Analysis of Students' Scientific Reasoning Profiles Using the Lawson's Classroom Test of Scientific Reasoning

Hebron Pardede*, Mariana Surbakti, Bajongga Silaban
Physics Education Study Program, Universitas HKBP Nommensen, Indonesia
*Corresponding Author: hebronpardede73@gmail.com

Received: 24th November 2025; **Accepted**: 23rd February 2026; **Published**: 23rd April 2026
DOI: https://dx.doi.org/10.29303/jpft.v12i1.10680

Abstract - *This study investigates the scientific reasoning profiles of physics education students using Lawson's Classroom Test of Scientific Reasoning (LCTSR). A descriptive quantitative design was employed with 50 undergraduate students from the Physics Education Study Program at Universitas HKBP Nommensen, Indonesia. The LCTSR instrument consists of 30 paired multiple-choice items assessing six dimensions of scientific reasoning: conservation reasoning, proportional reasoning, control of variables, probabilistic reasoning, correlational reasoning, and hypothetico-deductive reasoning. The results show that the mean LCTSR score was 12.4 out of 30, indicating that most students were at the transitional reasoning level. Specifically, 30% of students were classified as concrete reasoners, 56% as transitional reasoners, and only 14% as formal reasoners. Among the six reasoning aspects, conservation reasoning demonstrated the highest achievement (77.5%), whereas hypothetico-deductive reasoning was the weakest (16.7%). The findings indicate substantial difficulties in abstract reasoning processes. These results highlight the need for explicit instructional strategies to promote higher-order scientific reasoning in physics education programs.*

Keywords: *LCTSR, Physics Education, Scientific Reasoning*

INTRODUCTION

Scientific reasoning is the capacity to think systematically, critically, and rationally in connecting facts and evidence and considering alternatives before drawing conclusions. Lawson posits that scientific reasoning is a cognitive technic, framework, or priciple employed to analize information and formulate conclusions that extend beyond direct experience (Lawson, 2000). Furthermore, Lawson views science as a hypothetico-deductive enterprise involving the generation and testing of alternative explanations using scientific reasoning patterns (Lawson, 2004). This ability is essential for university students, particularly preserve teachers and science majors, as it supports their understanding of scientific concepts, conducting experiments, designing research, and solving scientific problems.

Numerous studies in Indonesia have indicated that university students exhibit low-to-moderate levels of scientific resoning ability, particularly in areas such as variable control, proportional reasoning, and hypothetico-deductive reasoning. In the context of proportional reasoning and variable control, studies indicate that most students struggle to understand and apply these aspects. Proportional reasoning, the ability to draw conclusions based on comparative and proportional relationships, is often associated with complex problem-solving strategies. A study examining students' proportional reasoning indicated that most participants exhibited low proficiency in applying this concept within mathematical contexts; numerous students were unable to resolve problems necessitating precise additive and multiplicative comprehension (Prayitno et al., 2019). Learning conditions may affect the ability to reason scientifically. A study in general physics instruction employing HOT-LAB modules at UIN Syarif Hidayatullah

Jakarta showed that preservice physics teachers' reasoning patterns on topics of heat and temperature were predominantly probabilistic reasoning (Saputra et al., 2023).

Ideally, university students' scientific reasoning ability should reach the formal-operational level, enabling them to think abstractly, formulate hypotheses, control variables, and apply probabilistic, correlational, and deductive reasoning effectively (Bao et al., 2018; Hrouzková & Richterek, 2021). Cognitive development advances through four stages: sensorimotor, preoperational, concrete operational, and formal operational. During the operational stage, individuals ought to posses to think abstractly, hypothetically, and deductively when solving problems. In line with this view, Lawson, in The Nature and Development of Scientific Reasoning: A Synthetic View, adapted Piaget's developmental framework to describe stages of scientific reasoning among university students, including concrete reasoning, transitional reasoning, and formal reasoning (Lawson, 2004). Students who reach the formal reasoning level demonstrate the ability to control variables, test hypotheses, and draw logical conclusions. However, Moore and Rubbo (2012) reported that many university students, particularly non-STEM majors, remain at concrete or transitional levels, emphasizing the need for targeted efforts to develop formal scientific reasoning in higher education.

Therefore, this study aims to analyze the scientific reasoning profiles of physics education students using the Lawson's Classroom Test of Scientific Reasoning (LCTSR).

