Exploring HOTS on global warming concepts, self-efficacy and learning motivation among high school students

Lina Aviyanti[1]*, Nuzulira Janeusse Fratiwi[1], Amalia Weka Gani[1], Abdul Salam[1], Gilbert Hugo T. Simbolon[1], Muhammad Guntur Purwanto[2]

[1]Universitas Pendidikan Indonesia, Dr. Setiabudi St. No.229, Bandung, West Java, 40154, Indonesia
[2]University of Minnesota-Twin Cities, 220 Morrill Hall, 100 Church Street SE, Minneapolis, MN 55455, United States
*Corresponding author, email: lina@upi.edu

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Abstract
This study aims to explore Higher-Order Thinking Skills (HOTS) in relation to global warming materials, self-efficacy, and learning motivation among high school students. This study employed a quantitative descriptive method, involving 268 students (119 males and 149 females) from three high schools in West Java, Indonesia. The instruments used in this study included two-tier multiple-choice questions to measure higher-order thinking skills (HOTS), the Physics Learning Self-Efficacy (PLSE) scale to assess self-efficacy, and a Likert scale questionnaire to evaluate learning motivation. Findings revealed that students excelled in analyzing and evaluating tasks but struggled with tasks involving creation. Self-efficacy was moderate, with students showing confidence in their theoretical knowledge but less so in applying it to real-world situations. Learning motivation was generally high, particularly in terms of resilience and achievement, though persistence and engagement required improvement. However, the regression analysis indicated no significant relationship between self-efficacy and HOTS or between learning motivation and HOTS, reflecting that self-efficacy and learning motivation alone do not directly predict students' performance in HOTS. These results emphasize the need for educational strategies that promote HOTS, enhance self-efficacy, and sustain learning motivation to equip students for increasingly complex global challenges.

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1. Introduction

Higher-Order Thinking Skills (HOTS) are advanced cognitive abilities that extend beyond basic memory and comprehension. These skills teach students how to critically evaluate problems, find novel solutions, and make sound decisions (Fratiwi et al., 2024; Jaenudin et al., 2020; Karwadi et al., 2024; Nourdad et al., 2018). HOTS are essential in education, especially in physics, for understanding abstract concepts and applying them to real-world problems such as global warming (Aviyanti et al., 2024). Previous research has emphasized the significance of HOTS in improving students' problem-solving skills and academic achievement (Nitriani et al., 2022; Tanujaya et al., 2017).

HOTS are distinguished by their non-algorithmic nature, requiring students to solve open-ended problems and assess complex criteria. These skills necessitate equal parts critical and creative thinking, allowing students to assess concepts and develop unique solutions (Abdullah et al., 2015; Li et al., 2024; Sebastian et al., 2023). For example, creative thinking promotes the generation of new ideas, whereas critical thinking ensures that these ideas are developed and appropriate to real-world circumstances. Inquiry-based and project-based learning have proven effective in fostering higher-order thinking skills (HOTS) (Sasson et al., 2018). However, research examining the application of these skills to complex global challenges, such as global warming, remains scarce. As a fundamental component of 21st-century education, the role of HOTS in addressing real-world issues like global warming warrants deeper exploration.

Unlike HOTS, this study investigates self-efficacy and learning motivation in relation to students' general confidence and interest in learning physics rather than global warming specifically. Self-

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efficacy, a fundamental notion in Bandura's social cognitive theory, has a significant impact on students' confidence in their capacity to acquire and effectively apply these abilities. Self-efficacy is a person's belief in their ability to attain certain goals through planned and purposeful activity (Bandura, 1977, 2021; Hamann et al., 2024). It has a tremendous impact on how pupils approach issues, adapt solutions, and deal with setbacks. According to research (Dauer et al., 2021), students who have higher levels of self-efficacy are more likely to interact with complicated academic material, particularly scientific concepts. Self-efficacy is important not only for engagement, but also for how students assess and adapt their learning approaches to achieve better results. For example, students who believe they understand and can apply physics principles are more likely to critically evaluate scientific discoveries and propose solutions to challenges such as global warming. Existing research has looked into the link between self-efficacy and academic success (Al-Abyadh & Abdel Azeem, 2022; Tus, 2020; Zysberg & Schwabsky, 2021), but limited study has been conducted to investigate how self-efficacy may influence students' HOTS performance.

