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Analysis of Students' Learning Difficulties in Understanding Thermal Expansion Concepts in Class XI Physics at SMA Negeri 4 Mataram

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Abstract— *Learning difficulties in physics represent a prominent issue frequently encountered by high school students, particularly regarding topics requiring robust conceptual comprehension such as thermal expansion. This study aims to analyze the learning difficulties experienced by class XI students at SMA Negeri 4 Mataram in understanding the concepts of solid, liquid, and gas expansion. The research methodology employed is descriptive qualitative with a survey approach, utilizing a student perception questionnaire covering five main indicators: problem orientation, learning organization, conceptual investigation, development and presentation of results, as well as analysis and evaluation. The research respondents consisted of class XI students who had fully completed the topic of temperature and heat. Data analysis reveals that the highest percentage of learning difficulty is located within the conceptual investigation indicator, where students face significant hurdles in distinguishing between linear, areal, and volumetric expansion (83.3%) and explaining the underlying physical mechanism of dimension increases in solids when heated (75.0%). The primary factors driving these difficulties include the abstract nature of microscopic expansion, limited visualization of physical phenomena, and a weak contextual link between theoretical propositions and the surrounding environment. The implications underscore the urgent need for non-conventional, highly interactive instructional strategies that bypass rigid frameworks.*

Keywords— Learning Difficulties, Thermal Expansion, High School Physics, Conceptual Perception.
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1. Introduction

Physics education at the senior high school (SMA) level is widely acknowledged as one of the most challenging academic disciplines for the majority of students. The intrinsic characteristics of physics, which demand not only formula memorization but also a profound conceptual understanding of natural phenomena, act as a primary catalyst for learning barriers [1]. One of the fundamental pillars within the class XI physics curriculum that routinely sparks cognitive hurdles is the topic of temperature and heat, specifically the concept of thermal expansion.

The concept of thermal expansion holds a critical position because it underpins various technological designs and

daily natural occurrences, ranging from the intentional gaps left in railway tracks, the spacing of window glass panes, to the fundamental operations of bimetallic strip thermometers [2]. Although macroscopic thermal expansion phenomena can be observed quite easily, a microscopic understanding of how the constituent particles of solids, liquids, and gases vibrate and drift further apart upon absorbing heat energy demands an advanced capacity for mental abstraction [3]. Consequently, numerous students trap themselves in partial understanding or harbor deeply rooted misconceptions.

Students are frequently competent at computing length or volume changes using standard algebraic formulas; however, they often fail entirely when prompted to explain why the expansion rate of liquids significantly outpaces that of solids, or why gas

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volume displays extreme sensitivity toward concurrent shifts in pressure and temperature [4]. Preliminary observations conducted at SMA Negeri 4 Mataram revealed that the physics instructional process continues to be heavily dominated by linear-conventional theory delivery, focusing predominantly on mathematical plug-and-chug problem-solving.

As a result, the core physical essence of thermal expansion is completely obscured, and students merely memorize template question patterns without mastering the structural concept.

When confronted with novel physical scenarios demanding analytical reasoning, students experience pronounced confusion. Therefore, executing a rigorous investigation into the exact location and causative elements of student learning difficulties specifically targeting thermal expansion is highly imperative [5]. This study is intentionally designed to chart student learning barriers independently of any rigid pedagogical models such as Problem-Based Learning (PBL), thereby capturing a pure, unadulterated portrait of the cognitive and perceptual hurdles experienced by students. By uncovering the specific points of student vulnerability across five primary indicators—problem orientation, learning organization, conceptual investigation, result development, and evaluative analysis—teachers can devise highly targeted pedagogical strategies to advance physics learning outcomes at SMA Negeri 4 Mataram [6].

2. Method

This study adopted a descriptive qualitative design paired with an analytical survey approach to objectively document and delineate the authentic learning barriers experienced by students during their engagement with thermal expansion concepts. The research was systematically executed at SMA Negeri 4 Mataram during the odd semester of the 2025/2026 academic year. The target subjects or respondents comprised class XI students who had fully completed their coursework on temperature and heat. Sampling was executed via a purposive sampling technique to guarantee that the gathered data strictly originated from students who underwent an active conventional learning environment [7].