RESEARCH METHODS

This study employed a descriptive quantitative design to analyze the scientific reasoning profiles of undergraduate students using the Lawson's Classroom Test of Scientific Reasoning (LCTSR). The participants consisted of 50 students enrolled in the Physics Education Study Program at Universitas HKBP Nommensen, drawn from two consecutive academic cohorts to minimize large differences in academic ability among participants. All participants had successfully completed prerequisite courses, namely Basic Physics, Calculus, and Physics Experiment (laboratory practicum). These courses provide essential foundations in conceptual physics understanding, mathematical reasoning, and experimental skills. The selection of students who had passed these prerequisite courses ensured that the participants possessed sufficient academic preparation to meaningfully respond to the LCTSR. Therefore, the instrument was considered appropriate and valid for use with this group.

The main research instrument was the LCTSR, comprising 30 paired multiple-choice items that evaluate six dimentions of scientific reasoning: (1) Conservation reasoning; (2) Proportional reasoning; (3) Control of variables; (4) Probabilistic reasoning; (5) Correlational reasoning; (6) Hypothetico-deductive reasoning.

Instrument reliability was examined using internal consistency analysis with Cronbach's alpha. The results yielded a coefficient of $\alpha = 0.81$, indicating good reliability and acceptable internal consistency of the LCTSR for this sample. This finding is consistent with prior validation studies reporting that the LCTSR demonstrates satisfactory reliability in measuring scientific reasoning abilities among secondary and university students (Lawson, 2000; Bao et al., 2018).

Data were collected during regular class sessions under standardized testing conditions. Participants were given 60 minutes to complete the LCTSR. All responses were collected anonymously and coded for analysis.

This study was conducted in accordance with ethical research standards. Participation was voluntary, and all participants provided informed consent prior to data collection. The research protocol was approved by the Faculty of Teacher Training and Education, Universitas HKBP Nommensen. Participants' identities were kept confidential, and the data were used solely for research purposes.

Data Analysis Techniques

Data were analyzed using descriptive statistics consisting of mean scores, percentages, and presentation in tables and graphs to illustrate the distribution of students' scientific reasoning in each aspect.

The reasoning levels derived from total LCTSR scores (maximum = 30) adhere to estalbised categorization (Lawson, 2000; Bao et al., 2009).

Table 1. LCTSR Score Categories

Score Range	Reasoning Category	Characteristics
0- 8	Concrete Reasoning	Difficulty in abstract reasoning; reliance on direct experience
9-16	Transitional Reasoning	Emerging abstraction; inconsistent performance across contexts
17-30	Formal Reasoning	Ability to hypothesize, control variables, and reason deductively and probabilistically

RESULTS AND DISCUSSION

Results

1. Total Scientific Reasoning Scores

The average LCTSR score of the 50 participants was 12.4 out of 30, positioning most students within the transitional reasoning category.

Table 2. Student Distribution by Reasoning Category

Reasoning Category	Score Range	Number of Students	Percentage
Concrete Reasoning	0- 8	15	30 %
Transitional Reasoning	9-16	28	56 %
Formal Reasoning	17-30	7	14 %

These results demonstrate that only a small proportion of students had reached the formal reasoning stage, while the majority remained at transitional or concrete levels.

2. Scientific Reasoning Profiles by Aspect

Table 2. Average Scores by LCTSR Component

Reasoning Aspect	Max Score	Mean Score	Percentage (%)
Conservation Reasoning	4	3.1	77.5 %
Proportional reasoning	6	2.4	40.0 %
Control of variables	6	2.0	33.3 %
Probabilistic reasoning	4	1.6	40.0 %
Correlational reasoning	4	2.3	57.6 %
Hypothetico-deductive	6	1.0	16.7 %

Students showed the highest achievement in conservation reasoning and the lowest performance in hypothetico-deductive reasoning. Low scores were also observed in control of variables and probabilistic reasoning, indicating difficulties in abstract reasoning and experimental logic.

Discussion

1. Distribution of Reasoning Categories

The predominance of transitional reasoning indicates that students had begun developing abstract thinking but lacked consistency across contexts. This finding aligns with Lawson (2000) and Coletta & Phillips (2005), who reported that many university students do not automatically attain formal reasoning without explicit cognitive training. Likewise, it was observed that the majority of preservice teachers exhibit transitional reasoning (Hidayah & Arafah, 2025).

