SciEd

SEAQIS Journal of Science Education

vol. 6 / no. 1 / June 2026
E-ISSN 2964-7533
P-ISSN 2987-8101

Indexed by: Google Scholar, GARUDA, DOAJ, Dimensions

DOI prefix: 10.58249 by Crossref

www.journal.qitepinscience.org

SciEd

SEAQIS Journal of Science Education

Director's Message

It is a distinct honor to welcome you to The SEAQIS Journal of Science Education (SciEd), Volume 6, Number 1 (2026). As an institution dedicated to raising the standards of science education, SEAMEO QITEP in Science (SEAQIS) continuously strives to champion context-responsive pedagogy and scientific literacy. This volume embodies that overarching mission, showcasing how cross-border collaboration can address the immediate and evolving needs of classrooms worldwide. By bringing together diverse perspectives from the Philippines, Indonesia, Nigeria, and Malawi, this edition underscores a shared global commitment to transforming educational systems at all levels, from primary classrooms to vocational and secondary tracks.

The research presented in this issue highlights critical pathways for future-proofing science education. From utilizing adaptive instructional models like the Teaching at the Right Level (TaRL) framework to exploring cutting-edge technology integration via solar cells and Arduino in vocational schools, these studies reflect our current educational reality. Furthermore, this volume addresses institutional readiness, particularly regarding how secondary school educators are actively positioning themselves at the forefront of the United Nations Sustainable Development Goals (SDGs). It is our sincere hope that the strategic insights and systemic assessments compiled in this issue will serve as a vital guide for policymakers, school leaders, and educational stakeholders aiming to foster meaningful, resilient, and forward-thinking science programs globally.

Sincerely,
Reza Setiawan, S.Si., M.T.
Director, SEAMEO QITEP in Science

From the Editor-in-Chief

I am proud to present the latest release of The SEAQIS Journal of Science Education (SciEd), Volume 6, Number 1 (2026). The five manuscripts curated for this edition offer an exceptional look into the practical, cognitive, and professional dimensions of modern science teaching. As an academic journal, our primary goal is to maintain the highest levels of scholarly rigor and ensure that the evidence-based findings we publish can genuinely advance classroom practices. This issue accomplishes exactly that, offering deep insights into laboratory management practices, student-teacher learning outcomes, and innovative problem-solving methodologies that strengthen the global discourse on science pedagogy.

An issue of this caliber is entirely the result of collective dedication, and I would like to extend my profound gratitude to everyone involved in its creation. First, I thank our contributing authors from the Philippines, Indonesia, Nigeria, and Malawi for entrusting SciEd with their valuable research and for their diligence during the revision process. I am equally indebted to our expert peer reviewers, whose rigorous evaluations, critical feedback, and voluntary time have preserved the high standards of our publication. Finally, I want to express my heartfelt appreciation to our dedicated editorial board, copyeditors, and production team. Their tireless behind-the-scenes work in managing the publication cycle, refining manuscripts, and overseeing the layout process has made this volume possible. We thank our readers for your continued support and trust that these pages will enrich your research and instructional endeavors.

Warm Regards,
Dr. Elly Herliani, M.Phil., M.Si.

Table of Contents

SEAQIS Journal of Science Education (SciEd)

Volume 6 | No 1 | June 2026

E-ISSN 2964-7533 | P-ISSN 2987-8101

The Desk

SEAQIS Journal of Science Education (SciEd)

Volume 6 | No 1 | June 2026
E-ISSN 2964-7533 | P-ISSN 2987-8101

SEAQIS Journal of Science Education (SciEd), The Southeast Asian Journal of Science Education, is a scientific publication of SEAMEO QITEP in Science published once a year. It contains scientific research articles in Science Education and a review article. A guide for the author can be found on the website.