On the other hand, learning motivation has a substantial impact on HOTS development, which is required to increase student engagement and perseverance. Intrinsic motivation comes from curiosity and genuine interest, but extrinsic motivation is influenced by external benefits such as grades or recognition (Diwakar et al., 2023). Highly motivated students are more likely to persevere in the face of adversity, employ advanced cognitive processes, and demonstrate resilience when faced with challenges. Teachers can boost student motivation by designing engaging and relevant learning activities that connect academic principles to real-world situations (Miller et al., 2021). Connecting global warming principles to students' daily lives or future goals, for example, motivates them to learn more about the topic. While previous research has established that motivation improves academic achievement (Hwang et al., 2021; Pedler et al., 2022; Theobald, 2021), this study seeks to fill this gap by identifying high school students' levels of learning motivation and examining how these levels in supporting HOTS development, particularly in physics.

Recent studies have explored the connections between HOTS, learning motivation, and self-efficacy, revealing positive correlations between these factors. For instance, research has shown that learning motivation is positively related to HOTS (Azizah et al., 2022; Panggabean et al., 2022), and self-efficacy significantly impacts HOTS performance (Leng et al., 2020). Implementing engaging learning models has been found to improve both HOTS and learning motivation among high school students (Ardiyanti et al., 2021). Additionally, factors such as initial ability have been shown to influence HOTS development (Panggabean et al., 2022). This study aims to address these gaps by investigating not only the profiles of HOTS, self-efficacy, and learning motivation but also the relationships between these three variables and their relationships. Specifically, the study examines the predictive relationships of self-efficacy and learning motivation with HOTS, offering a more integrated perspective. By identifying these connections, the study seeks to provide insights into how self-efficacy and learning motivation influence students' ability to engage with and excel in higher-order cognitive tasks, addressing real-world challenges and offering practical implications for educators and policymakers in designing effective instructional strategies.

2. Method

This study employed a quantitative descriptive design to provide an overview of participants' characteristics and profiles, and to explore relationships between research variables. This approach focuses on capturing detailed descriptions of a phenomenon without inferential statistical analysis, making it suitable for examining surface-level data features. Descriptive statistics and correlation analysis were used to summarize the data and identify relationships between variables, including students' higher-order thinking skills (HOTS), self-efficacy, and learning motivation.

2.1. Participants

A total of 268 Grade X students, aged 15-16 years, from three high schools in West Java (two schools in Bandung City and one school in Bekasi City) participated in this study. All three schools implement the same curriculum, known as the 'Kurikulum Merdeka'. The sample selection in this study was conducted using convenience sampling techniques. Creswell (2014) revealed that convenience sampling is a non-probability sampling method that allows researchers to select participants based on their availability, without any strict selection criteria. Figure 1 demonstrates that 119 participants were male (44%), while 149 participants were female (56%).

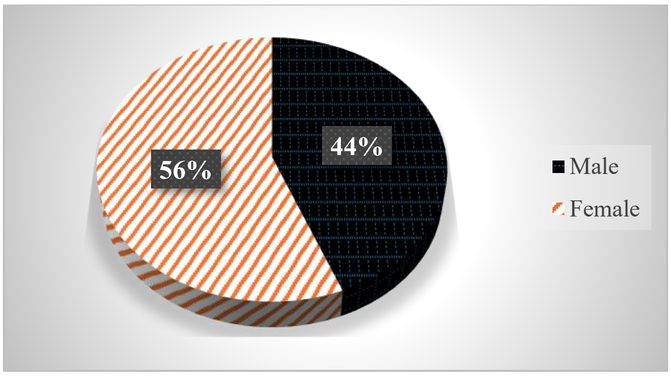

Figure 1. Distribution of participants

2.2. Instruments

This study used three validated tools to assess HOTS, self-efficacy, and learning motivation. Each instrument was thoroughly evaluated to guarantee its suitability for the study and dependability in gathering the desired data. Data were collected through the distribution of a HOTS (Higher Order Thinking Skills) test, a self-efficacy questionnaire (PLSE), and a learning motivation questionnaire to the participants, using a cross-sectional research design due to time constraints and resource limitations.

