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Analysis of Students Scientific Reasoning Ability and the Correlation to Students Cognitive Ability in Physics Learning

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Abstract: This study aims to identify students scientific reasoning ability in Palu city and the correlation between students' scientific reasoning abilities and their cognitive aptitude within the context of physics education. In this study, we adopted a descriptive quantitative research method where the respondents consist of four high schools in Palu city, namely SMAN 1, SMAN 7, SMAN 6, and SMAN 4 Palu. An instrument by Lawson (LCSTR) was adapted for this study and it consist of 12 items two tier multiple-choice that contains conservation of mass and volume, proportional thinking, control of variables, probabilistic thinking, correlational thinking, and hypothetical deductive reasoning. Meanwhile, for the cognitive understanding test, we utilized a static fluid concept comprehension test. The findings of this research using SPSS to analyzed find that Pearson correlation coefficient is 0,54 that revealed significant correlations between students' scientific reasoning abilities and their cognitive aptitude in the context of physics learning. These correlations provided valuable insights into how these components influence each other and impact students' performance and achievement in physics. The study's result has implications for educators as a reference in the selection of models and methods of physics learning appropriate to train and develop students scientific reasoning skills.

Keywords: Cognitive Ability; LCSTR; Scientific Reasoning Ability

Introduction

In the realm of education, the pursuit of effective teaching and learning strategies remains an ongoing quest. One of fundamental objectives of educators is to equip students with not only subject specific knowledge but also the essential skills required to analyze, solve problems, and think critically. Learning of Science requires logical skills and high levels of reasoning ability of students (Kiswantoa, 2017; Riyanti, 2018). In the field of physics education, this entails nurturing students' scientific reasoning abilities and understanding the intricate relationships between these cognitive processes and their breaded cognitive abilities (Anwar, 2015).

Scientific reasoning, characterized by the capacity to question, hypothesize, experiment, and draw evidence-based conclusions, plays a pivotal role in fostering a deeper comprehension of scientific concepts. In parallel students' cognitive abilities, encompassing memory, attention, and problem-solving skills, form the foundation upon which their academic success hinges (Bao, 2018).

Scientific reasoning is an indispensable ability in 21st century education and plays a significant role in student's academic performance (Göhner, 2022). Scientific reasoning ability in students refers to their capacity to apply logical and critical thinking skills to understand and analyze scientific concepts and phenomena. It involves the ability to form hypotheses, design experiments, collect and interpret data, and draw valid conclusions based on evidence (Lawson, 2009; Fatima, 2008). Developing scientific reasoning ability in students is crucial for fostering their understanding of science and preparing them for future scientific endeavors (Lawson, 2005). Scientific reasoning is crucial for critical thinking and is a key part of science, but the challenge is that student's wo can reason well may not

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always use a scientific approach in their thinking (Bao, 2022; Wei, 2022; Lemmer, 2020).

Teachers can facilitate this development by providing opportunities for hands-on experiments, encouraging critical thinking discussions, and guiding students through the scientific inquiry process (Steinberg, 2013). Scientific reasoning is closely linked to cognitive development, particularly in the realm of formal operational thinking and contributes to academic achievement, cognitive ability and problem-solving (Nyberg, 2020). From the perspective of science literacy, scientific reasoning is indeed a cognitive ability that is essential for understanding and evaluating scientific information. It involves the application of logical and critical thinking skills to assess and interpret various aspects of scientific (Koerber, 2019).

Scientific reasoning, a crucial skill in the realm of education and scientific inquiry, is not only nurtured by students' innate abilities but also profoundly influenced by the methodologies employed by their educators (Putri, 2020). One of the pivotal factors that can significantly impact the development of scientific reasoning is the approach, models, and teaching methods employed by teachers in the classroom (Novia, 2017). In the context of physics education, where complex concepts often demand innovative pedagogical strategies, it becomes imperative to explore how these instructional approaches can shape and enhance students' scientific reasoning abilities (Luo, 2021).

