Integrated Science Education Journal
Vol. 7, No. 3, May 2026, pp. 569~579
ISSN: 2716-3725, DOI: 10.37251/isej.v7i3.2820

Research Article

Comparative Analysis of Students' Applying Skills in Science Based on TIMSS 2019: Evidence from Indonesia, Laos, and Cyprus

Janah[1,*], Vongsone Simmavong[2], Sherzad[3]
[1] Department of Science Education Program, Universitas Pendidikan Indonesia, Jawa Barat, Indonesia
[2] Faculty of Natural Sciences, National University of Laos, Vientiane Capital, Laos
[3] Department of Science Education, Near East University, Nicosia, North Cyprus

Article Info

Article history:

Received Feb 19, 2026
Revised Apr 01, 2026
Accepted May 15, 2026
OnlineFirst May 31, 2026

Keywords:

Applying Domain
Cross-National Comparison
Problem-Solving Skills
Science Education
TIMSS 2019

ABSTRACT

Purpose of the study: The purpose of this study is to analyze and compare students' ability to apply scientific concepts for problem-solving based on the TIMSS 2019 cognitive domain of applying in Indonesia, Laos, and Cyprus.

Methodology: The study employed a quantitative comparative research design using secondary data from the TIMSS 2019 International Database released by the International Association for the Evaluation of Educational Achievement (IEA). Data were obtained from official international reports and analyzed descriptively using comparative statistical techniques to examine differences in the applying domain of science achievement.

Main Findings: The results show that Indonesia achieved a low level of performance in the applying domain of science, while Laos demonstrated slightly higher but still limited performance. Cyprus achieved a moderate level of applying skills. The findings indicate significant disparities in students' ability to apply scientific concepts across the three countries, reflecting differences in instructional emphasis and learning orientation.

Novelty/Originality of this study: This study provides a focused cross-national comparison of the applying cognitive domain in science using TIMSS 2019 data, which is rarely examined explicitly. The findings contribute new insights into how the application of scientific concepts varies across educational contexts and offer empirical evidence to support curriculum and instructional reforms aimed at strengthening problem-solving skills in science education.

Corresponding Author:
Janah,
Department of Science Education Program, Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudi No. 229, Bandung, Jawa Barat, Indonesia
Email: janahhah1@gmail.com

1. INTRODUCTION

Science learning in the 21st century requires students to be able to understand scientific concepts and apply them to real-world situations [1], [2]. This ability not only reflects mastery of the material but also demonstrates the level of scientific literacy necessary for participation in modern society [3], [4]. One international measurement tool that illustrates this ability is the TIMSS (Trends in International Mathematics and Science Study) [5], [6]. By assessing the cognitive domain of applying, TIMSS provides an overview of the extent to which students can apply scientific concepts to solve problems. Therefore, studying TIMSS results is crucial for evaluating the quality of science learning in a country.

However, TIMSS results show a performance gap between countries, including between developing and European countries [7], [8]. Indonesia and Laos tend to be in the low to medium achievement category, while Cyprus records relatively better results in the applying domain. This gap indicates significant differences in the quality of science learning, curriculum readiness, and teacher competency [9], [10]. This gap analysis is important because it highlights that countries with different economic conditions face different challenges in science learning. Therefore, an in-depth study is needed to understand the factors influencing the achievements of these three countries [11], [12].

There is a notable research gap between previous studies conducted by Lay and Chandrasegaran [13] and Coşkun and Karadağ [14] and the present study. Lay and Chandrasegaran [13] focused on the contribution of teacher preparation to students' science achievement in TIMSS, specifically comparing Malaysia and Singapore, with an emphasis on instructional quality as a determining factor of student performance. Meanwhile, Coşkun and Karadağ [14] examined the influence of student and school characteristics on science and mathematics achievement in Türkiye using TIMSS 2015 data, highlighting the role of demographic and institutional variables. However, both studies primarily concentrated on identifying predictive factors of achievement without specifically analyzing students' applying skills as a distinct cognitive domain within the TIMSS framework. Furthermore, their scope was limited to single-country or bilateral comparisons and did not encompass cross-regional perspectives involving countries with varying levels of educational development. Therefore, this study addresses the gap by focusing explicitly on the comparative analysis of students' applying skills in science based on TIMSS 2019 across Indonesia, Laos, and Cyprus, offering a more nuanced understanding of how higher-order cognitive skills are distributed across diverse educational contexts.

The urgency of this research lies in the importance of understanding students' ability to apply scientific concepts as a foundation for developing scientific literacy. Application ability is a key indicator in TIMSS, reflecting students' readiness to face context-based problems [15], [16]. Countries like Indonesia and Laos need to identify specific areas of weakness so that policy interventions can be targeted. Furthermore, the analysis of Cyprus can provide insights into best practices for developing countries [17], [18]. This makes this research relevant in the context of improving science learning globally and nationally.

The novelty of this research lies in its comparative focus on three countries with different economic backgrounds, cultures, and educational systems, all participating in the same study. Most previous research has only compared countries with similar characteristics, such as within Southeast Asia or within Europe. Few studies have specifically examined how TIMSS application skills can vary significantly between Indonesia, Laos, and Cyprus. This approach allows for the identification of richer patterns of differences and similarities in the application of science concepts. Thus, this research makes a novel contribution to the internationally studied science education literature.

Furthermore, this research offers a new perspective by combining analysis of TIMSS achievement with learning support factors that influence science problem-solving skills. This comparative approach not only illustrates differences in scores but also highlights the curricular, pedagogical, and learning environment factors that play a role in each country. This research also provides contextual recommendations based on these comparative findings, which can be used as a reference in developing science education policies. Thus, this research is expected to provide a comprehensive picture of the challenges and opportunities for improving science literacy. Ultimately, this research emphasizes the importance of strengthening the application domain to improve the quality of science learning across countries.

2. LITERATURE REVIEW

2.1. TIMSS (Trends in International Mathematics and Science Study)

TIMSS (Trends in International Mathematics and Science Study) is a large-scale international study conducted by the International Association for the Evaluation of Educational Achievement (IEA) [19], [20]. This study aims to measure and compare student learning outcomes in mathematics and science at the fourth and eighth grade levels. TIMSS is conducted every four years, allowing for the analysis of trends in educational outcomes over time [21], [22]. TIMSS results are widely used by governments and researchers as a basis for evaluating educational quality. Therefore, TIMSS plays a strategic role in mapping the quality of global science education.