The HOTS instrument consists of 23 questions in the form of two-tier multiple-choice questions that were specifically created to measure students' higher-order thinking in respect to global warming materials. The HOTS instrument findings were separated into three cognitive levels: C4 (analyzing), C5 (evaluating), and C6 (creating). A pilot test was conducted with 30 students to evaluate the instrument's validity and reliability. Wright Map analysis was used to confirm that the instrument covered a broad range of student abilities. Construct validity was confirmed with a raw variance explained by measures of 41.90%, surpassing the 20% threshold for unidimensionality, indicating that the instrument was well-calibrated (Sumintono, 2018). Furthermore, the instrument had high reliability: item reliability was 0.88, person reliability was 0.89, and Cronbach's alpha was 0.90. Expert validation was also carried out to confirm the instrument's relevance and quality. The average expert validity scores for each component of the instrument were as follows on Table 1. HOTS instrument expert validation scores.

Table 1. HOTS instrument expert validation scores

Aspect	Average Validation Score	Category
Material Aspect	0.957	High
Construction Aspect	0.959	High
Language Aspect	0.978	High

These high scores demonstrate the instrument's good validity and applicability for measuring HOTS in this setting.

The Physics Learning Self-Efficacy (PLSE) test was developed expressly for this study and assessed students' self-efficacy in six areas: science content, higher-order thinking skills, laboratory usage, everyday application, science communication, and scientific literacy. 32 items for PLSE were coded using a five-point Likert scale. This questionnaire was developed based on the findings of Suprapto et al. (2017, p.11), who investigated the relationship between studying physics and self-efficacy among Indonesian students. Experts in physics education reviewed the instrument to ensure that the content was relevant and the language was understandable. These experts offered feedback to ensure that the measure was valid and reliable in assessing student self-efficacy. In sum, the PLSE instrument had satisfactory validity and reliability (Suprapto et al., 2017).

To assess learning motivation, a 20-item Likert-scale questionnaire was used, adapted from Ribie et al. (2023) that had satisfactory validity and reliability. This instrument assessed a variety of fundamental qualities of motivation, including perseverance in learning, resilience in the face of adversity, interest in learning, the ability to defend one's opinion, difficulty letting go of beliefs, pleasure in problem-solving, and achievement in learning. Meetings with professionals (lecturers) from Universitas Pendidikan Indonesia (UPI) and physics teachers were held to validate the instrument and make suggestions for improving item alignment with study objectives. To obtain a clear picture of students' motivation levels, responses were rated on a five-point Likert scale ranging from "Never" (1) to "Always" (5).

2.3. Data Analysis

The data for this study was evaluated employing quantitative descriptive analysis, with the goal of categorizing and interpreting the results based on participant responses. Descriptive statistics, including percentages, were used to provide an overview of students' performance across HOTS levels (analyzing, evaluating, and creating), as well as their self-efficacy and learning motivation scores. This analysis highlighted strengths and areas needing improvement in students' cognitive and affective profiles. Additionally, linear regression analysis was conducted to explore the predictive relationships between self-efficacy, learning motivation, and HOTS.

3. Results and Discussion

This section contains the study's findings and interpretations, organized into three important areas: Higher-Order Thinking Skills (HOTS), self-efficacy, and learning motivation. The findings are reviewed and discussed to get insight into the profiles of students in these areas, with an emphasis on their strengths and areas for development.

3.1. Higher-Order Thinking Skills (HOTS)

The HOTS analysis in this study revealed great variance in student performance, as illustrated by the Wright Map in Figure 2.

