated by the transitional category, and there is still quite a high level of concrete reasoning. Students' systems thinking skills are relatively low, especially forest thinking skills.

REFERENCES

Agustina, T. W., Rustaman, N., Riandi, R., & Purwianingsih, W. (2019). Traditional biotechnology content as a media in engaging students with system thinking skills. *Scientiae Educatia*, *7*(2), 197. https://doi.org/10.24235/sc.educatia.v7i2.3099

Boersma, K., Waarlo, A. J., & Klaassen, K. (2011). The feasibility of systems thinking in biology education. *Journal of Biological Education*, *45*(4), 190–197. https://doi.org/10.1080/00219266.2011.627139

Cantu, L. L., & Herron, J. D. (1978). Concrete and formal piagetian stages and science concept attainment. *Journal of Research in Science Teaching*, *15*(2), 135–143. https://doi.org/10.1002/tea.3660150208

Desi, M., Suhendar, S., & Herlina, H. (2023). Implementation of contextual teaching and learning (ctl) strategies and field visit techniques to improve student learning outcomes in biotechnology materials. *Equator Science Journal*, *1*(2), 39–49. https://doi.org/10.61142/esj.v1i2.9

Dolansky, M. A., Moore, S. M., Palmieri, P. A., & Singh, M. K. (2020). Development and validation of the systems thinking scale. *Journal of General Internal Medicine*, *35*(8), 2314–2320. https://doi.org/10.1007/s11606-020-05830-1

Dorani, K., Mortazavi, A., Dehdarian, M. A., Mahmoudi, H., Khandan, M., & Mashayekhi, A. (2015). Developing question sets to assess systems thinking skills. *Proceedings of the 33rd International Conference of the System Dynamics Society*, *Richmond 2000*.

Hester, P. T., & Adams, K. M. (2014). *Systemic Thinking: Fundamentals for Understanding Problems and Messes*. Springer US. http://systemicthinking.com/origins.html

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: foundations for the twenty-first century. *Science Education*, *88*(1), 28–54. https://doi.org/10.1002/sce.10106

Lawson, A. E. (1978). The development and validation of a classroom test of formal reasoning. *Journal of Research in Science Teaching*, *15*(1), 11–24. https://doi.org/10.1002/tea.3660150103

Millar, R., & Abrahams, I. (2009). Practical Work : Making it More Effective. *School Science Review*, *91*(334), vol 91, no. 334, pp. 59-64. http://www.gettingpractical.org.uk/documents/RobinSSR.pdf%0Ahttps://pure.york.ac.uk/portal/en/publications/practical-work(c03cbc1b-69e7-4d33-879b-05081247b0ee)/export.html

Muzdalifah, M., & Ismail, I. (2023). Implementation of the role playing method to improve student learning outcomes in the solar system subject science. *Equator Science Journal*, *1*(2), 50–56. https://doi.org/10.61142/esj.v1i2.6

Nursani, Z. (2014). Analisis argumentasi dan penguasaan konsep dalam menggambarkanketerampilan berpikir sistem pada pembelajaran fisiologi manusia. *Prosiding Mathematics and Sciences Forum*, 449–459.

Oliva, J. M. (2003). The structural coherence of students' conceptions in mechanics and conceptual change. *International Journal of Science Education*, *25*(5), 539–561. https://doi.org/10.1080/09500690210163242

Partnership for 21st Century Skills. (2015). *Partnership for 21st Century Skills-Core Content Integration*. 1–70. www.P21.org.

Rakhmawan, A., & Vitasari, M. (2016). Kemampuan berpikir logis sebagai prediktor keberhasilan mahasiswa dalam perkuliahan kimia dasar. *Jurnal Penelitian Dan Pembelajaran IPA*, *2*(1), 99. https://doi.org/10.30870/jppi.v2i1.652

Sutarno, S. (2018). Pengembangan model virtual higher order thinking skills laboratory untuk meningkatkan keterampilan berfikir kritis dan pemecahan masalah secara kreatif mahasiswa calon guru fisika. In *Angewandte Chemie International Edition, 6(11), 951–952.*

Tobin, K. G., & Capie, W. (1978). The development and validation of a group test of logical thinking. *Journal of Research in Science Teaching*, *15*(1), 11–24.

Yuniar, Y., Lovisia, E., & Yolanda, Y. (2024). Feasibility analysis of inquiry-based physics teaching modules to improve the collaboration skills of class xi man 2 lubuklinggau . *Equator Science Journal*, *2*(1), 7–13. https://doi.org/10.61142/esj.v2i1.111