The primary instrument for data collection was a student perception questionnaire that had undergone rigorous validation by both subject matter and measurement instrument experts. The instrument consists of 12 items, blending both positive and negative statements engineered from a modified cognitive adaptation framework. These items span five core dimensions: (1) Problem Orientation, (2) Learning Organization, (3) Conceptual Investigation, (4) Result Development and Presentation, and (5) Analysis and Evaluation. Responses were captured via a five-point Likert scale, providing options of Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), and Strongly Disagree (SD).

The empirical data compiled from the respondents' questionnaires were scrutinized through a hybrid quantitative-

qualitative descriptive analysis technique. The specific difficulty percentage for each individual item statement was calculated using a simple frequency percentage formula:

$$\boldsymbol{P = \frac{\sum f}{N} \times 100\%}$$

Where P represents the percentage of learning difficulty, Σf is the frequency of student responses indicating active difficulty (the accumulation of SA and A selections for negative difficulty statements), and N is the total sample size (N = 12) [5]. Relying on these calculated percentages, the data were categorized into distinct tiered difficulty thresholds ranging from very low to exceptionally high, and then qualitatively decoded to harvest comprehensive conclusions.

3. Result and Discussion

Analysis of publication productivity shows a clear

Following the data gathering process involving 12 primary respondents from class XI at SMA Negeri 4 Mataram (comprising I Wayan Raditya, Carissa Odela, Desak Made Putri Saraswati, Leon Cassidy, Yusuf Islam, Muhammad Rehan Ramadhani, Firas Sibgiltay, Fitri Almadina, Ni Nyoman Juwita Apriani, Novia Andini, Satya, and Dinan), a varied yet structurally consistent pattern of questionnaire responses emerged. The detailed tabulation of the student perception data is presented in Table 1 below.

Table 1. Frequency Tabulation of Student Learning Difficulty Questionnaire (N = 12)

No	Questionnaire Statement Item	SA	A	U	D	SD	Percentage Difficulty
1	I find it difficult to comprehend thermal expansion phenomena presented by the teacher at the start of class.	4	5	2	1	0	75.0%
2	I am confused when attempting to link everyday thermal expansion occurrences with theoretical content.	3	6	2	1	0	75.0%
3	I encounter difficulties collaborating effectively in groups when discussing thermal expansion topics.	2	4	3	2	1	50.0%
4	I do not clearly understand my specific task or role during group learning activities.	1	5	4	2	0	50.0%

5	It is difficult to explain the physical reason why a solid body increases in size when subjected to heat.	5	4	2	1	0	75.0%
6	I experience difficulty distinguishing the distinct expansion behaviors across solids, liquids, and gases.	4	5	2	1	0	75.0%
7	I lack a clear understanding of the difference between linear, areal, and volumetric expansion.	6	4	1	1	0	83.3%
8	I feel it is difficult to articulately explain the results of our group discussions concerning expansion.	3	5	3	1	0	66.7%
9	I lack confidence when presenting our empirical observations regarding thermal expansion in front of the class.	4	4	3	1	0	66.7%
10	I struggle to extract valid conclusions from experimental results or group dialogues about expansion.	3	6	2	1	0	75.0%
11	I find it difficult to map the mathematical concepts of thermal expansion to real-world instances around me.	4	5	2	1	0	75.0%
12	Conventional, standalone self-study without any technological innovation leaves me highly confused.	1	2	2	5	2	25.0%

Through a rigorous extraction of the quantitative results presented in Table 1, it is immediately visible that the most severe learning barriers blocking the class XI students at SMA Negeri 4 Mataram reside squarely within the conceptual investigation domain (Items 5, 6, and 7). The apex of cognitive difficulty is reached in Item 7, where an overwhelming 83.3% of the sample pool (10 out of 12 respondents) explicitly reported a profound deficiency in understanding the spatial geometric transformations and mathematical scaling rules dividing linear (α), areal ($\beta = 2\alpha$), and volumetric ($\gamma = 3\alpha$) expansion. This pattern mirrors earlier scientific assertions that students face deep obstacles when performing spatial translation from onedimensional vectors to higher-dimensional blocks [8]. To clarify the distribution patterns across all parameters, the compiled analytical metrics are visualized graphically in Fig. 1.