However, the persistence of transitional reasoning among preservice physics teachers is concerning. As future educators, they are expected to model and facilitate scientific thinking. The results suggest that cognitive development does not progress automatically through disciplinary exposure alone.

2. Reasoning Profiles by Aspect

The high score in conservation reasoning likely reflects students' familiarity with concrete and observable phenomena. In contrast, hypothetico-deductive reasoning requires abstract model construction and systematic hypothesis testing-skills that demand structured practice.

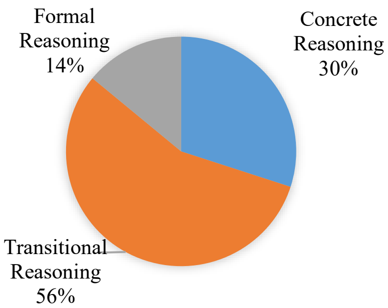

Figure 1. Distribution of Students by Scientific Reasoning Profiles (LCTSR)

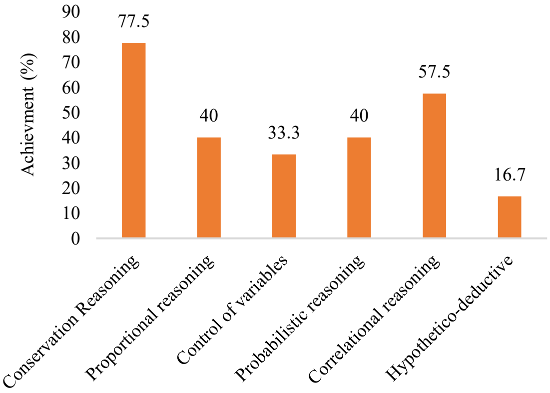

Figure 2. Students' Achievement by Scientific Reasoning Aspect

Figure 1 illustrates the distribution of students among various types of scientific reasoning categories. The majority of students fall within the transitional reasoning category. This indicates that most students remain in a developmental phase in which scientific reasoning skills are not yet fully consolidated, and the consistent use of abstract thinking is still limited. Figure 2 shows how well students did in six different areas of scientific reasoning. The highest proficiency is observed in conservation reasoning, suggesting that students find it relatively easier to understand concepts that are concrete and closely related to everyday experiences. Conversely, the hypothetical-deductive reasoning aspect displays the lowest performance, highlighting students' challenges in formulating and systematically testing hypotheses. This is consistent with Bao, who argue that hypothetico-deductive thinking requires explicit training (Bao et al., 2009) and Hrouzková (Hrouzková, T. & Richterek, L., 2021) who highlighted students' difficulties in formulating and systematically testing hypotheses. Weak performance was also observed in control of variables and probabilistic reasoning, consistent with findings by Zulkipli (Zulkipli et al., 2020). Two other aspects with relatively low performance are control of variables and probabilistic reasoning, reflecting students' limited ability to engage in abstract scientific thinking and data-based analysis. Meanwhile, proportional reasoning and correlational reasoning demonstrate moderate performance, showing that students have begun to understand relationships among variables, albeit not consistently. This result is consistent with Bhaw (Bhaw at al., 2023), who reported that students often exhibit partial coherence in their scientific reasoning, particularly in tasks involving relationships among variables, indicating emerging but still inconsistent proportional and correlational reasoning skills.

3. Pedagogical Implications

These findings imply that physics instruction should move beyond content transmission. Concrete strategies include:

1) Structured inquiry cycles requiring students to explicitly state and test hypotheses, (Strat, T,T.S., et al., 2024). 2) Laboratory redesign emphasizing variable manipulation and prediction justification, Pols, C.F.J. & Dekkers, P. 2024). 3) Problem-Based Learning (PBL) scenarios requiring evidence-based reasoning (Wheeler, L. B., & Gonczi, A. L., 2023)

Curriculum design in physics education programs should intentionally embed reasoning skill development across courses rather than assuming it emerges naturally.

4. Study Limitations

This study involved a relatively small sample (n = 50) from a single institution, limiting generalizability. Additionally, gender differences were not examined. Future research should involve multi-institutional samples and explore instructional interventions longitudinally.

CONCLUSION

Most physics education students in this study were classified at the transitional reasoning level. Although students demonstrated strong conservation reasoning, they experienced substantial difficulties in hypothetico-deductive reasoning, control of variables, and probabilistic reasoning.