An understanding of the 21st century learning paradigm is essential for schools to implement a pedagogical framework that goes beyond subject-specific knowledge and promotes competencies such as scientific reasoning ability. While extensive research has been conducted on scientific reasoning, it is evident that its prevalence varies among different nations. Studies on scientific reasoning are a rare occurrence in Indonesia (Pelamonia, 2017). In 2009, a study revealed that Indonesia ranked 60th out of 65 countries in terms of students scientific reasoning ability, with a score 385. This score is notably below the OECD's average of 501, particularly in the field of science (Purwana, 2016). This proves that the educational system has yet to foster the capacity for logical thinking that include scientific reasoning abilities. Based on the above description, knowing the scientific reasoning ability of each student is important to do. Therefore, what do we know about students' scientific reasoning ability in Palu? Is the physics learning that has been implemented in school able to encourage students' scientific reasoning ability? The information can be used as a consideration in the selection of appropriate models, methods, and physics learning media that can improve students' scientific reasoning abilities and cognitive ability.

This study aims to identify students' scientific reasoning ability 11th grade students in Palu. The data collection was carried out at 4 high schools in the Palu city, namely SMAN 1 Palu, SMAN 4 Palu, SMAN 7 Palu and SMAN 6 Palu. This research delves into the nexus between students' scientific reasoning abilitiy and their cognitive aptitude within the context of physics education. By scrutinizing this interplay, we aim to shed light on how these components influence each other and, more importantly, how they collectively impact students' performance and achievement in the realm of physics. Understanding the dynamics of scientific reasoning and cognitive abilities in physics learning can have profonde implications for educators, curriculum developers, and policymakers. Insight gained from this study may guide the development of more effective teaching strategies, tailored interventions, and educational policies that better address the unique challenges faced by students in mastering the intricacies of physics. The results obtained are expected to be used as a reference in the selection of models and methods of physics learning appropriate, to train and develop students' scientific reasoning skills. In this study students' scientific reasoning skills was identified using scientific reasoning test from Lawson Classroom Test of Scientific Reasoning Instrument.

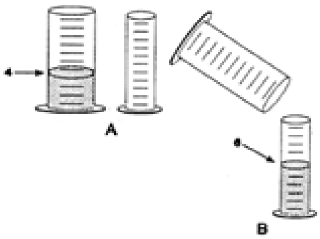
Method

In this study, we adopted a descriptive quantitative research method to identify students scientific reasoning abilities and their correlation with the cognitive abilities in physics learning. Research respondents were 11th grade students in Palu, namely SMAN 1 Palu, SMAN 4 Palu, SMAN 6 Palu, SMAN 7 Palu. The research instrument consisted of a multiple-choice scientific reasoning test which adopted from Lawson (2009) and Hrouzková & Richterek (2021). Classroom Test of Scientific Reasoning (LCTSR) with 24 questions and physics concept comprehension test 18 questions. In LCTSR each question has a choice of answer and a choice of reason underlying the answer. Score 1 if the answer and reason are correct and score 0 if the answer or reason is wrong, or both are wrong. As for the category of scientific reasoning patterns:

Table 1. Categories of scientific reasoning Levels

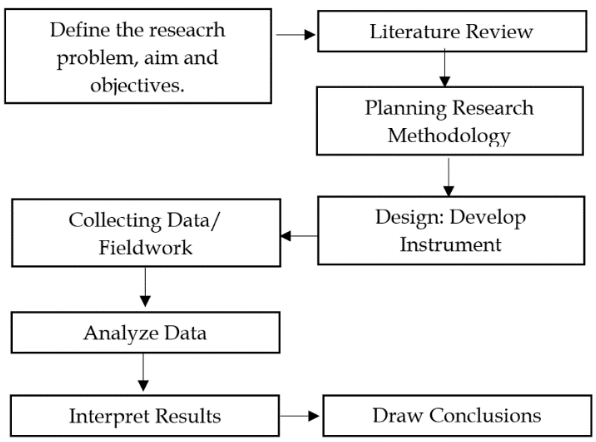
Score (%)	Category
81-100	Verry Good
61-80	Good
41-60	Satisfactory
21-40	Less
0-20	Verry Less