SciEd Editorial Office
SEAMEO QITEP in Science, Kompleks Balai Besar Guru dan Tenaga Kependidikan Provinsi Jawa Barat, Gedung B, Jl. Dr. Cipto No.9, Bandung, West Java 40171, Indonesia
E-mail: seaqis.journal@seameo.id | Home page: journal.qitepinscience.org

Cover:
Policy-Early Childhood-STEM-innovation

2026

SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 6, No: 1, PP: 01-09
www.journal.qitepinscience.org

Research Paper

Open Accsess

Perceived Differences in Course Learning Outcomes Between Science Interns and Cooperating Teachers

Mercy Joy R. Mendez, PhD [1*]

[1] *College of Teacher Education Faculty, University of Mindanao, Matina, Davao City, Philippines*
**Corresponding author, e-mail: mercyjoy_mendez@umindanao.edu.ph*

Article history:
Received: June 1, 2025
Revised: March 7, 2026
Accepted: April 14, 2026

Abstract

This study aims to examine the differences between science interns' perceptions of their course learning outcomes and their cooperating teachers' evaluations to better understand gaps in self-assessment and inform strategies for improving teacher preparation and mentoring practices. The data for this study were collected from 228 science interns and 219 cooperating teachers from selected universities and colleges in Region XI, Philippines, through face-to-face and online surveys via Google Forms. An adapted standardised questionnaire was used to assess specific course learning outcomes, including critical thinking, communication, career and teamwork, global understanding and citizenship, and academic development and educational success. A quantitative descriptive research design was employed, and purposive sampling was used to select the respondents. Subject matter experts reviewed the questionnaire to ensure content validity, and a pilot test confirmed its reliability (Cronbach's alpha = 0.856). Data were analysed using the weighted mean and the paired t-test. Results showed that both science interns (M=4.52, SD=0.3) and their cooperating teachers (M=4.32, SD=0.43) reported high levels of attainment for the assessed learning outcomes. The paired t-test indicated a statistically significant difference between the two groups' ratings (t = 31.224, p = 0.00), with cooperating teachers' evaluations slightly lower than interns' self-assessments. These findings suggest that while interns generally perceive themselves as performing well, cooperating teachers provide a more conservative perspective. Establishing clear and consistent evaluation criteria and providing targeted feedback can help align perceptions, enhance self-awareness, and support professional development of science interns.

Keywords: Course Learning Outcomes aAtainment, Internship, Education

Introduction

Preparing effective teachers goes beyond teaching content. It depends on how pre-service teachers are evaluated and guided. Research shows that mentors often give higher scores than university supervisors, leading to inconsistent assessments (Nel, 2025). Interns may struggle with self-efficacy, while cooperating teachers balance competing responsibilities, complicating supervision (Plopino & Carbonell, 2025). Self-assessment can promote growth but may mislead without clear guidance (Kilic & Saglam, 2023).

Meanwhile, practitioner feedback, whether affirming, restrictive, or emotionally charged, shapes how interns view their own performance relative to their mentors' perspectives (Tubal et al., 2025). These challenges highlight a critical need for structured, reflective, and aligned evaluation practices that effectively support the professional development of future teachers.

Student interest in a teaching career significantly influences learning outcomes and overall success (Arif et al., 2022). In addition, Dela Fuente (2021) highlighted that the success of pre-service teachers in professional examinations is important for both individuals and the institutions that grant their degrees, as it reflects the quality of education provided.

Critical thinking skills are essential for addressing the challenges of the 21st century, enabling individuals to effectively analyse evidence, make reasoned judgments, and understand interconnected systems, thus facilitating problem-solving and decision-making (Farillon, 2022).

Furthermore, the development of collaborative communication skills in academic settings enhances graduates' employability (Lewis, 2021; Rosselot-Merritt & Bloch, 2020; Blakeman & Taylor, 2019). Consequently, the findings of Hidayatulloh and Ashoumi (2022) indicated that both communication and collaboration skills independently and concurrently impacted students' readiness for work.

In education, careers entail teaching and collaborating with peers, administrators, and parents to foster an optimal learning environment. Teamwork involves coordinating a group of skilled individuals towards a shared goal, operational objective, and effective self-management (Ifechi et al., 2022); and it is the sum of the abilities of the individuals who make up the team (Lee, 2021). Meanwhile, well-defined career goals empower university students to self-regulate their learning and concentrate their efforts throughout their academic journey (Floris et al., 2023).

Moreover, Bernardo et al. (2022) revealed that Filipino students' positive attitudes toward global citizenship education are influenced by their environmental concerns, willingness to participate in related activities, sense of connection with the world, willingness to address littering, and engagement in class leadership voting.

The final indicator, academic development and educational success, as described by Boholano et al. (2021) centres on learners' knowledge, understanding, and ability to succeed. With support and instructional guidance, successful learners can construct meaningful and coherent representations of knowledge over time (Lucas & Corpuz, 2020).