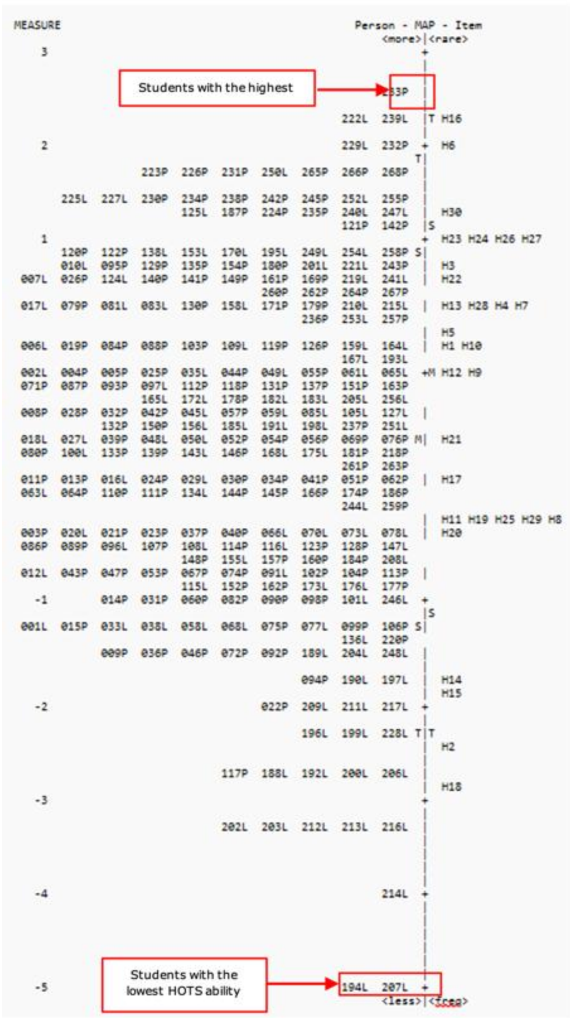

Figure 2. Wright map analysis of students' HOTS

Figure 2 shows the Wright Map, which provides a thorough picture of student performance and item difficulty. The Wright Map's left side depicts the distribution of participants, with numbers representing student identification codes and "L/P" denoting the students' gender (L = male, P = female). The right side depicts the distribution of HOTS items, allowing for an assessment of their difficulty levels.

The study found that student 233P had the most ability, ranking as an outlier above two standard deviations and demonstrating higher cognitive performance when compared to their peers. Conversely, students 194L and 207L showed the lowest ability, reflecting challenges in engaging with HOTS tasks. These findings are consistent with prior studies by Lu et al. (2021), which identified similar variability in students' higher-order thinking abilities, often influenced by factors such as prior knowledge, cognitive development, and instructional approaches.

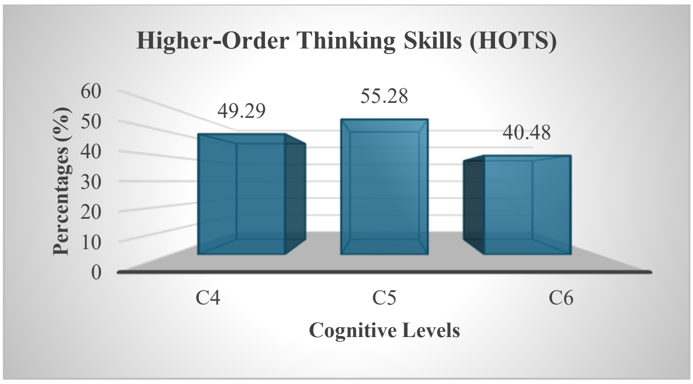

Figure 3. Percentages of students' HOTS on each level

Figure 3 provides additional insights on HOTS performance by illustrating the distribution of scores across cognitive levels. The statistics revealed that 49.29% of students scored at C4 (Analyzing) and 55.28% at C5 (Evaluating), both of which were classified as moderate. However, just 40.48% of students fared well in C6 (Creating), the highest cognitive level that requires generating new ideas and solving complicated issues. These findings are consistent with those of Rozi et al. (2021), who discovered that students excel in lower levels of cognitive processes such as analysis and assessment but struggle with creative thinking. As a result, it is evident that further strategies to promote creativity and innovation in physics education must be introduced.

In the context of physics education, fostering creativity is essential to address complex global challenges such as climate change and energy efficiency. While students demonstrate competence in assessing and evaluating their surroundings, the study highlights a clear need to prioritize the development of creative thinking. Although students excel in cognitive processes like analysis and evaluation, they often struggle with higher-order creativity, which is crucial for solving real-world problems. By encouraging creativity, educators can help students apply their knowledge in innovative ways, bridging the gap between academic learning and real-world problem-solving. Teachers should design learning experiences that challenge students to engage with physics-related issues, such as mitigating climate change or developing sustainable energy solutions. Through project-based and inquiry-driven learning approaches, students can develop the skills to create, test, and refine solutions that are relevant to real-world applications, thereby enhancing both their creative thinking and their ability to address some of the most pressing global issues.