Table 2. Example of question in instrument LCTR

Question in instrument LCTR
5. To the right are drawings of a wide and a narrow cylinder. The cylinders have equally spaced marks on them. Water is poured into the wide cylinder up to the 4th mark (see A). This water rises to the 6th mark when poured into the narrow cylinder (see B). Both cylinders are emptied (not shown) and water is poured into the wide cylinder up to the 6th mark. How high would this water rise if it were poured into the empty narrow cylinder?  to 8 to 9 to 10 to 12 none of these answers is correct. aused the answer cannot be determined with the information given. it went up 2 more before, so it will go up 2 more again. it goes up 3 in the narrow for every 2 in the wide. the second cylinder is narrower. for every 2 in the wide it goes up 1 more in the narrow.

$$P = \frac{f}{n} x100\% \quad (1)$$

Description:
P : Percentage of answer
f : Frequency of student answers
n : Total number of students



Figures 1. Research Flow

Furthermore, to assess students' level of scientific reasoning, an analysis of the achievement of each scientific reasoning indicator is conducted by calculating the overall percentage of scientific reasoning abilities using equation 1. Before conducting the correlation analysis, a preliminary test was conducted, namely normality and linearity test. The normality test aimed to determine whether the data followed a normal distribution or not. Meanwhile, the linearity test was performed to assess whether the data exhibited a linear relationship between students' scientific reasoning ability and their understanding of physics concepts. These tests were essential to ensure the validity of the subsequent correlation analysis. Data analysis was conducted using SPSS for windows to perform bivariate correlation analysis, specifically examining the correlation between two variables: students' scientific reasoning abilities and cognitive abilities in physics learning. This analytical approach allowed us to explore the extent and nature of the relationship between these two critical aspects of student performance in the context of physics education.

Result and Discussion

This research utilizes instruments for conceptual understanding and scientific reasoning that have been tested for their validity and reability. Based on the data analysis results, it is evident that the instruments of conceptual understanding and scientific reasoning employed possess good reability and validity values, which are, in sequence 0.702 and 0.745. Therefore, it meets the criteria for these instruments to be used as research tools.

Based on the research that has been done by using Lawson classroom test of scientific reasoning and cognitive test, the respective average scores for scientific reasoning and cognitive test were 58,9 and 60,9 and its falls into the satisfactory category with score 60%. The assessment of six scientific reasoning indicators reveals that most students are lacking in mass conservation reasoning dimension and the hypothetical deductive reasoning dimension. This means that students, in turn, exhibit low reasoning patterns when it comes to converting mass and providing reasons or hypotheses for a given problem. Students rely on their prior knowledge to answer questions rather than relying solely on the information provided in the question or problem (Woolley, 2018). The students' low scientific reasoning abilities indicate that they have not received relevant instruction that caters to the necessary factors for their development. The teacher has not given physics questions that require high reasoning skills during the learning process. As a result, when given scientific reasoning test (LCSTR), students find it difficult in handling the questions (Krell, 2020). The learning approach impact the development of students reasoning abilities (Bao, 2018).

Table 3. Scientific reasoning dimension, item numbers and topic areas of the LCTSR.

Dimension	Item Number	Topic Area
Conservation of weight	1.2	The effect on mass by of changing the shape of two identical clay balls
Conservation of volume	3. 4	The effect on displaced volume by a glass marble of equal size and a heavier steel marble
Proportional reasoning	5. 6. 7. 8	The effect on height by changing the width of measuring cylinders while keeping the volume constant
Control of variables	9. 10	The effect of string length on the period of a pendulum by varying the mass of the pendulum
	11. 12.	The effect of red light and gravity on fruit flies
	13. 14	The effect of blue light and gravity on fruit flies
Probability	15. 16	The chance of picking red blocks from a bag of red and yellow identical blocks
	17. 18	The chance of picking red round or blue round pieces of wood from a bag of red, blue and yellow round and square pieces of wood.
Correlational reasoning	19. 20	Predicting if there is a correlation between the mice size and tail color from given pictorial data
Hypothetical-deductive reasoning	21. 22	Design an experiment to investigate why waters rises in an inverted glass that covers a lit candle in a water bath.
	23. 24	Design an experiment to investigate why red blood cells shrink after adding salt water to the sample