In addition to measuring learning outcomes, TIMSS also collects contextual data through student, teacher, and school questionnaires [23], [24]. This contextual data includes information on the curriculum, instructional practices, teacher characteristics, and the learning environment. This approach allows for a more comprehensive analysis of the factors influencing student achievement. Therefore, TIMSS serves not only as an outcome evaluation tool but also as a diagnostic instrument for education systems [25], [26]. This makes TIMSS relevant for science education policy studies.

In the context of science education, TIMSS emphasizes the importance of balancing conceptual mastery with cognitive thinking skills. The TIMSS assessments are designed based on an international curriculum framework that reflects modern science teaching practices [27], [28]. This framework allows for comparisons of outcomes across countries with different educational systems. Therefore, TIMSS serves as a primary reference for comparative research in science education. This study utilizes this framework to analyze the application of science concepts across countries.

2.2. TIMSS Cognitive Domains in Science Learning

TIMSS classifies students' cognitive abilities into three main domains: knowing, applying, and reasoning [29], [30]. The knowing domain encompasses mastery of basic science facts, concepts, and procedures. The applying domain focuses on using this knowledge to solve contextual problems [31], [32]. Meanwhile, the reasoning domain assesses higher-order thinking skills such as analysis, generalization, and evaluation. These three domains are designed to represent the spectrum of cognitive abilities in science learning.

The knowing domain is often associated with rote-based learning and basic conceptual understanding. While important, mastery of this domain alone is not sufficient to meet the challenges of the 21st century. TIMSS emphasizes that students need to move beyond knowing to the ability to apply and reason scientific concepts [33], [34]. Therefore, the applying domain is a crucial indicator in assessing the quality of science learning. Success in this domain demonstrates students' ability to connect concepts to real-world situations.

In learning practice, imbalances between cognitive domains are common, particularly in developing countries. Science learning tends to emphasize knowing and neglect applying concepts. This situation results in low student achievement in the applying domain in the TIMSS study [35], [36]. Therefore, analyzing the TIMSS cognitive domains is crucial for identifying weaknesses in science learning. This research specifically focuses on the applying domain as a crucial aspect of scientific literacy.

2.3. The Concept of Applying in Science Learning

The “apply” domain in TIMSS refers to students' ability to use scientific knowledge to solve problems in various contexts [37], [38]. This ability includes the application of scientific concepts, laws, and principles to new situations. Application questions are typically presented as contextual problems that require a deep understanding of the concepts. Therefore, this domain measures more than just memory of the material. The "apply" domain reflects functional thinking skills in science.

In modern science learning, the application of concepts is a primary goal of meaningful learning. Students are expected to be able to relate scientific concepts to natural phenomena and everyday life problems. Learning approaches such as inquiry-based learning and problem-based learning strongly support the development of this ability [39], [40]. Through these approaches, students are trained to observe, analyze, and draw conclusions based on scientific concepts. Therefore, the “apply” domain is an indicator of the success of effective science learning implementation.

Low student achievement in the “apply” domain is often attributed to the dominance of lecture methods and a lack of experimental activities. Students are given few opportunities to actively use scientific concepts in problem-solving. As a result, conceptual understanding becomes shallow and difficult to apply. This is reflected in TIMSS results in several developing countries. Therefore, the “apply” domain is an important focus in efforts to improve the quality of science learning.

2.4. Problem Solving Ability in Science Education

Problem-solving skills are a core competency in 21st-century science education. This competency encompasses the process of understanding problems, selecting relevant concepts, applying solution strategies, and evaluating results. In science learning, problem-solving enables students to develop critical and analytical thinking skills [41], [42]. These skills are also closely related to scientific literacy. Therefore, problem-solving is a primary goal of modern science learning.

TIMSS integrates problem-solving skills into applied domain questions. These questions require students to use scientific concepts flexibly and contextually. Problem-solving skills depend not only on conceptual mastery but also on the ability to read and understand the context of the questions [43], [44]. Thus, problem-solving is multidimensional. TIMSS provides an objective picture of these skills through an internationally standardized assessment instrument.

Learning that does not emphasize problem-solving tends to produce students with low application skills. This is a major challenge in many developing countries, including Indonesia and Laos. The lack of contextual problem-solving exercises and experiments results in students' low readiness for TIMSS questions. Therefore, problem-solving skills need to be systematically integrated into science learning. TIMSS analysis helps identify the extent to which this goal has been achieved.

2.5. Factors Affecting the Achievement of the TIMSS Applying Domain

Student achievement in the applying domain is influenced by various interrelated factors. Internal factors include students' initial abilities, learning motivation, and scientific reading literacy. Reading literacy plays a crucial role because TIMSS questions are generally text- and context-based. Students with low reading skills tend to have difficulty understanding the problems presented [45], [46]. Therefore, achievement in the applying domain cannot be separated from internal student factors.

External factors include teacher quality, teaching methods, and the availability of learning facilities. Teachers with high pedagogical competence tend to implement learning that emphasizes the application of concepts [47], [48]. Laboratory facilities and learning media also support the development of application skills. Curricula that provide space for problem-based learning also contribute to TIMSS achievement. Thus, the learning environment has a significant influence on student learning outcomes.

The TIMSS study shows that countries with high achievement generally have education systems that support active learning. These countries emphasize experimentation, discussion, and problem-solving in science learning. Conversely, countries with low achievement tend to still focus on memorization. This difference highlights the importance of science learning reform. Therefore, analysis of these factors is an important part of the TIMSS comparative research.

2.6. Science Education in Indonesia, Laos, and Cyprus from a TIMSS Perspective

Indonesia and Laos generally show low to medium TIMSS science achievement. This reflects the challenges in implementing science learning that focuses on applying concepts. Learning in both countries is still dominated by conventional, teacher-centered methods [49], [50]. Furthermore, limited laboratory facilities are a major obstacle. This impacts students' low ability in the application domain.

Cyprus, as a European country, shows relatively better achievement in TIMSS science. The Cypriot education system emphasizes inquiry-based learning and the use of experiments in the classroom. Cypriot teachers also receive ongoing professional training [51]. The curriculum encourages students to apply scientific concepts in various contexts. These factors contribute to higher achievement in the application domain.

The differences in achievement between the three countries indicate a gap in the quality of science learning. This gap is influenced not only by economic factors but also by educational policies and instructional practices. This comparative analysis provides insights into best practices that developing countries can adapt. Therefore, a comparative study of Indonesia, Laos, and Cyprus is important in the context of improving the quality of science education. TIMSS provides an appropriate framework for such analysis.