3.2. Self-Efficacy

Figure 4 displays the students' self-efficacy profiles, which demonstrate moderate confidence across all six assessed categories. Students had the highest self-efficacy in Scientific Literacy (SL), with an average score of 67%. Similarly, the Laboratory Usage (LU) and Higher-Order Thinking (HOT) categories had modest self-efficacy scores of approximately 64%, indicating that students were confident in their abilities in these domains. These findings are consistent with those of Suprapto et al. (2017), who found that physics students frequently exhibit moderate self-efficacy, particularly in content-specific knowledge, but express relatively low confidence in their ability to apply this knowledge to practical, real-world circumstances.

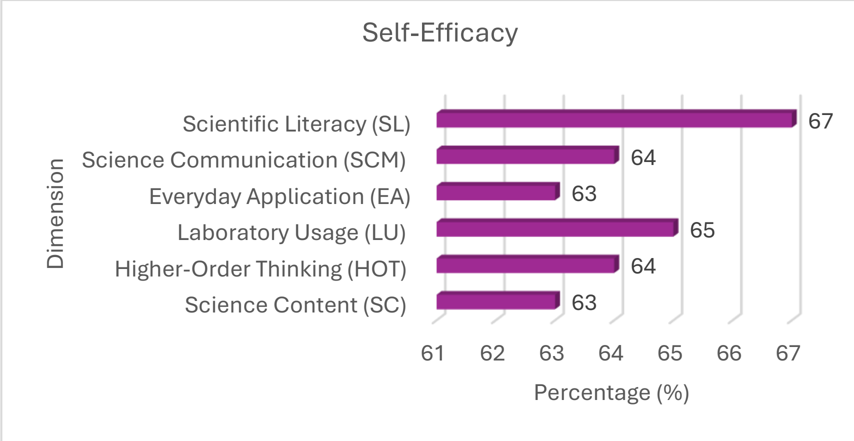

Figure 4. Percentages of students' self-efficacy on each dimension

In contrast, attributes such as Everyday Application (EA) and Scientific Content (SC) received substantially lower scores (63%), indicating that, while students are typically confident in their theoretical grasp, their ability to apply this knowledge to real-world situations is limited. This is congruent with the findings of Schunk (2023), who discovered that students show higher self-efficacy in academic topics but do not use their knowledge in practice.

Although self-efficacy in this study was not directly linked to specific issues such as global warming, the findings provide a broad overview of students' confidence in various physics-related scenarios. To address the identified gaps, it is crucial for educators to integrate instructional strategies such as collaborative projects and experiential learning activities. These methods would enhance students' self-efficacy in applying their knowledge across diverse contexts (Gale et al., 2021; Wong et al., 2023). Such approaches would empower students to tackle real-world challenges more effectively, fostering both academic and practical success in their physics education.

3.3. Learning Motivation

Figure 5 depicts the learning motivation information, which show that students are generally interested in specific dimensions. The highest scores were in Resilience in Facing Difficulties (80%) and Achievement in Learning (73%), indicating students' ability to persevere in the face of academic problems as well as their sense of accomplishment in class. These findings agree with Goldman et al. (2024), who stressed the importance of motivation in overcoming hurdles and obtaining academic achievement. This is particularly important in the context of physics education, where the abstract and complex nature of the subject may challenge students' resilience and perseverance.