Additionally, learners' achievement across all disciplines is a significant focus in education, with motivation, as emphasised by Wang and Guan (2020), being a critical factor that can lead to various positive outcomes. Promoting social and emotional competencies, such as emotional management, goal attainment, empathy, relationship-building, and decision-making, is crucial for academic and life success (Mahoney et al., 2020).

This study is anchored in the Input–Environment–Output model proposed by Astin (1993), which emphasises the interdependence of student inputs, environment, and outputs. Student *inputs* include characteristics and backgrounds such as demographics and academic preparedness; the *environment* refers to academic programmes, extracurricular activities, and support services; and *outputs* include outcomes such as academic achievement, personal development, and career success. Examining the perceived differences in course learning outcomes attainment between science interns and their cooperating teachers provides insights into the alignment between pre-service teachers' self-assessments and mentor evaluations.

The study's primary aim is to determine the level of course learning outcomes attainment in terms of critical thinking, communication, career development and teamwork, global understanding and citizenship, and academic development and educational success among science interns and their cooperating teachers. Second, the study aims to determine whether there is a significant difference in perceptions of course learning outcomes attainment between science interns and cooperating teachers. Third, the study hypothesises that there is no significant difference in course learning outcomes attainment between science interns and cooperating teachers.

Methodology

Respondents of the Study

The study's respondents were the BSED science interns of AY 2023-2024 from selected universities and colleges in Region XI, Philippines, and their corresponding cooperating teachers. Only 228 actively participating science interns out of the total population of 254, along with 219 cooperating teachers, were qualified to participate in the survey.

Based on Raosoft computation, the recommended sample size for the given population was 154; therefore, the 228 science interns and 219 cooperating teachers in this study were highly acceptable since they were more than the recommended sample size.

Furthermore, purposive sampling was used to identify the respondents from each selected higher education institution since the researcher purposely chose BSED science interns and corresponding science cooperating teachers for this study. Only those qualified and willing to participate in the survey were considered. Accordingly, this sampling technique was appropriate for this study, based on the ideas of Vijayamohan (2024) and Nikolopoulou (2022), that the sample was collected based on specific requirements that fit the study's objectives.

Materials/Instruments

Aligned with the quantitative research design, the researchers used a structured questionnaire for data collection. To determine the level of course learning outcomes attainment, as assessed by both science interns and cooperating teachers, the researchers used an adapted questionnaire from the work of Prentice and Robinson (2010), which consisted of 25 items grouped into five learning outcomes factors, with five items assigned to each factor: critical thinking, communication, career and teamwork, global understanding and citizenship, and academic development and educational success.

Since the study was conducted in different contexts and involved different respondents, the validity and reliability of the questionnaire were carefully considered. The instrument underwent expert validation, and the validators' suggestions and recommendations were incorporated into the final version of the questionnaire. A pilot test was conducted with 30 randomly selected respondents from non-participating schools to assess the instrument's internal consistency. The computed Cronbach's alpha coefficient was 0.856, indicating good reliability according to Zakariya (2022).

For data analysis, the weighted mean was used to determine the level of attainment of the course learning outcomes as perceived by the respondents. At the same time, an independent–samples t-test was used to examine significant differences in perceptions between science interns and their cooperating teachers. The following scale was used to interpret the results: 1.00–1.79 (very low), 1.80–2.59 (low), 2.60–3.39 (moderate), 3.40–4.19 (high), and 4.20–5.00 (very high).

Design and Procedure

The study employed a quantitative descriptive research design. As Creswell (2014) describes, this design aims to provide a numerical description of trends, attitudes, or opinions within a population by studying a sample. This approach is appropriate since it is commonly used in survey research to collect data that can be statistically analysed to identify patterns and generalisations.

After securing permission and approval for the study, the data were gathered through a validated survey questionnaire administered via both face-to-face and online platforms. Then, the researcher ensured that respondents were fully aware of the study's purpose and their role as part of the ethical procedures.

The researcher reached out to the respondents through social media and then verified their email addresses using data generated from the Google Forms. Meanwhile, printed copies were distributed to those who responded face-to-face, including cooperating teachers.

The protection of respondents' privacy and security, including their identity and confidential information, was ensured by strictly following the guidelines of R.A. 10173, also known as the Data Privacy Act of 2012. Furthermore, all data collected were used solely for research purposes. Subsequently, the dataset underwent thorough cleaning, organisation, and preparation for a series of statistical analyses.