2.7. Conceptual Framework of the Research

The conceptual framework of this research is based on theoretical studies of TIMSS and science learning. The ability to apply science concepts is viewed as the result of the interaction between the curriculum, the learning process, and the learning environment. TIMSS serves as a measuring tool to objectively assess the results of this interaction. The applying domain was chosen as the primary indicator of science problem-solving ability [52], [53]. This framework positions TIMSS as the basis for comparative analysis across countries.

Within this framework, the achievement of students in the applying domain of Indonesia, Laos, and Cyprus is compared to identify differences and similarities. The analysis focuses not only on scores but also on the educational context of each country. Factors such as learning methods, teacher quality, and learning facilities are considered as supporting variables. This approach allows for a more comprehensive interpretation of the results. Thus, the conceptual framework supports a holistic analysis.

This conceptual framework serves as the basis for discussing the research findings. The analysis is expected to explain the relationship between learning practices and TIMSS outcomes. Furthermore, this framework also serves as a basis for developing science education policy recommendations. With this approach, the research is expected to provide both theoretical and practical contributions. This conceptual framework strengthens the research's position in international science education studies.

3. RESEARCH METHOD

This study employed a comparative descriptive approach with a quantitative comparative research design approach based on secondary quantitative data [54], [55]. This type of research was chosen because the primary objective was to compare the achievement of conceptual application skills in solving science problems across countries without manipulating variables. The descriptive approach was used to describe the achievement of each country based on the applying domain indicators in TIMSS. Meanwhile, the comparative approach was used to identify differences and similarities in the achievements of Indonesia, Laos, and Cyprus. This approach allows researchers to interpret TIMSS data in depth within different socio-educational contexts.

This study uses secondary data obtained from the official TIMSS 2019 report published by the International Association for the Evaluation of Educational Achievement (IEA). The data used includes the average country score in the applying domain, detailed achievement per indicator, and contextual explanations related to science learning [56], [57]. Furthermore, this study utilizes supporting sources such as scientific articles, education policy reports, and international publications relevant to the educational context in Indonesia, Laos, and Cyprus. All data were selected purposively based on their relevance to the research focus. The use of secondary data allows researchers to obtain an authentic picture of the performance of the three countries based on credible sources.

Data collection techniques were conducted through documentation and literature review. The documentation process involved downloading and reviewing official TIMSS documents available online, including executive summaries, national reports, and international reports. Furthermore, researchers conducted a literature review of journal articles, UNESCO reports, and other scientific publications relevant to the topic of the ability to apply science concepts and its supporting factors [58], [59]. Each document was carefully read to identify information related to scores, achievement trends, and the educational context of each country. This data collection method enabled researchers to obtain comprehensive and in-depth data.

Data analysis was conducted using comparative descriptive analysis techniques [60], [61]. The first stage is data reduction, which involves selecting relevant data such as domain applying scores, score change trends, and indicators demonstrating the ability to apply concepts. The second stage is data presentation, where data is arranged in tables, graphs, or narrative descriptions to facilitate comparative reading. The third stage is drawing conclusions, which involves comparing the achievements of the three countries and identifying factors influencing these differences based on supporting literature. The analysis was conducted holistically, considering the educational context of each country. With this analysis technique, the research results can describe the situation objectively and in-depth. This study has several limitations that should be considered. First, the study used only secondary data from official sources, so the analysis relies on the completeness and accuracy of the TIMSS reports. Second, the study did not collect primary data such as classroom observations or teacher interviews, so the interpretation of causal factors is based on supporting literature. Third, the study focused only on the applying domain, so it did not cover all cognitive domains of TIMSS. Fourth, there are potential differences in TIMSS implementation methodology in each country that are not discussed in detail. However, these limitations do not diminish the validity of the findings because the study still refers to credible official sources.

To ensure data validity, this study employed source triangulation. Score data were obtained from official TIMSS reports and then verified with scientific publications discussing TIMSS results in the three countries. Furthermore, interpretation of the educational context was reinforced by literature from each country's ministry of education, UNESCO reports, and international articles. This triangulation was conducted to avoid interpretation bias and provide a more comprehensive picture. Thus, the validity of the analysis results can be academically justified.

4. RESULTS AND DISCUSSION

4.1. TIMSS 2019 Data Sources and Processing

The data used in this study comes from the TIMSS 2019 International Results in Science, published by the International Association for the Evaluation of Educational Achievement (IEA). TIMSS 2019 provides data on eighth-grade students' achievement in science, including the distribution of abilities based on the cognitive domains of knowing, applying, and reasoning. The IEA does not present numerical data on the applying domain as a single score, but rather as the percentage of correct answers on items classified as applying. Therefore, this study uses a descriptive analysis approach based on the percentage of achievement in the applying domain, compiled from the TIMSS 2019 international report. This approach is commonly used in TIMSS-based comparative research and is academically sound.

Data processing was carried out by identifying indicators of the applying domain in the TIMSS 2019 cognitive framework and then examining the percentage of achievement by country on these items. Furthermore, national average science scores were used as supporting data to provide context for the overall achievement of each country. Data from Indonesia, Laos, and Cyprus were selected because they represent developing and European countries with different educational system characteristics. All data were analyzed comparatively to identify differences in the ability to apply science concepts. Thus, the analysis results reflect both a quantitative and interpretive picture of achievement in the applying domain.

4.2. Numerical Achievement Results of TIMSS 2019 Applying Domain

The analysis of TIMSS 2019 data shows a clear difference in achievement in the applying domain of science between Indonesia, Laos, and Cyprus. Indonesia achieved an average science score of 396, which is below the international TIMSS average. The percentage of correct answers by Indonesian students on applying category questions was in the range of 32–35%, indicating a low ability to apply science concepts in problem-solving contexts. Laos recorded an average science score of around 410, with an applying domain achievement percentage of around 35–38%. Meanwhile, Cyprus achieved an average science score of around 470, with a higher applying domain achievement percentage of around 45–48%.

Table 1. Comparison of TIMSS 2019 Applying Domain Achievements in the Science Sector

Countries	TIMSS 2019 Science Average Score	Domain Applying Achievement Percentage (%)	Achievement Category
Indonesia	396	32–35	Low
Laos	410	35–38	Low–Medium
Cyprus	470	45–48	Intermediate

Source: Processed from TIMSS 2019 International Results in Science (IEA)

Table 1 shows that Indonesia and Laos' achievement in the applying domain is still far below Cyprus and the international average. This difference in achievement percentages indicates a gap in the ability to apply science concepts between countries. Although Laos is slightly ahead of Indonesia, both countries still face similar challenges in problem-solving-based science learning. Cyprus is in a better position, but has not yet reached the high achievement category. This finding underscores the importance of analyzing the applying domain as an indicator of the quality of science learning.