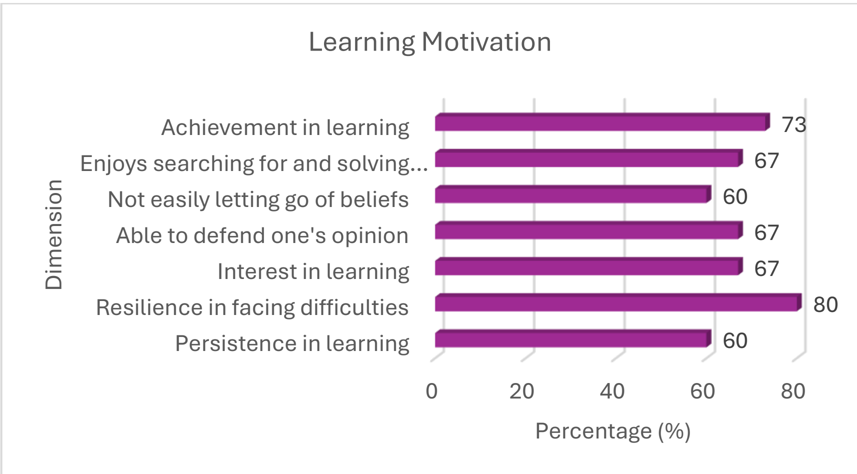

Figure 5. Percentages of students' learning motivation on each dimension

Interest in Learning (67%) and Enjoyment in Problem Solving (67%) were given moderate ratings, indicating that while students are engaged in the subject, they may not always be fully immersed in problem-solving tasks. This pattern aligns with the findings of Maloy et al. (2019), who observed that students often show enthusiasm for learning initially but may not sustain this engagement, particularly in challenging subjects like physics. In the context of physics education, this suggests that while students may be motivated at the beginning, the nature of physics problems and concepts can affect their continued interest. Addressing these gaps through active learning approaches, such as project-based learning, may help students maintain their interest and satisfaction in tackling real-world challenges.

The lowest results were recorded in Persistence in Learning (60%) and Not Easily Letting Go of views (60%), showing that students may struggle to maintain constant effort and confront their own views when faced with challenges. These findings are consistent with prior research by Cook & Artino (Cook & Artino, 2016), which discovered that persistence and the ability to critically assess one's own beliefs are important components of long-term academic accomplishment. In the context of physics education, fostering these attributes is particularly relevant, as the subject often requires students to challenge deeply held misconceptions and adopt new ways of thinking. While this study does not specifically link learning motivation to topics such as global warming, the results suggest that physics educators should focus on developing students' resilience and critical thinking. Educators can achieve this by creating learning environments that encourage reflection, perseverance, and constructive challenges to students' existing ideas, helping them engage more deeply with complex physics concepts.

Table 2. Result for linear regression of self-efficacy and learning motivation

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.002	1	3.002	2.296	.131b
	Residual	347.791	266	1.307		
	Total	350.793	267			

a. Dependent Variable: HOTS
b. Predictors: (Constant), PLSE

According to Table 2, the examination of the association between Physics Learning Self-Efficacy (PLSE) and Higher-Order Thinking Skills (HOTS) shows no significant influence, with a Sig. value of 0.131. The study's findings could be attributed to Indonesian students' lack of systematic HOTS instruction. Unlike prior studies (Abdul Malik et al., 2020; Leng et al., 2020), which found a positive association between self-efficacy and HOTS, the educational environment in Indonesia may not regularly incorporate HOTS-focused instruction, restricting the development of these skills. This gap is particularly concerning, as HOTS are essential for solving complex real-world problems such as those encountered in environmental science and energy efficiency.

HOTS demand structured opportunities for students to examine, evaluate, and create. However, traditional education techniques in Indonesia frequently prioritize rote memory and subject recall over critical thinking and problem solving (Minasyan & Supriatna, 2024). This educational gap may cause students' self-efficacy to be more closely connected with their ability to succeed in standard academic activities rather than complicated cognitive processes such as HOTS. Without appropriate exposure or instruction in HOTS, students may be unable to use their confidence in meaningful ways when confronted with higher-order problems.

In physics education, fostering HOTS is critical for students to not only understand the theoretical concepts but also apply them to real-world situations such as climate change, renewable energy, and other global challenges. This gap reveals a potential systemic issue in which students' perceptions in their academic talents (self-efficacy) are insufficiently linked to their ability to complete higher-order cognitive tasks. It is consistent with the view that self-efficacy alone cannot drive performance in areas where abilities are underdeveloped or inadequately supported by teaching (Narayanan et al., 2023). Educators in Indonesia must consequently focus on explicitly incorporating HOTS into curricula, using instructional methodologies such as inquiry-based learning, project-based activities, and real-world problem-solving scenarios. By embedding HOTS into the physics curriculum, educators can ensure that students develop the cognitive skills necessary for solving complex. By incorporating HOTS into daily learning practices, students may build the abilities and confidence required to solve complicated challenges, making self-efficacy a more dependable predictor of HOTS success.