The weighted mean was utilised to determine the level of course learning outcomes attainment of science interns and their corresponding cooperating teachers. T-test was used to compare the means of pre-service science teachers and cooperating teachers' course learning outcomes and to determine whether there was a significant difference between the two groups.

Results and Discussion

Level of Students' Course Learning Outcomes Attainment as Perceived by Science Interns and Cooperating Teachers

Table 1 presents the level of course learning outcomes attainment as perceived by BSED science interns and their cooperating teachers in terms of critical thinking, communication, career and teamwork, global understanding and citizenship, and academic development and educational success.

The overall mean of 4.42 is described as very high. This means that these outcomes are consistently demonstrated by the interns.

The similar perceptions of the two groups suggest strong alignment in how students' performance is viewed, indicating self-awareness among pre-service teachers and validation from their cooperating teachers.

Furthermore, the overall standard deviation is 0.39, showing that participants had generally similar and positive responses.

Table 1 Level of Students' Course Learning Outcomes Attainment as perceived by Pre-service Science Teachers and Cooperating Teachers.

Course Learning Outcomes	Science Interns		Cooperating Teachers		Total		Descriptive Level
	Mean	SD	Mean	SD	Mean	SD	
Critical Thinking	4.48	0.53	4.23	0.55	4.36	0.55	Very High
Communication	4.51	0.50	4.34	0.52	4.43	0.52	Very High
Career and Teamwork	4.44	0.55	4.35	0.50	4.40	0.53	Very High
Global Understanding and Citizenship	4.55	0.48	4.33	0.51	4.44	0.51	Very High
Academic Development and	4.60	0.42	4.35	0.49	4.48	0.47	Very High

Educational Success							
Overall	4.52	0.31	4.32	0.43	**4.42**	**0.39**	**Very High**

As found, academic development and educational success have the highest mean value of 4.48, which indicates that attainment in this domain is consistently evident.

It implies that science interns are able to see the connections between their academic learning in college and real-life experiences, set specific professional development goals, regularly reflect on their teaching practices to identify areas for personal and professional growth, and are determined to apply for teaching positions driven by their passion for delivering quality science education to diverse learners.

The result accords with the study of Magulod (2019) that students' academic performance reflects their learning experiences, considering both intellectual and non-intellectual factors, including learning style preferences, which contribute to more effective learning experiences.

On the other hand, critical thinking has the lowest mean of 4.36 among the course learning outcomes, yet it remains categorised as very high. This indicates that course learning outcomes attainment in terms of critical thinking is consistently evident.

This implies that science interns are able to employ critical thinking to analyse complex scientific concepts and theories in depth and apply logical reasoning and problem-solving strategies effectively when faced with scientific challenges.

The findings align with Farillon (2022), who emphasises that strong critical thinking skills are essential for addressing the challenges of the 21st century. These skills enable individuals to analyse evidence effectively, make reasoned judgments, and understand interconnected systems, thereby facilitating problem-solving, decision-making, creativity, and curiosity, and are pivotal for academic, career, and lifelong achievements.

Significant Difference in the Level of Students' Course Learning Outcomes Attainment as Perceived by Cooperating Teachers and Practice Science Teachers

Table 2 presents the significant difference in the level of course learning outcomes attainment as perceived by cooperating teachers and practice science teachers.

Table 2 Significant Difference in the Level of Course Learning Outcomes Attainment Perceived by Science Interns and Cooperating Teachers.

Students' Course Learning Outcomes	***t***	***p***	**Decision for H_O**	**Interpretation**
Critical Thinking	23.123***	.000	Rejected	Significant
Communication	13.828***	.000	Rejected	Significant
Career and Teamwork	3.320^{NS}	.069	Failed to reject	Not Significant

Global Understanding and Citizenship	20.780***	.000	Rejected	Significant
Academic Development and Educational Success	34.798***	.000	Rejected	Significant
Overall	**31.224*** **	**.000**	**Rejected**	**Significant**

It is reflected that the overall *t*-value of 31.224 and *p*-value of .000 indicates that there is a significant difference in the overall ratings of course learning outcomes attainment.

This difference highlights a trend where cooperating teachers rated pre-service science teachers positively, but generally more conservatively than the pre-service science teachers rated themselves.