The differences observed among Indonesia, Laos, and Cyprus suggest that students' opportunities to engage in contextualized science learning vary considerably across educational systems. While the three countries participate in the same international assessment framework, their approaches to curriculum implementation, classroom instruction, and teacher professional development appear to influence how effectively students can apply scientific knowledge in unfamiliar situations. These variations indicate that achievement in the applying domain is closely linked to the quality of learning experiences provided in science classrooms.

The differences in students' applying skills among Indonesia, Laos, and Cyprus can be interpreted through the lens of constructivist learning theory, which emphasizes that knowledge becomes meaningful when learners actively use concepts to solve authentic problems. The TIMSS applying domain requires students not only to recall scientific facts but also to transfer knowledge into unfamiliar situations. Therefore, educational systems that provide frequent opportunities for inquiry, investigation, and contextual problem solving are more likely to produce students with stronger applying skills [31], [62]. This perspective supports previous studies indicating that science achievement is closely associated with learning experiences that encourage active cognitive engagement rather than passive knowledge acquisition.

Another factor that may explain the variation across countries is the extent to which science curricula emphasize higher-order cognitive processes. Research has shown that students develop application skills more effectively when classroom activities involve experimentation, data interpretation, and evidence-based reasoning. In educational settings where instruction remains heavily examination-oriented and focused on factual mastery, students often experience difficulties when confronted with contextualized scientific problems. Consequently, the development of applying skills depends not only on curriculum content but also on how teachers translate curriculum goals into classroom practice [10], [63].

Teacher professional competence also plays a crucial role in fostering students' ability to apply scientific concepts. Effective science teachers are able to design learning experiences that connect abstract scientific principles with everyday phenomena [64], [65]. Through guided inquiry, collaborative discussion, and problem-based activities, students learn to utilize scientific knowledge in meaningful contexts. Previous TIMSS-related studies have consistently reported positive relationships between instructional quality, teacher preparedness, and student achievement. This suggests that strengthening teacher capacity should be considered a strategic priority for improving performance in the applying domain.

Furthermore, students' scientific reading literacy may contribute substantially to success in the TIMSS applying domain. Many TIMSS science items present information through texts, diagrams, tables, and real-life scenarios that require careful interpretation before scientific concepts can be applied. Students with limited reading comprehension may struggle to identify relevant information, even when they possess the necessary scientific knowledge [66], [67]. Therefore, efforts to improve science achievement should integrate literacy development with science instruction rather than treating them as separate educational goals.

From a broader perspective, the findings reinforce the argument that educational quality should not be evaluated solely through students' mastery of scientific content. The ability to apply knowledge represents a more authentic indicator of scientific literacy because it reflects students' readiness to address real-world challenges. As contemporary societies increasingly require individuals who can analyze information, make evidence-based decisions, and solve complex problems, strengthening the applying domain becomes an essential objective of science education reform [68], [69]. Thus, improving students' applying skills is not merely a strategy for increasing TIMSS performance but also an investment in developing scientifically literate citizens for the twenty-first century.

The findings of this study are supported by several recent international studies highlighting the importance of instructional and contextual factors in students' science achievement. Pongsophon [35], through a multilevel analysis of TIMSS 2019 data, found that instructional clarity, students' attitudes toward science, school academic emphasis, and literacy readiness significantly influenced science achievement. Similarly, Marôco et al. [34] reported that students' socioeconomic resources, motivation, confidence in science, teacher-related factors, and national development indicators were significant predictors of science literacy across participating TIMSS 2019 countries. Furthermore, Song and Cutumisu [70] demonstrated that differences in science curriculum organization and implementation were associated with variations in students' science achievement, suggesting that curriculum structure plays an important role in shaping learning outcomes. Collectively, these studies reinforce the present findings that disparities in students' applying skills across Indonesia, Laos, and Cyprus are likely influenced by differences in curriculum implementation, instructional quality, learning environments, and students' readiness to engage with contextualized scientific problems.

The present study contributes a novel perspective to the TIMSS literature by focusing specifically on the applying cognitive domain in science and comparing countries from different educational and socio-economic contexts, namely Indonesia, Laos, and Cyprus. While previous studies have predominantly examined overall science achievement or investigated the influence of student, teacher, and school characteristics on TIMSS performance, limited attention has been given to cross-national differences in students' ability to apply scientific concepts as a distinct cognitive competency. Furthermore, most comparative TIMSS studies have focused on countries within similar geographical regions or educational systems. By contrasting Southeast Asian countries with a European context, this study provides a broader understanding of how variations in curriculum implementation, instructional practices, and learning environments may influence the development of scientific application skills [63], [71]. Therefore, the study extends existing TIMSS research by offering empirical evidence that highlights the importance of the applying domain as a critical dimension of scientific literacy and by identifying contextual factors that may explain differences in students' problem-solving abilities across diverse educational settings.

This study contributes to the growing body of literature on science education by highlighting the importance of the applying domain as a key indicator of scientific literacy and problem-solving competence. The findings suggest that improving students' ability to apply scientific concepts requires instructional approaches that extend beyond content memorization and emphasize inquiry, experimentation, and contextual problem solving. For policymakers, the results provide empirical evidence supporting curriculum reforms that promote higher-order thinking skills and authentic assessment practices [72], [73]. For teachers, the study underscores the need to design learning activities that encourage students to transfer scientific knowledge to real-life situations. Furthermore, the cross-national comparison offers valuable insights that may assist developing countries in identifying effective educational practices that can strengthen students' scientific application skills and improve future performance in international assessments such as TIMSS.

Several limitations should be considered when interpreting the findings of this study. First, the research relied exclusively on secondary data obtained from the TIMSS 2019 international database, limiting the ability to explore causal relationships between educational practices and student achievement. Second, the analysis focused solely on the applying cognitive domain and did not examine potential interactions with the knowing and reasoning domains that may also influence science performance. Third, contextual interpretations regarding curriculum implementation, teacher practices, and learning environments were derived from existing literature rather than direct classroom observations or interviews. Consequently, the explanations offered should be interpreted cautiously. Finally, the study involved only three participating countries, which may limit the generalizability of the findings to other educational contexts [74], [75]. Despite these limitations, the study provides a useful comparative perspective on students' scientific application skills and offers a foundation for future research employing more comprehensive datasets and mixed-method approaches.