These findings emphasize the need for instructional approaches that explicitly cultivate formal scientific reasoning. Physics education curricula should incorporate inquiry-based laboratories, structured hypothesis testing, and problem-based learning to promote higher-order cognitive development.

ACKNOWLEDGMENT

The researcher expresses gratitude to the Institute for Research and Community Service (LPPM) of Universitas HKBP Nommensen Medan for facilitating this study, and extends thanks to the authors whose works served as valuable references cited in this research.

REFERENCES

Lawson, Anton E. (2000). *Basic Inferences of Scientific Reasoning, Argumentation, and Discovery*. Science Education, 94(2), 336–364. https://doi.org/10.1002/sce.20357

Lawson, Anton E. (2004). *The Nature and Development of Scientific Reasoning: A Synthetic View*. International Journal of Science and Mathematics Education, 2(3), 307–338. https://doi.org/10.1007/s10763-004-3224-2

Prayitno, A., Rossa, A., & Widayanti, F. D. (2019). *Level Penalaran Proporsional Siswa Dalam Memecahkan Missing Value Problem*. Jurnal Riset Pendidikan Matematika, 6(2), 177–187. https://doi.org/10.21831/jrpm.v6i2.19728

Saputra, F. H., Alatas, F., & Suryadi, A. (2023). *Jenis Penalaran Ilmiah Apa yang Digunakan Mahasiswa Dalam Menyelesaikan Permasalahan Suhu Dan Kalor?: Studi Pada Praktikum Fisika Umum: Indonesia*. Jurnal Kumparan Fisika, 6(1), 27-36. https://doi.org/10.33369/jkf.6.1.27-36

Bao, L., Xiao, Y., Koenig, K., & Han, J. (2018). *Validity evaluation of the Lawson classroom test of scientific reasoning*. Physical Review Physics Education Research, 14(2), 20106. https://doi.org/10.1103/PhysRevPhysEducRes.14.020106

Hrouzková, T., & Richterek, L. (2021). *Lawson classroom test of scientific* *reasoning at entrance university level*. In Proceedings of the 4th International Baltic Symposium on Science and Technology Education (pp. 74-85). Šiauliai: Scientia Socialis, Republic of Lithuania. https://doi.org/10.33225/BalticSTE/2021.74

Moore, J. C., & Rubbo, L. J. (2012). *Scientific reasoning abilities of nonscience majors in physics-based courses*. Physical Review Special Topics - Physics Education Research, 8(1), 10106. https://doi.org/10.1103/PhysRevSTPER.8.010106

Coletta, V. P., & Phillips, J. A. (2005). *Interpreting FCI Scores: Normalized Gain, Preinstruction Scores, and Scientific Reasoning Ability*. American Journal of Physics, 73(12), 1172–1182. https://doi.org/10.1119/1.21171092.16470.f3

Hidayah, N., & Arafah, R. A. D. (2025). *Identification of Prospective Teacher's Scientific Reasoning Ability Using the Lawson Classroom Test of Scientific Reasoning (Ctsr)*. Teaching Jurnal Inovasi Keguruan Dan Ilmu Pendidikan, 5(3), 577-586. https://doi.org/10.51878/teaching.v5i3.6985

Zulkipli, Z. A. (2020). *Identifying Scientific Reasoning Skills of Science Education Students*. Asian Journal of University Education, *16*(3), 275. https://doi.org/10.24191/ajue.v16i3.10311

Bhaw, N., Kriek, J., & Lemmer, M. (2023). *Insights from coherence in students' scientific reasoning skills*. Heliyon, *9*(7). https://doi.org/10.1016/j.heliyon.2023.e17349

Strat, T. T. S., Henriksen, E. K., & Jegstad, K. M. (2024). *Inquiry-based science education in science teacher education: a systematic review*. Studies in Science Education, 60(2), 191-249. https://doi.org/10.1080/03057267.2023.2207148

Pols, C. F. J., & Dekkers, P. J. J. M. (2024). *Redesigning a first year physics lab course on the basis of the procedural and conceptual knowledge in science model*. Physical Review Physics Education Research, 20(1), 010117. https://doi.org/10.1103/PhysRevPhysEducRes.20.010117

Wheeler, L. B., & Gonczi, A. L. (2023). *Finding the variables that react: Relationships between ability beliefs and student achievement in an inquiry-based introductory chemistry laboratory course*. Journal of Research in Science Teaching, 60(7), 1488-1519. https://doi.org/10.1002/tea.21840