This implies that cooperating teachers hold slightly different standards or criteria for evaluating these competencies. The result affirms the ideas of Tubal et al. (2025) that practitioner feedback, whether affirming, restrictive, or emotionally charged, shapes how interns view their own performance relative to mentors' perspectives.

The notable evaluation disparities between cooperating teachers and science interns can be ascribed to variations in expectations, evaluation standards, and experiences. Furthermore, the result agrees with the point of Duignan (2024) that this may be attributed to the Dunning-Kruger effect, where new or less experienced teachers may overestimate their classroom management or teaching skills.

Conclusion

Based on the study's findings, it can be concluded that the attainment of course learning outcomes, as perceived by science interns and cooperating teachers, was very high across all domains, including critical thinking, communication, career and teamwork, global understanding and citizenship, and academic development and educational success. A significant difference was found between the perceptions of interns and cooperating teachers, indicating variations in self-assessment and evaluation standards. This underscores the importance of clear communication, consistent evaluation criteria, and structured feedback to align perceptions and support professional growth.

The findings also align with Astin's Input-Environment-Output Model, demonstrating how the internship environment, mentorship, and practical experiences influence the development of course learning outcomes, particularly in areas such as critical thinking, which benefit from enhanced environmental support.

Recommendations

Although overall course learning outcomes attainment was very high, critical thinking emerged as a relative area of weakness. To strengthen science interns' critical thinking skills, teacher education programmes should integrate inquiry-based learning, problem-solving tasks, and reflective teaching activities throughout the internship.

Cooperating teachers should model higher-order questioning, encourage open-ended discussions, and provide constructive feedback on reasoning and evidence-based thinking. Incorporating critical thinking rubrics into lesson planning and post-teaching reflections can further support consistent skill development.

Additionally, structured feedback mechanisms should be implemented to foster open dialogue regarding learning outcomes and evaluation criteria, ensuring alignment between interns' self-assessments and cooperating teachers' evaluations, and promoting professional growth.

Acknowledgments

My heartfelt gratitude goes to the school heads, cooperating teachers, and science interns for allowing the researcher to conduct this study and to my research adviser and colleagues in the College of Teachers for their support in completing this study.

References

Andayani, M. S., Divayana, D. G., & Suyasa, P. W. (2023). The influence of interest in being a teacher on learning outcomes in microteaching in semester VI students of the education program technical information. In *Proceedings of the 5th International Conference on Vocational Education and Technology (IConVET 2022)*, 6 October 2022, Singaraja, Bali, Indonesia.

Arif, A., Rahman, F., Zainurrahman, M., & Arieffandy, A. (2022). Correlation between interest in becoming a teacher and educational subject learning outcomes for automotive engineering education students. *Automotive Engineering and Vocational Education Journal (AEEJ)*, 3(2), 57–63. https://doi.org/10.24036/aeej.v3i2.169

Astin A. W. (1993). *What matters in college? Four critical years revisited*. San Francisco, CA: Jossey-Bass.

Blakeman, R., & Taylor, M. (2019). Team creative brief: creative and account teams speak out on best practices. *Journal of Advertising Education, 23(1), 39-52.* https://doi.org/10.1177/1098048218812132

Bernardo, A.B., Cordel, M.O., Ricardo, J.G., Galanza, M.A., & Almonte-Acosta, S.A. (2022). Global Citizenship Competencies of Filipino Students: Using Machine Learning to Explore the Structure of Cognitive, Affective, and Behavioral Competencies in the 2019 Southeast Asia Primary Learning Metrics. *Education*

Boholano, H. B., Jamon, B. E. V., Merin, J. A., Polinar, D. D. G., Corales, E. F., Argate, R. T., Chua, L. I., Barredo, B. S., Palma, R. C., & Cajes, R. C. (2021). *Field Study 1*. Mutya Publishing House Inc.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

Dela Fuente, J. A. (2021). Contributing factors to the performance of pre-service physical science teachers in the Licensure Examination for Teachers (LET) in the Philippines. *Journal of Educational Research in Developing Areas*, *2*(2), 141–152. https://doi.org/10.47434/JEREDA.2.2.2021.141

Duignan, B. (2024). *Dunning-Kruger effect*. *Encyclopedia Britannica*. Retrieved March 8, 2024, from https://www.britannica.com/science/Dunning-Kruger-effect