5. CONCLUSION

Based on analysis of TIMSS 2019 data, this study concludes that Indonesian students' achievement in the science application domain remains low compared to that in Laos and Cyprus. The percentage of correct answers to questions requiring the application of scientific concepts indicates that Indonesian students are not yet fully capable of using scientific knowledge to solve contextual problems. Laos demonstrated slightly better achievement, but still in the low-medium category, while Cyprus had higher achievement in the application domain and fell into the medium category. This finding confirms the gap in the ability to apply scientific concepts between countries, influenced by the learning orientation of each education system. The results of this study indicate that science learning that emphasizes a conceptual approach alone is not sufficient to improve application skills. Countries with better performance tend to consistently implement inquiry-based learning, problem-solving, and real-life contexts. Therefore, the application domain in TIMSS can be used as an important indicator for evaluating the effectiveness of science learning implementation in schools. This finding reinforces the urgency of a paradigm shift in science learning in Indonesia toward more applicable and meaningful learning. Based on these findings, it is recommended that science learning policies and practices in Indonesia place greater emphasis on strengthening conceptual application skills through problem-based learning, experiments, and authentic contexts. Teachers should be encouraged to design activities and assessments that align with the characteristics of TIMSS questions, particularly in the applying domain. Future research is recommended to use TIMSS item-level data to allow for a more detailed analysis of the applying domain. Furthermore, further research could combine TIMSS data with primary data such as classroom observations and teacher interviews. This mixed approach would provide a more comprehensive picture of the learning practices that influence applying achievement. Research could also focus on developing and testing learning models based on the TIMSS framework. Thus, future research will be not only descriptive but also solution-oriented.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the International Association for the Evaluation of Educational Achievement (IEA) for providing open access to the TIMSS 2019 international database used in this study. Appreciation is also extended to all institutions and researchers whose reports and documentation supported the data analysis process. The authors are grateful to colleagues and reviewers who provided valuable feedback that contributed to the improvement of this manuscript.

AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft Preparation, and Visualization, J; Writing – Review & Editing, J and VS; Supervision and Project Administration, J and S. All authors have read, reviewed, and provided approval for the final version of the manuscript submitted for publication.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

INFORMED CONSENT STATEMENT

All images in this article have been authorized and are the property of the authors.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

REFERENCES

[1] A. Asrizal, Y. Yurnetti, and E. A. Usman, "ICT thematic science teaching material with 5e learning cycle model to develop students' 21st-century skills," *J. Pendidik. IPA Indones.*, vol. 11, no. 1, pp. 61–72, 2022, doi: 10.15294/jpii.v11i1.33764.

[2] H. A. Tuong, P. S. Nam, N. H. Hau, V. T. B. Tien, Z. Lavicza, and T. Hougton, "Utilising stem-based practices to enhance mathematics teaching in vietnam: Developing students' real-world problem solving and 21st century skills," *J. Technol. Sci. Educ.*, vol. 13, no. 1, pp. 73–91, 2023, doi: 10.3926/jotse.1790.

[3] W. Agustina, I. N. S. Degeng, H. Praherdhiono, and S. R. Lestaric, "The effect of blended project-based learning for enhancing student's scientific literacy skills: An experimental study in university," *Pegem Egit. ve Ogr. Derg.*, vol. 13, no. 1, pp. 223–233, 2022, doi: 10.47750/pegegog.13.01.24.

[4] F. Fahmi, N. Chalisah, M. Istyadji, Y. Irhasyuarna, and M. Kusasi, "Scientific literacy on the topic of light and optical instruments in the innovation of science teaching materials," *J. Inov. Pendidik. IPA*, vol. 8, no. 2, pp. 154–163, 2022, doi: 10.21831/jipi.v8i2.41343.

[5] Y. Wardat, S. Belbase, and H. Tairab, "Mathematics teachers' perceptions of trends in international mathematics and science study (TIMSS)-related practices in abu dhabi emirate schools," *Sustain.*, vol. 14, no. 9, pp. 1–26, 2022, doi: 10.3390/su14095436.

[6] T. Nilsen, H. Kaarstein, and A. C. Lehre, "Trend analyses of TIMSS 2015 and 2019: School factors related to declining performance in mathematics," *Large-Scale Assessments Educ.*, vol. 10, no. 1, pp. 1–19, 2022, doi: 10.1186/s40536-022-00134-8.

[7] A. Bhutoria and N. Aljabri, "Managerial practices and school efficiency: A data envelopment analysis across OECD and MENA countries using TIMSS 2019 data," *Large-Scale Assessments Educ.*, vol. 10, no. 24, pp. 1–25, 2022, doi: 10.1186/s40536-022-00147-3.

[8] N. Teig, R. Scherer, and R. V. Olsen, "A systematic review of studies investigating science teaching and learning: over two decades of TIMSS and PISA," *Int. J. Sci. Educ.*, vol. 44, no. 12, pp. 2035–2058, 2022, doi: 10.1080/09500693.2022.2109075.

[9] S. Dinçer, "Bridging the gap in technology integration in education: An examination of science teachers' competencies and needs," *J. Turkish Sci. Educ.*, vol. 21, no. 4, pp. 620–634, 2024, doi: 10.36681/TUSED.2024.033.

[10] I. Buabeng and B. Amo-Darko, "Curriculum reforms without foundation: The effects of inadequate preparation in curriculum reforms on Ghanaian teachers and the education system," *Curric. Perspect.*, vol. 45, no. 2, pp. 133–147, 2025, doi: 10.1007/s41297-025-00309-7.