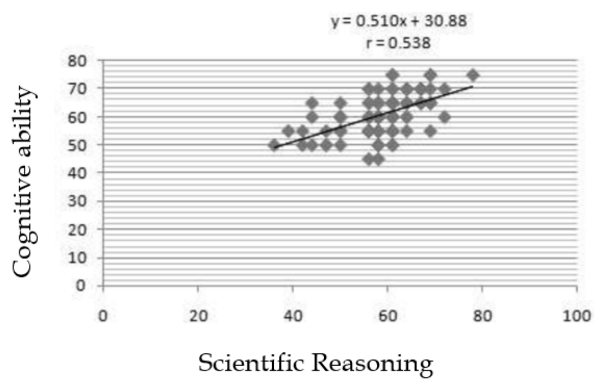
When talking about the results of cognitive abilities that 61% and falls into satisfactory category, students may not understand concept well because they might not be very interested in the learning process. In many schools, the teaching is primarily teacher-centered, which means students have less involvement in gaining knowledge and motivation at the beginning of the lesson (Burais, 2020). Some teaching methods can make students passive, where they mainly receive information from the teacher, and teachers are more active in the learning process. This approach is often referred to as a teacher-centered approach, where students have limited opportunities to express their ideas or thoughts in class (Konita, 2019). The learning model used by the teacher when teaching does not facilitate scientific skills, such as planning investigations, collecting data, and communicating experimental results (Kambeyo, 2017). From a constructive perspective, teachers should serve as facilitators, not just sources of knowledge. Learning should be structured to actively involve students in scientific research activities (Bao, 2019).

In the preliminary analysis, specifically the Kolmogorov-Smirnov normality test conducted using SPSS for windows, a significance value pf 0,51 was obtained, which is greater than 0.05. Therefore, it can be concluded that the data for scientific reasoning and cognitive skills of the students follow a normal distribution. Subsequently, for the linearity test, a significant value of 0.66 was obtained, indicating that there is a linear relationship between the variables of scientific reasoning ability and cognitive skills of students in the physics concept.

The results of data analysis using the SPSS program for windows show a correlation between scientific reasoning and cognitive ability, with a pearson correlation coefficient of 0,54 as indicated in Table 4.

Table 4. The pearson correlation coefficient between students cognitive and scientific reasoning ability

		Scientific Reasoning ability	Cognitive Ability
Scientific Reasoning ability	Pearson correlation Sig.(2-tailed) N	1 112	.538 .000 112
Cognitive Ability	Pearson correlation Sig.(2-tailed) N	.538 .000 112	1 112



Figures 2. Scatter plot between students cognitive and scientific reasoning ability

Then, based on the significance value which is 0,000< 0,005 it can be concluded that there is a significant correlation between the two. The relationship between scientific reasoning ability and cognitive ability is moderate and positive in direction, as seen in the scatter plot Figures 2. This figures also shows that the relationship between them forms a straight-line pattern called a linear correlation.

From the obtained data, it can be concluded that the greater the students' scientific reasoning ability, the greater their cognitive ability in the subject of physics. This result will demonstrate that scientific reasoning ability supports good academic performance in physics for students. Improving how students learn can enhance their reasoning abilities, which, in turn, can impact their academic achievements and performance on concept tests. The Positive impact of scientific reasoning on conceptual understanding aligns with previous research, which showed that reasoning skills are a significant predictor of academic achievement and success in studies (Johnson, 1998). In the field of physics, conceptual understanding and problem-solving skills are often considered essential components of achievement (Ates, 2007). This study's findings further support the notion that there is a strong correlation between reasoning and understanding (Rubbo, 2012). Therefore, a more comprehensive and proactive approach is necessary for enhancing learning activities and fostering students reasoning skills (Bao, 2018).

Conclusion

Based on the result of the study it can be concluded that the scientific reasoning ability of student in Palu has falls into the satisfactory category with score 60% and there is positive correlation between scientific reasoning ability and cognitive ability with a pearson correlation coefficient of 0,54. This suggests that as students' scientific reasoning ability improves, their grasp of cognitive ability in the subject also tends to increase. In other words, these two aspects of learning are intertwined, with one reinforcing the other. This correlation underscores the importance of fostering strong scientific reasoning abilities in students, as it appears to directly contribute to their enhanced cognitive ability. Hence, the results from this study can serve as evaluation tools for teachers as educators. They can use these findings to implement teaching methods or approaches in the future that encourage the development of students scientific reasoning abilities.