Farillon, L. M. F. (2022). Scientific reasoning, critical thinking, and academic performance in science of selected Filipino senior high school students. *Utamax: Journal of Ultimate Research and Trends in Education*, *4*(1), 51–63. https://doi.org/10.31849/utamax.v4i1.8284

Floris, M., Paganin, G., Guglielmi, D., & Mazzetti, G. (2024). Motivation is not enough: How career planning and effort regulation predict academic achievement. *Current Psychology*, *43*, 9280–9289. https://doi.org/10.1007/s12144-023-05070-6

Hidayatulloh, M. K. Y., & Ashoumi, H. (2022). The perspective of work readiness in vocational school students with 21st-century communication and collaboration skills. *Cypriot Journal of Educational Sciences*, *17*(7), 2199–2206. https://doi.org/10.18844/cjes.v17i7.7588

Ifechi, A. N., Okoli, I. E., & Nwosu, K. C. (2022). Influence of professional career development and teamwork on employee job satisfaction: Evidence from private universities in Nigeria. *Journal La Bisecoman*, *3*(3), 80–95. https://doi.org/10.37899/journallabisecoman.v3i3.649

Kilic, D., & Saglam, N. (2023). The use of self-assessment in improving pre-service teachers' professional development. Science Insights Education Frontiers, 19(2), 3057–3071. https://doi.org/10.15354/sief.23.or436

Lee, C. (2021). Effects of self-efficacy, teamwork, and self-leadership on job satisfaction as mediated by career planning: By year of college of maritime sciences. *Journal of the Korean Society of Marine Environment and Safety*. Retrieved March 9, 2024, from http://www.kosomes.or.kr/journal/article.php?code=80749

Lewis, W. M. (2021). Employee perceptions of collaborative communication skills learned in the informal workplace. *Walden University ScholarWorks*. Retrieved March 9, 2024, from https://scholarworks.waldenu.edu/cgi/viewcontent.cgi?article=11865&context=dissertations

Lucas, M. R., & Corpuz, B. (2020). *Facilitating learner-centered teaching* (5th ed.). Lorimar Publishing Inc.

Magulod, G. C. (2019). Learning styles, study habits and academic performance of Filipino university students in applied science courses: Implications for instruction. *Journal of Technology and Science Education*. Retrieved March 9, 2024, from https://files.eric.ed.gov/fulltext/EJ1210888.pdf

Mahoney, J.L., Weissberg, R.P., Greenberg, M.T., Dusenbury, L., Jagers, R.J., Niemi, K., Schlinger, M., Schlund, J., Shriver, T.P., VanAusdal, K., & Yoder, N. (2020). Systemic social and emotional learning: Promoting educational success for all preschool to high school students. *The American Psychologist, 75*(1), 94–105. https://doi.org/10.1037/amp0000455

Nel, B. P. (2025). Mentor and supervisor score differences in evaluating pre-service mathematics teachers. Perspectives in Education, 43(4), 327–340. https://doi.org/10.38140/pie.v43i4.9564

Nikolopoulou, K. (2022). What is purposive sampling? Definitions and examples. *Scribbr*. Retrieved March 4, 2024, from https://www.scribbr.com/methodology/purposive-sampling/

Plopino, M. E. B., & Carbonell, S. S. (2025). Assessment of instructional supervision level of pre-service teachers in learning delivery. *International Journal of Research and Innovation in Social Science, 9(5), 2554–2579.* https://doi.org/10.47772/IJRISS.2025.905000198

Prentice, M., & Robinson, G. (2010). Improving student learning outcomes with service learning. *American Association of Community Colleges*. Retrieved December 10, 2023 from, https://eric.ed.gov/?id=ED535904

Rosselot-Merritt, J., & Bloch, J. (2020). Mentoring in business and professional communication: Case study of a multiyear dynamic. *Business and Professional*

Communication Quarterly, 83(1), 5-33. https://doi.org/10.1177/2329490619885891

Tubal, F. S. C., Saluta, R. M. B., Cabrido, C. B., & Embang, S. I. (2025). Pre-service teachers' lived experiences with feedback and its role in their professional becoming. International Journal of Learning, Teaching and Educational Research, 24(9), 628–648. https://doi.org/10.26803/ijlter.24