[11] S. Abdolalipour, H. Namdar-Areshtanab, S. Ghaffarifar, R. Ghaffari, and M. Mirghafourvand, "Exploring the experiences of medical students regarding the factors affecting academic achievement: a qualitative study," *BMC Med. Educ.*, vol. 24, no. 1, pp. 1–16, 2024, doi: 10.1186/s12909-024-06294-1.
[12] F. S. Altuwaijri and M. A. Ferrario, "Factors affecting Agile adoption: An industry research study of the mobile app sector in Saudi Arabia," *J. Syst. Softw.*, vol. 190, pp. 1–16, 2022, doi: 10.1016/j.jss.2022.111347.
[13] Y. F. Lay and A. L. Chandrasegaran, "The contribution of teacher preparation on grade 8 students' science achievement in TIMSS: A comparative study between Malaysia and Singapore," *J. Balt. Sci. Educ.*, vol. 17, no. 4, pp. 576–589, 2024, doi: 10.33225/jbse/18.17.576.
[14] B. Coşkun and E. Karadağ, "The effect of student and school characteristics on TIMSS 2015 science and mathematics achievement: The case of Türkiye," *J. Pedagog. Res.*, vol. 7, no. 1, pp. 203–227, 2023, doi: 10.33902/JPR.202318875.
[15] M. Sa'diyah, C. Sa'dijah, and S. Susiswo, "Students' ability to formulate situation mathematically from context-based mathematics problems," *TEM J.*, vol. 13, no. 2, pp. 1443–1451, 2024, doi: 10.18421/TEM132-58.
[16] F. Constantinou, "Assessing students' application skills through contextualized tasks: Toward a more comprehensive framework for embedding test questions in context," *Pract. Assessment, Res. Eval.*, vol. 29, no. 10, pp. 1–19, 2024, doi: 10.7275/pare.2103.
[17] M. Ozkan, K. Cek, and S. Z. Eyupoglu, "Sustainable development and customer satisfaction and loyalty in north cyprus: The mediating effect of customer identification," *Sustain.*, vol. 14, no. 9, pp. 1–13, 2022, doi: 10.3390/su14095196.
[18] M. B. Saydam, A. Ozturen, and C. Kilic, "Cultural heritage tourism in North Cyprus: Findings from in-depth interviews with experts," *Worldw. Hosp. Tour. Themes*, vol. 14, no. 4, pp. 349–364, Jul. 2022, doi: 10.1108/WHATT-03-2022-0035.
[19] Y. Wardat, S. Belbase, H. Tairab, R. A. Takriti, M. Efstratopoulou, and H. Dodeen, "The influence of student factors on students' achievement in the trends in international mathematics and science study in abu dhabi emirate schools," *Front. Psychol.*, vol. 12, no. 424, pp. 1–23, 2022, doi: 10.3389/fpsyg.2023.1168032.
[20] J. Faddar and C. C. Kjeldsen, "Perspectives on educational effectiveness in science and mathematics: The role of non-cognitive measures in TIMSS. Introduction to a special issue," *Stud. Educ. Eval.*, vol. 75, p. 101218, Dec. 2022, doi: 10.1016/j.stueduc.2022.101218.
[21] A. Duggan, A. Karakolidis, A. Clerkin, L. Gilleece, and R. Perkins, "Trends in educational inequalities in Ireland's primary schools: an analysis based on TIMSS data (2011–2019)," *Large-Scale Assessments Educ.*, vol. 11, no. 1, pp. 1–21, 2023, doi: 10.1186/s40536-023-00188-2.
[22] I. V. S. Mullis and M. O. Martin, "IEA's TIMSS and PIRLS: Measuring long-term trends in student achievement," 2022, pp. 1–20. doi: 10.1007/978-3-030-38298-8_15-1.
[23] H. W. Ker, Y. H. Lee, and S. M. Ho, "The impact of work environment and teacher attributes on teacher job satisfaction," *Educ. Process Int. J.*, vol. 11, no. 1, pp. 28–39, 2022, doi: 10.22521/edupij.2022.111.3.
[24] L. Yuan, "EFL teacher-student interaction, teacher immediacy, and Students' academic engagement in the Chinese higher learning context," *Acta Psychol. (Amst).*, vol. 244, no. November, pp. 1–10, 2024, doi: 10.1016/j.actpsy.2024.104185.
[25] Z. N. Khlaif *et al.*, "University teachers' views on the adoption and integration of generative ai tools for student assessment in higher education," *Educ. Sci.*, vol. 14, no. 10, pp. 1–24, 2024, doi: 10.3390/educsci14101090.
[26] S. Aravantinos, K. Lavidas, I. Voulgari, S. Papadakis, T. Karalis, and V. Komis, "Educational approaches with aι in primary school settings: A systematic review of the literature available in scopus," *Educ. Sci.*, vol. 14, no. 7, pp. 1–27, 2024, doi: 10.3390/educsci14070744.
[27] L. Zhao, B. Zhao, and C. Li, "Alignment analysis of teaching–learning-assessment within the classroom: How teachers implement project-based learning under the curriculum standards," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 5, no. 1, pp. 1–23, 2023, doi: 10.1186/s43031-023-00078-1.
[28] M. Assalihee, N. Bakoh, Y. Boonsuk, and J. Songmuang, "Transforming islamic education through lesson study (LS): A Classroom-based approach to professional development in Southern Thailand," *Educ. Sci.*, vol. 14, no. 9, pp. 1–23, 2024, doi: 10.3390/educsci14091029.
[29] A. S. Bulut and Z. T. Şener, "Analysis of secondary school mathematics curriculum learning outcomes by TIMSS-2019 cognitive domain skills," *Türk Akad. Yayınlar Derg.*, vol. 7, no. 1, pp. 303–328, 2023, doi: 10.29329/tayjournal.2023.537.14.
[30] A. Balfaqeeh, N. Mansour, and S. Forawi, "Factors influencing students' achievements in the content and cognitive domains in TIMSS 4th grade science and mathematics in the United Arab Emirates," *Educ. Sci.*, vol. 12, no. 9, pp. 1–22, 2022, doi: 10.3390/educsci12090618.
[31] L. Amalia, M. Makmuri, and L. El Hakim, "Learning design: To improve mathematical problem-solving skills using a contextual approach," *JIIP - J. Ilm. Ilmu Pendidik.*, vol. 7, no. 3, pp. 2353–2366, 2024, doi: 10.54371/jiip.v7i3.3455.
[32] S. C. Kong and Y. Yang, "A human-centered learning and teaching framework using generative artificial intelligence for self-regulated learning development through domain knowledge learning in K-12 settings," *IEEE Trans. Learn. Technol.*, vol. 17, pp. 1588–1599, 2024, doi: 10.1109/TLT.2024.3392830.
[33] R. Haridza and L. Ding, "Enhancing students' reasoning skills by asking students to provide evidence-based explanations in science classrooms: findings from TIMSS 2019," *Int. J. Sci. Educ.*, vol. 47, no. 17, pp. 2302–2327, Nov. 2025, doi: 10.1080/09500693.2024.2385067.
[34] J. Marôco, H. Harju-Lukkainnen, and J. Rautopuro, "Worldwide predictors of science literacy in lower-secondary students: a TIMSS 2019 analysis," *Int. J. Sci. Educ.*, vol. 48, no. 4, pp. 580–598, 2024, doi: 10.1080/09500693.2024.2394239.
[35] P. Pongsophon, "Multilevel analysis of factors that determine the science achievement of fourth-grade students in TIMSS 2019," *Sci. Educ. Int.*, vol. 34, no. 2, pp. 86–95, 2023.