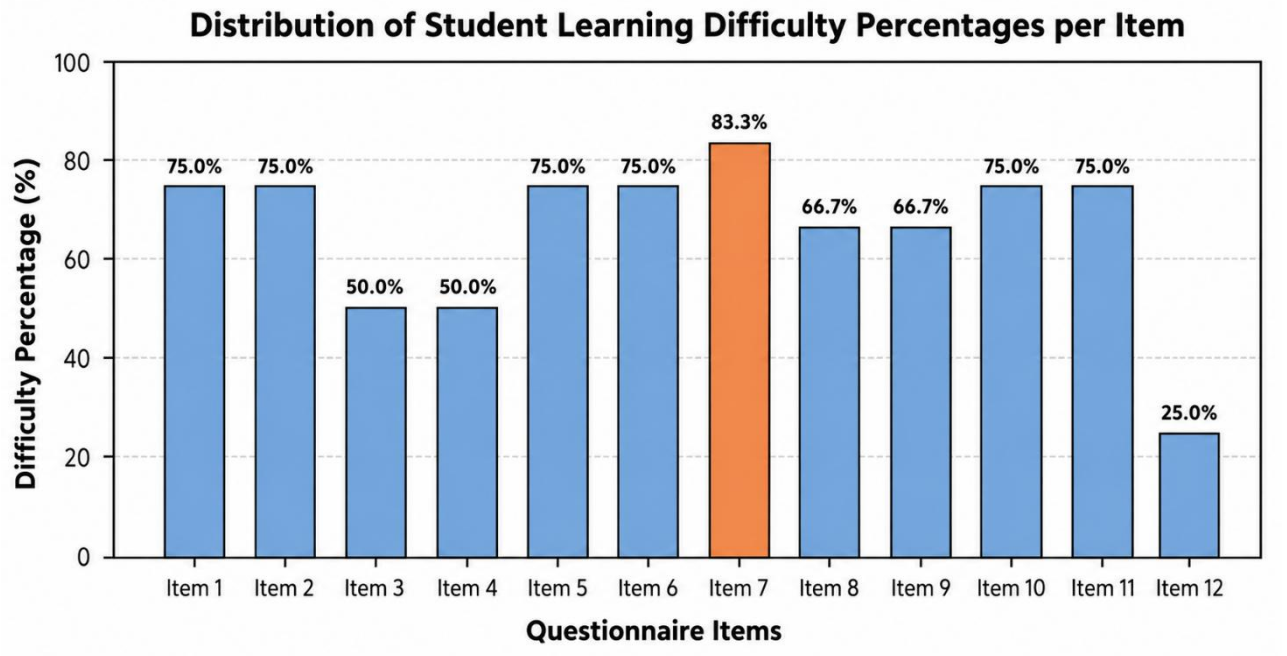

Fig. 1. Distribution of Student Learning Difficulty Percentages per Item Statement

The subsequent cognitive barrier, yielding an identical severity score of 75.0% in Item 5, relates to the students' inability to describe the internal microscopic mechanics triggering solid-body dimension expansion during thermal absorption. Qualitative disclosures reveal that while students easily parrot the macro-level rule that structures "grow larger" when heated, they fail to anchor

this rule to the escalating kinetic energy of atomic lattices that forces average inter-atomic equilibrium spacing to extend. This severe decoupling of macro-phenomena from micro-models represents a classic structural bottleneck in mental model formation within foundational physics [9]. This vulnerability is further aggravated by Item 6 (75.0%), where students stumble when contrasting liquid expansion (which bypasses linear stages and translates immediately to volume shifts) against gaseous expansion (which dictates active integration of external pressure constraints).