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Author Contributions

In this study, the author provides different contribution to this work. conceptualized the research idea, designed of methodology, management, and coordination responsivity, K, NK; Validation, Analyzed data, conducted a research and investigation process, I, N; Writing-review and editing, NK.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Anwar, E. (2015). A Study of Reasoning Ability of Secondary School Students In Relation to Their Intelligence. *Journal of Humanities and Social Science,* 20 (5), 29-31. http://dx.doi.org/10.31703/grr.2020(V-I).39

Ates, S. &. (2007). The effects of students' cognitive styles on conceptual understandings and problem-solving skills in introductory mechanics. *Research in Science & Technological Education,* 167–178. https://doi.org/10.1080/02635140701250618

Bao, K. K. L (2022). Theoretical model and quantitative assessment of scientific thinking and reasoning. *Physical Review Physics Educcation Research*. 18 (1). https://doi.org/10.1103/PhysRevPhysEducRes.18.010115

Bao, L. (2019). Physics education research for 21st century learning. *Disciplinary and Interdisciplinary Science Education Research.* 1(1). https://doi.org/10.1186/s43031-019-0007-8

Bao, Y. X. L (2018). Validity Evaluation of the Lawson Classroom test Of Scientific Reasoning. *Physical Review Physics Education Research*. 14 (2). https://doi.org/10.1103/PhysRevPhysEducRes.14.020106

Burais, M. I.L. (2020). Peningkatan Kemampuan Penalaran Matematis Siswa Melalui Model Discovery Learning. *Jurnal Didaktik Matematika*, 6(1), 77-86. https://doi.org/10.46244/numeracy.v6i1.434

Fatima, S. K. (2008). *Reasoning Ability of School Students*. New Delhi: Discovery Publishing House.

Göhner, M. a. (2022). Preservice Science Teachers' Strategiesin Scientific Reasoning: The Case of Modeling. Research in Science Education, 52(2), 395-414. https://doi.org/10.1007/s11165-020-09945-7

Hrouzková, T., & Richterek, L. (2021). *Lawson Classroom Testof Scientific Reasoningat Entrance University Level. International Baltic Symposium on Science and Technology Education.* Šiauliai, Lithuania: Vilnius University.

Johnson, A. L. M. A. (1998). What Are The Relative Effects Of Reasoning Ability And Prior Knowledge On Biology Achievement In Expository And

Inquiry Classes. *Journal of Research in Science Teaching*, 315 (1) 89-103. https://doi.org/10.1002/(SICI)1098-2736(199801)35:1%3C89::AID-TEA6%3E3.0.CO;2-J

Kambeyo, L. (2017). Scientific Reasoning Skills: A Theoretical Background on Science Education. *NERA Journal*, 40-64. Retrieved from https://core.ac.uk/download/pdf/326019028.pdf

Kiswantoa, A. (2017). The Effect Of Learning Methods And The Ability Of Students Think Logically To The Learning Outcomes On Natural Sciences Of Grade Iv`S Student. *Advances in Social Science, Education and Humanities Research.* https://doi.org/10.2991/icset-17.2017.168

Koerber, S. &. (2019). Individual differences in early scientific thinking: Assessment, cognitive influences, and their relevance for science learning. *Journal of Cognition and Development*, 20(4), 510-533. https://doi.org/10.1080/15248372.2019.1620232

Konita, M. A.M. (2019). Kemampuan Penalaran Matematis dalam Model Pembelajaran Connecting, Organizing, Reflecting, Extending (CORE). *PRISMA, Prosiding Seminar Nasional Matematika*, 611-615. Retrieved from https://journal.unnes.ac.id/sju/index.php/prisma/article/view/29072

Krell, C. R. (2020). Assessing Pre-Service Science Teachers' Scientific Reasoning Competencies. *Research in Science Education,* 50, 2305–2329. https://doi.org/10.1007/s11165-018-9780-1