Table 3. Result for linear regression of self-efficacy and learning motivation

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.519	1	.519	.394	.531b
	Residual	350.275	266	1.317		
	Total	350.793	267			

a. Dependent Variable: HOTS
b. Predictors: (Constant), LMQ

According to Table 3, the study's analysis of the association between learning motivation and Higher-Order Thinking Skills (HOTS), which had a Sig. value of 0.531, found no significant correlation. This finding differs with past research, which frequently emphasizes the favorable impact of motivation on cognitive function and academic accomplishment. The setting and teaching approaches widespread in the school environment may account for this outcome. While learning motivation is an important driver of student engagement, it may not have a direct impact on the development of HOTS unless students are specifically taught how to apply motivating efforts to higher-order activities. Many schools, particularly in Indonesia, continue to prioritize achieving tangible goals such as test scores over developing abilities such as analysis, evaluation, and creativity. In physics education, this emphasis on surface-level goals can hinder the development of HOTS, which are necessary for tackling real-world issues in physics. As a result, even highly driven students may focus their efforts on memorizing surface-level knowledge rather than engaging in the deeper cognitive processes necessary for HOTS.

Furthermore, the lack of a meaningful association may indicate that motivation alone is insufficient to improve HOTS unless it is accompanied by appropriate teaching strategies. Mitarlis et al. (2020) found that motivation must be combined with specialized instructional approaches, such as inquiry-based or problem-based learning, to foster the skills associated with HOTS. These methods allow students to engage actively with real-world problems, helping them connect abstract concepts with practical applications. Without these approaches, students may lack the necessary guidance to convert their intrinsic or extrinsic desire into meaningful participation in complex tasks.

This research also implies that, while students may be motivated to learn, their motivational energy may not align with the demands of HOTS-related activities. In physics education, aligning students' motivation with the requirements of higher-order problem-solving is crucial for fostering the critical thinking necessary to address issues such as global warming, climate change, energy conservation, and environmental sustainability. To bridge this gap, educators should develop ways that directly connect motivational elements to higher-order activities. Aligning classroom exercises with real-world challenges, promoting collaborative problem-solving, and providing constructive feedback can help students recognize the importance of HOTS in both academic and practical contexts. Such activities would ensure that physics education not only builds foundational knowledge but also prepares students to tackle critical global issues. Future research enhance the relationship between learning motivation and HOTS by creating a learning environment where motivation is purposefully directed toward higher-order activities.

4. Conclusion

According to the study's findings, there was significant variability in students' Higher-Order Thinking Skills (HOTS), with strengths in analysis and evaluation, but challenges arose in the development of creating, which is critical for addressing complex issues such as global warming. Students had moderate self-efficacy in theoretical knowledge and scientific literacy, but they were less confident in applying this information to real-world circumstances. Furthermore, students' learning motivation was typically good, particularly in terms of resilience in the face of adversity and learning achievement, however their involvement and persistence in overcoming problems may be improved. The findings also revealed no significant relationships between self-efficacy and HOTS (Sig. = 0.131) or between learning motivation and HOTS (Sig. = 0.531), suggesting that self-efficacy and learning motivation alone may not directly influence the improvement of HOTS in this context.

Educators ought to concentrate on strengthening students' skills in creating and applying learning methodologies that require the application of knowledge in real-world contexts. Problem-based or project-based learning methods can help students gain confidence in using their knowledge in practical settings. Furthermore, more interactive learning environments are needed to enhance perseverance and engagement by encouraging reflection and constructive challenges to existing concepts, thus boosting students' motivation and resilience while dealing with difficult subjects. By integrating explicit HOTS training into classroom practices, educators can better align students' confidence and motivation with their cognitive performance.

Author Contributions

All authors have equal contributions to the paper. All the authors have read and approved the final manuscript.

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Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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