Vijayamohan, P. (2024). *Purposive sampling 101: Definitions, types, and examples*. SurveySparrow. RetrievedMArch 3, 2024, from https://surveysparrow.com/blog/purposive-sampling/

Wang, Y. L., & Guan, H. F. (2020). Exploring demotivation factors of Chinese learners of English as a foreign language based on positive psychology. *Revista Argentina de Clínica Psicológica, 29*, 851–861. https://doi.org/10.24205/03276716.2020.116

Zakariya, Y. F. (2022). Cronbach's alpha in mathematics education research: Its appropriateness, overuse, and alternatives in estimating scale reliability. *Frontiers in Psychology, 13*, 1074430. https://doi.org/10.3389/fpsyg.2022.1074430

2026

SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 6, No: 1, PP: 10-20
www.journal.qitepinscience.org

SciEd
SEAQIS Journal of Science Education

Research Paper | Open Accsess

Improving Problem-Solving Ability in IPAS Through Problem-Based Learning Integrated with the TaRL Approach in Grade V Elementary School

Atika Dewi [1*]

[1] Master of Elementary Education, Universitas Muria Kudus, Kudus, 59352, Indonesia
**Corresponding author, e-mail: tikafox34@gmail.com*

Article history:
Received: March 26, 2025
Revised: March 13, 2026
Accepted: May 04, 2026

Abstract

Problem-solving ability is an essential skill that needs to be developed from an early stage to train students to analyse situations and determine appropriate solutions. However, several studies indicate that students' problem-solving ability is still relatively low. This study aimed to examine the effectiveness of a problem-based learning (PBL) model integrated with the Teaching at the Right Level (TaRL) approach in improving problem-solving ability in IPAS learning among fifth-grade elementary school students. This study employed a pre-experimental method with a one-group pretest–post-test design involving 15 fifth-grade students from an elementary school at Pati regency. The research instruments consisted of written tests used for the pretest and post-test and observation sheets to assess students' problem-solving processes. Data analysis was conducted through method triangulation by comparing the results of written test analysis with classroom observation results. The written test data were analysed using descriptive statistics and N-Gain analysis. The results showed that the implementation of the PBL model integrated with the TaRL approach contributes to the improvement of students' problem-solving ability in IPAS learning. The written test analysis indicated an increase in the average score from the pretest to the post-test of 13.34%, along with an increase in the number of students who achieved criteria for learning objectives. The N-Gain analysis result of 0.56 indicated a moderate improvement in students' problem-solving ability. In addition, the comparison between the written test results and classroom observations showed a consistent pattern in students' problem-solving performance.

Keywords: Problem-Based Learning, tTaching at the right level, PBL, TaRL, IPAS, Problem-Solving.

Introduction

Problem-solving ability is an essential skill that needs to be developed from an early stage, as it helps students analyse situations and determine appropriate solutions in everyday life. This skill is closely related to critical thinking, which is one of the key competencies in 21st-century learning (Bariyyah, 2021). Therefore, developing problem-solving ability is important to train students in understanding problems, analysing information, and determining effective solutions independently (Halimah et al., 2023).

Problem-solving ability refers to the process of identifying problems and developing appropriate solution strategies, particularly for non-routine problems (Rambe & Afri, 2020). According to Polya (Siolimbona et al., 2023), problem-solving is explained as an effort to develop a problem-solving strategy through four stages: 1) understanding the problem, 2) designing a solution plan, 3) implementing a solution plan, and 4) re-examining the process and results.

Furthermore, Krulik & Rudnick (Shodiqin et al., 2020) introduced heuristics, which are five stages of problem-solving that can be applied at all levels of teaching. These stages include: 1) *read*, 2) *explore*, 3) *select a strategy*, 4) *solve*, and 5) *look back and extend*. In this heuristics approach, all stages are inseparable. The reading and exploring stages often take place simultaneously as does the thinking process. Similarly, in the problem-solving stage, there is also a process of considering and determining which strategy to use.

However, students' problem-solving abilities are still relatively low. Results from the Programme for International Student Assessment (PISA) 2022 indicate that Indonesian students' performance in science remains below the OECD average, particularly in interpreting scientific phenomena and applying knowledge to real-life contexts. This indicates that students' higher-order thinking and problem-solving skills still need improvement.