Lawson, A. E. (2005). What is the role of induction and deduction in reasoning and scientific inquiry? *Journal of Research in Science Teaching*, 42(6), 716-740. https://doi.org/10.1002/tea.20067

Lawson, A.E.; Clark, B.; Cramer-Meldrum, E.; Falconer, K.A.; Sequist, J.M.; Kwon, Y.-J. (2000). Development of Scientific Reasoning in College Biology: Do Two Levels of General Hypothesis-Testing Skills Exist? *J. Res. Sci. Teach*, 37, 81–101. http://dx.doi.org/10.1002/(SICI)1098-2736(200001)37:1%3C81::AID-TEA6%3E3.0.CO;2-I

Lawson. A. E, B. (2009). The Nature And Development Of Development Of Scientific Reasoning: a synthetic view. *International Journal of Science Education*, 307-338. https://doi.org/10.1007/s10763-004-3224-2

Lemmer, J. K. (2020). Analysis of students' conceptions of basic magnetism from a complex systems perspective. *Research in Science Education,* 375-392. https://doi.org/10.1007/s11165-018-9693-z

Luo, D. S. M. (2021). Evaluating Scientific Reasoning Ability: Student Performance And The Interaction Effects Between Grade Level, Gender, And Academic Achievement Level. *Thinking Skills and Creativity.* https://doi.org/10.1016/j.tsc.2021.100899

Novia, R. (2017). The Analysis of Students Scientific Reasoning Ability In Solving The Modified Lawson Classroom Test of Scientific Reasoning (MLCTSR) Problems by Applying The Levels Of Inquiry. *Jurnal Pendidikan IPA Indonesia*, 116-122. https://doi.org/10.15294/jpii.v6i1.9600

Nyberg, K. K. (2020). How to Measure Scientific Reasoningin Primary School: A Comparison of Different Test Modalities. *European Journal of Science and Mathematics Education*, 8(3), 136-144. https://doi.org/10.30935/scimath/9552

Pelamonia, E. M. J. (2017). Empowerment Scientific Reasoning in Science Learning for Junior High School Students in Ambon City. *Proceeding International Seminar on Education Universitas Patimura,* 104-113 Retrieved from https://ojs.unpatti.ac.id/index.php/ises/article/view/385

Purwana, L. D. (2016). Profil Kompetensi Awal Penalaran Ilmiah (Scientific Reasoning) Mahasiswa pada Perkuliahan Fisika Sekolah. *Prosiding Simposium Nasional Inovasi Dan Pembelajaran Sains,* 753-756. Retrieved from https://ifory.id/proceedings/2016/4chQ7E9Cp/snips_2016_unang_purwana_3e6beb7ae0769e91a997aefaa2887217.pdf

Putri, N. -H. (2020). Students' scientific reasoning skills in a fluid and its correlation with project activity. *Journal of Physics: Conference Series*. 1567 032083. https://doi.org/10.1088/1742-6596/1567/3/032083

Riyanti, H. S. (2018). Enhancing Students' Logical-Think-ing Ability in Natural Science Learning with Generative Learning Model. *Biosainti-fika: Journal of Biology & Biology Educatio,* 10 (3), 648-654. https://doi.org/10.15294/biosaintifika.v10i3.16612

Rubbo, J. C. (2012). Scientific Reasoning Abilities Of Nonscience Majors In Physics-Based Courses. *Physics education research*, 8, 1-8. https://doi.org/10.1103/PhysRevSTPER.8.010106

Steinberg, R. a. (2013). Understanding And Affecting Science Teacher Candidates' Scientific Reasoning In Introductory Astrophysics. *American Physical Society,* 9 020111, 1-10. https://link.aps.org/doi/10.1103/PhysRevSTPER.9.020111

Wei, Z. J. (2022). Examining The Nature Of Practical Work In School Science Textbooks: Coverage Of The Diversity Of Scientific Methods. *Science & Education,* 943-960. https://doi.org/10.1007/s11191-021-00294-z

Woolley, A. M. J. S. (2018). Undergraduate students demonstrate common false scientific reasoning strategies. *Thinking Skills and Creativity*, 01-113. https://doi.org/10.1016/j.tsc.2017.12.004