Under the problem orientation and evaluative analysis metrics (Items 1, 2, and 11), a uniform difficulty rate of 75.0%

was verified. Students are clearly crippled when forced to build functional bridges connecting concrete daily phenomena with highly idealized theoretical definitions. This points to a pervasive pedagogical layout failure, wherein textbook physics is taught as an encapsulated matrix of symbols completely separate from the physical world [10]. Conversely, group collaboration elements (Items 3 and 4) registered lower conflict metrics (50.0%), proving that social dynamics are healthy, yet purely hindered by individual cognitive overload and role ambiguity within the technical assignments [11]. Item 12 (25.0%) highlights that while conventional paths are suboptimal, students strongly crave structured technological or visual interventions to lift the cognitive fog [12].

4. Conclusion and Recommendations

In summary, this investigation demonstrates that the class XI students at SMA Negeri 4 Mataram encounter serious conceptual and perceptual learning difficulties regarding thermal expansion. The most severe cognitive blockage is located inside the conceptual investigation domain, punctuated by an 83.3% failure rate in spatially and mathematically differentiating linear, areal, and volumetric frameworks, followed closely by a 75.0% deficiency in modeling microscopic atomic-lattice vibrations. These barriers are heavily driven by abstract concepts, weak visualization tools, and a disconnect between classroom theory and real-world contexts. To resolve these challenges, physics educators must pivot away from conventional lecture methods and embrace interactive, multi-representational technologies that vividly model microscopic dynamics and cultivate strong contextual thinking.

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References

[1] S. Rahmawati and N. Azizah, "Integration of local wisdom in science learning: A contextual approach," Journal of Science Education Research, vol. 12, no. 2, pp. 45–53, May 2023.
[2] D. S. Mahmudah, "Integration of character values and local wisdom in science learning," M.S. thesis, Faculty of Education,University of Mataram, Mataram, Indonesia, 2024.
[3] M. Hidayat and T. F. Sari, "Developing character-based learning materials for junior high school," International Journal of Educational Studies, vol. 10, no. 1, pp. 21–30, Jan. 2022.
[4] L. P. Wulandari, "Exploring students' generic skills through causality-based learning," Indonesian Journal of Science Education, vol. 8, no. 3, pp. 99–110, Sep. 2024.
[5] P. D. Fraenkel, N. E. Wallen, and H. H. Hyun, How to Design and Evaluate Research in Education, 9th ed. New York, NY: McGraw-Hill Education, 2020.
[6] J. W. Creswell, Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research, 5th ed. Boston, MA: Pearson, 2018.
[7] D. L. Morgan, Integrating Qualitative and Quantitative Methods: A Pragmatic Approach, Thousand Oaks, CA: SAGE Publications, 2014.
[8] A. N. Putri and R. Hakim, "Design of contextual-based instructional media for environmental education," in Proc. 4th Int. Conf. on Education and Technology (ICET), Surabaya, Indonesia, 2023, pp. 201–206.
[9] A. S. Yusuf, "Integrating moral values into science curriculum," in Educational Innovation for Sustainable Development, N. W. Karim, Ed. Singapore: Springer, 2022, ch. 2, pp. 33–47.
[10] H. Lestari, "Developing local-wisdom-based science learning materials," in Proc. Int. Conf. on Science Education (ICSE), Yogyakarta, Indonesia, 2022, pp. 112–118.
[11] T. S. Nugroho, "Students' scientific reasoning through causality learning model," in Proc. 6th Nat. Seminar on Science Education (NSSE), Bandung, Indonesia, 2024, pp. 88–93.
[12] H. K. Tan, "Environmental literacy through local wisdom," in Sustainability and Learning, P. Brown, Ed. London: Springer, 2020, ch. 6, pp. 112–128.