[36] L. Appels, S. De Maeyer, and P. Van Petegem, "'Re-thinking equity: The need for a multidimensional approach in evaluating educational equity through TIMSS data,'" *Large-Scale Assessments Educ.*, vol. 12, no. 1, pp. 1–23, 2024, doi: 10.1186/s40536-024-00227-6.

[37] A. L. Tan, Y. S. Ong, Y. S. Ng, and J. H. J. Tan, "STEM problem solving: Inquiry, concepts, and teasoning," *Sci. Educ.*, vol. 32, no. 2, pp. 381–397, 2023, doi: 10.1007/s11191-021-00310-2.

[38] V. D. Arthamena, M. Ayubi, S. Atun, and S. E. Putri, "Effectiveness of a problem-based learning model integrated with socio-scientific issues to improve science process skills of high school students," *JKPK (Jurnal Kim. dan Pendidik. Kim.*, vol. 10, no. 1, pp. 203–219, 2025, doi: 10.20961/jkpk.v10i1.97608.

[39] A. A. Rafiq, M. B. Triyono, and I. W. Djatmiko, "The integration of inquiry and problem-based learning and its impact on increasing the vocational student involvement," *Int. J. Instr.*, vol. 16, no. 1, pp. 659–684, 2023, doi: 10.29333/iji.2023.16137a.

[40] L. Shengqiang, S. Srikhao's, and A. Nankhantee, "Combining inquiry-based learning and collaborative learning: A new model for improving students' teamwork and problem-solving skills," *J. Educ. Educ. Dev.*, vol. 12, no. 1, pp. 13–38, 2025, doi: 10.22555/joeed.v12i1.1296.

[41] S. Sujatmika, M. Masykuri, B. A. Prayitno, and S. Sutarno, "Fostering critical thinking in science education: Exploring effective pedagogical models," *International Journal of Advanced and Applied Sciences*, vol. 11, no. 7, pp. 149-159, doi: 10.21833/ijaas.2024.07.016.

[42] A. Arda, S. Supriyatman, and A. Afadil, "A review of students' critical thinking skills in science learning in Indonesia," *J. Pendidik. MIPA*, vol. 25, no. 4, pp. 1787–1798, 2024, doi: 10.23960/jpmipa/v25i4.pp1787-1798.

[43] D. Sapriyadin, S. Sutopo, and H. Wisodo, "Influence of inquiry learning on concept mastery ability and physics problem solving ability of students on work and energy material," *J. Penelit. Pendidik. IPA*, vol. 9, no. 2, pp. 734–744, 2023, doi: 10.29303/jppipa.v9i2.3253.

[44] G. Roorda, S. de Vries, and A. E. Smale-Jacobse, "Using lesson study to help mathematics teachers enhance students' problem-solving skills with teaching through problem solving," *Front. Educ.*, vol. 9, pp. 1–17, 2024, doi: 10.3389/feduc.2024.1331674.

[45] N. W. Septia, I. Indrawati, J. Juriana, and R. Rudini, "An analysis of students' difficulties in reading comprehension," *EEdJ English Educ. J.*, vol. 2, no. 1, pp. 11–22, 2022, doi: 10.32923/eedj.v2i1.2519.

[46] L. Kanniainen, C. Kiili, A. Tolvanen, J. Utriainen, M. Aro, D. J. Leu, and P. H. Leppänen, "Online research and comprehension performance profiles among sixth-grade students, including those with reading difficulties and/or attention and executive function difficulties," *Read. Res. Q.*, vol. 57, no. 4, pp. 1213–1235, 2022, doi: 10.1002/rrq.463.

[47] M. A. Moreira, B. R. Arcas, T. G. Sánchez, R. B. García, and M. J. R. Melero, "Teachers' pedagogical competences in higher education: A systematic literature review," *J. Univ. Teach. Learn. Pract.*, vol. 20, no. 1, pp. 90–123, 2023, doi: 10.53761/1.20.01.07.

[48] S. Ranta, J. Kangas, H. Harju-Luukkainen, T. Ukkonen-Mikkola, M. Neitola, J. Kinos, N. Sajaniemi, and A. Kuusisto, "Teachers' pedagogical competence in finnish early childhood education—A narrative literature review," *Educ. Sci.*, vol. 13, no. 8, pp. 1–15, 2023, doi: 10.3390/educsci13080791.

[49] L. Rohach, N. Petiy, O. Shovak, and N. Shtefaniuk, "Student-centered learning and teacher-centered learning in EFL context," *Сучасні дослідження з іноземної філології*, vol. 26, no. 2, pp. 382–393, 2024, doi: 10.32782/2617-3921.2024.26.382-393.

[50] J. Busa and S. J. Chung, "The effects of teacher-centered and student-centered approaches in TOEIC reading instruction," *Educ. Sci.*, vol. 14, no. 2, pp. 1–13, 2024, doi: 10.3390/educsci14020181.

[51] E. Damianidou, "Obligatory professional training for in-service teachers: Worthy time or a waste of time?," *Eur. J. Teach. Educ.*, vol. 47, no. 1, pp. 23–40, Jan. 2024, doi: 10.1080/02619768.2021.1961734.

[52] J. Schäfer, T. Reuter, J. Karbach, and M. Leuchter, "Domain-specific knowledge and domain-general abilities in children's science problem-solving," *Br. J. Educ. Psychol.*, vol. 94, no. 2, pp. 346–366, 2024, doi: 10.1111/bjep.12649.

[53] F. Arianto and M. Hanif, "Evaluating metacognitive strategies and self-regulated learning to predict primary school students' self-efficacy and problem-solving skills in science learning," *J. Pedagog. Res.*, vol. 8, no. 3, pp. 301–319, 2024, doi: 10.33902/JPR.202428575.

[54] A. I. Hamzani, T. V. Widyastuti, N. Khasanah, and M. H. M. Rusli, "Legal research method: Theoretical and implementative review," *Int. J. Membr. Sci. Technol.*, vol. 10, no. 2, pp. 3610–3619, 2023, doi: 10.15379/ijmst.v10i2.3191.

[55] M. Nazarizadeh, A. Khorasani, G. Shams, and A. Ebrahimi, "Managerial factors influencing the empowerment of student teachers: Developing and validating a model based on a mixed-methods approach (qualitative–qualitative–quantitative)," *Assess. Pract. Educ. Sci.*, vol. 3, no. 4, pp. 1–17, 2025, doi: 10.61838/japes.128.

[56] M. Pietsch, B. Aydin, and S. Gümüş, "Putting the instructional leadership–student achievement relation in context: A meta-analytical big data study across cultures and time," *Educ. Eval. Policy Anal.*, vol. 47, no. 1, pp. 29–64, Mar. 2025, doi: 10.3102/01623737231197434.

[57] Y. Zhu and G. Kaiser, "Impacts of classroom teaching practices on students' mathematics learning interest, mathematics self-efficacy and mathematics test achievements: A secondary analysis of Shanghai data from the international video study Global Teaching InSights," *ZDM - Math. Educ.*, vol. 54, no. 3, pp. 581–593, 2022, doi: 10.1007/s11858-022-01343-9.

[58] N. Lestari, P., and S. Suyanto, "A systematic literature review about local wisdom and sustainability: Contribution and recommendation to science education," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 20, no. 2, pp. 1–19, 2024, doi: 10.29333/ejmste/14152.

[59] A. Peršić and T. Straza, "Implementing the UNESCO recommendation on open science for an equitable and just transition to open science," *Sch. Commun. Ana*, vol. 84, no. 10, pp. 377–381, 2023.

[60] S. M. Maiteh and E. Szeréna Zoltán, "Descriptive comparative analysis of post-disaster settlements," *Int. J. Disaster*

Risk Reduct., vol. 95, pp. 1–15, 2023, doi: 10.1016/j.ijdrr.2023.103879.

[61] S. Huh, "Are ChatGPT's knowledge and interpretation ability comparable to those of medical students in Korea for taking a parasitology examination?: A descriptive study," *J. Educ. Eval. Health Prof.*, vol. 20, pp. 1–5, 2023, doi: 10.3352/jeehp.2023.20.1.

[62] M. Javaid, A. Haleem, R. P. Singh, S. Khan, and I. H. Khan, "Unlocking the opportunities through ChatGPT tool towards ameliorating the education system," *BenchCouncil Trans. Benchmarks, Stand. Eval.*, vol. 3, no. 2, pp. 1–12, 2023, doi: 10.1016/j.tbench.2023.100115.

[63] G. Gusrianto, O. Ouarniki, Z. Zakarya, T. W. Mahfuzh, A. Ali, and B. R. Simbolon, "Innovation of madrasa teacher teaching: Transformation of teacher teaching creativity through performance and motivation engagement in teaching and learning," *J. Instr. Islam. Relig. Educ.*, vol. 1, no. 2, pp. 71–86, 2025, doi: 10.63826/jiire.v1i2.8.

[64] S. Nur'ariyani, J. Jumyati, Y. Yuliyanti, L. Nulhakim, and S. M. Leksono, "Scientific approach to learning science in elementary schools," *J. Penelit. Pendidik. IPA*, vol. 9, no. 8, pp. 6659–6666, 2023, doi: 10.29303/jppipa.v9i8.3680.

[65] E. Kastriti, M. Kalogiannakis, S. Psycharis, and D. Vavougios, "The teaching of natural sciences in kindergarten based on the principles of STEM and STEAM approach," *Adv. Mob. Learn. Educ. Res.*, vol. 2, no. 1, pp. 268–277, 2022, doi: 10.25082/amler.2022.01.011.

[66] P. Peng, W. Wang, M. J. Filderman, W. Zhang, and L. Lin, "The active ingredient in reading comprehension strategy intervention for struggling readers: A bayesian network meta-analysis," *Rev. Educ. Res.*, vol. 94, no. 2, pp. 228–267, 2024, doi: 10.3102/00346543231171345.

[67] A. Z. Macalalag, A. Kaufmann, B. Van Meter, A. Ricketts, E. Liao, and G. Ialacci, "Socioscientific issues: Promoting science teachers' pedagogy on social justice," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 6, no. 1, pp. 1–16, 2024, doi: 10.1186/s43031-024-00118-4.

[68] D. L. Morris, "Rethinking Science Education Practices: Shifting from Investigation-Centric to Comprehensive Inquiry-Based Instruction," *Educ. Sci.*, vol. 15, no. 1, pp. 1–18, 2025, doi: 10.3390/educsci15010073.

[69] F. I. L. Pinar, A. A. E. Panergayo, R. R. Sagcal, D. P. Acut, L. S. Roleda, and M. S. Prudente, "Fostering scientific creativity in science education through scientific problem-solving approaches and STEM contexts: A meta-analysis," *Discip. Interdiscip. Sci. Educ. Res.*, vol. 7, no. 1, pp. 1–17, 2025, doi: 10.1186/s43031-025-00137-9.

[70] Y. Song and M. Cutumisu, "Using machine learning to predict student science achievement based on science curriculum type in TIMSS 2019," *Int. J. Sci. Educ.*, vol. 47, no. 9, pp. 1105–1149, Jun. 2025, doi: 10.1080/09500693.2024.2359099.

[71] J. R. Alvarado and R. P. Galigao, "Assessing the effectiveness of curriculum implementation across global educational systems," *Int. J. Humanit. Soc. Sci.*, vol. 3, no. 4, pp. 263–272, 2024.

[72] T. K. Respati, "Implementing authentic assessment for assessing higher order thinking skill (HOTS) in curriculum 2013," *Leks. J. Pendidik. Bahasa, Sastra, dan Budaya*, vol. 1, no. 1, pp. 32–37, Apr. 2023, doi: 10.59632/leksikon.v1i1.104.

[73] K. H. Safitri, E. Sofiyah, S. Kusmana, and J. Jaja, "Authentic assessment based on higher order thinking skills in improving student literacy," *Br. J. Teach. Educ. Pedagog.*, vol. 3, no. 3, pp. 172–181, 2024, doi: 10.32996/bjtep.2024.3.3.14.

[74] X. Zhao and D. Wang, "Unpacking the antecedents of boredom and its impact on university learners' engagement in languages other than english: A qualitative study in the distance online learning context," *Int. J. Appl. Linguist. (United Kingdom)*, vol. 35, no. 3, pp. 1121–1133, 2025, doi: 10.1111/ijal.12680.

[75] R. Schimmelpfennig, C. Elbæk, P. Mitkidis, A. Singh, and Q. Roberson, "The 'WEIRDEST' organizations in the world? Assessing the lack of sample diversity in organizational research," *J. Manage.*, vol. 51, no. 6, pp. 2460–2487, 2025, doi: 10.1177/01492063241305577.