Based on observations in the fifth grade at one elementary school in Pati Regency, Central Java, Indonesia, it was found that students' problem-solving skills remain at a low level, which is consistent with the results of the PISA evaluation. During the learning process, students showed a lack of enthusiasm when answering questions verbally and lacked skill in finding appropriate solutions to problems. The results of working on problems with problem solving seem brief without systematic explanations. In fact, some students found it difficult to understand the problems and were unsure how to proceed. This shows that students' problem-solving skills need to be improved so that they can be applied not only in learning activities but also in their daily lives.

One subject that can facilitate the development of problem-solving skills is the Natural and Social Sciences (IPAS), which integrates scientific and social concepts to help students understand real-life phenomena. Through IPAS learning, students are expected to connect conceptual knowledge with real-world problem situations. This subject is the right place to train students to develop solution strategies based on conceptual understanding to help improve problem-solving skills. Simarmata et al. (2022) stated that mastery and understanding of concepts affect the problem-solving process. Solving non-routine problems not only requires memorisation of procedures and concepts but also requires the ability to synthesize various concepts and connect the links between concepts that have been learned to find effective solutions (Sari & Aripin, 2018).

One learning model that supports the development of problem-solving ability is Problem-Based Learning (PBL), which engages students in solving real-life problems through investigation and discussion (Auliah et al., 2023; Hayun & Syawaly, 2020; Ramadhani et al., 2024). In the context of fifth-grade students, PBL activities can be implemented through observing phenomena, discussing problems in groups, collecting information, and presenting solutions. These activities provide opportunities for students to actively practise problem-solving stages.

Ardianti et al. (2021) explain PBL as a learning model where students are faced with real problems as a stimulus at the beginning of learning to trigger learning motivation and effort to solve problems. PBL exposes real contextual problems to students to be solved both individually and in groups using critical thinking and problem-solving skills so that new knowledge is constructed through the process (Rifai et al., 2020).

The implementation of PBL generally follows several main steps, including observing problems, posing questions, collecting relevant information, analysing data to determine possible solutions, and communicating the results of the problem-solving process (Hariyanti, 2021). These stages guide students to actively explore problems and develop solution strategies through investigation and discussion.

Although PBL shows a positive effect on problem-solving skills, it also has some shortcomings in its implementation. Hermansyah (2020) found that without sufficient understanding of the underlying reasons for the problem-solving process, PBL does not significantly contribute to students' understanding of the material. Other research indicate that one of the obstacles to the implementation of PBL is the mindset and ability of students who have diverse abilities and mindsets, thus requiring appropriate approaches to support students' learning according to their needs (Auliah et al., 2023; Helyandari et al., 2020).

However, differences in students' initial abilities can become a challenge in implementing PBL effectively. Therefore, an appropriate approach is needed to accommodate students' diverse learning needs. One approach that can be integrated with PBL is the Teaching at the Right Level (TaRL) approach, which groups students based on their level of understanding rather than their grade level (Febriani & Shaliha, 2023). Through initial assessment, teachers can identify students' learning levels and provide appropriate support based on these needs (Suharyani et al., 2023). Based on this information, teachers can design learning support that is more targeted and responsive to students' needs.

Although there are many studies that examine the effectiveness of PBL or the TaRL approach in improving problem-solving skills, there are limited studies that specifically integrate the PBL model with the TaRL approach in improving problem-solving skills through IPAS learning at the elementary schools. Most studies still focus on the application of PBL in the context of mathematics learning and do not consider differences in students' initial abilities and learning readiness of diverse students. The TaRL approach is also more widely used to improve literacy and numeracy skills (Suharyani et al., 2023; Wulandari et al., 2024).

This study aims to integrate the Problem-Based Learning (PBL) model with the TaRL approach to improve problem-solving skills in IPAS subjects in grade V elementary school. By applying the TaRL-based PBL model, it is expected that students can develop problem-solving skills according to their cognitive levels through problem-based learning in real-life contexts so that they can construct their knowledge independently.

Methodology

This study used an experimental method with a pre-experimental design, using a one group pretest–post-test design (Creswell, 2023). In this design, a single group of students was observed before and after the implementation of the learning intervention. The pretest was administered to identify students' initial problem-solving abilities, while the post-test was conducted after the implementation of learning using the Problem-Based Learning (PBL) model integrated with the Teaching at the Right Level (TaRL) approach. The comparison between pretest and post-test results was used to describe changes in students' problem-solving abilities following the intervention.

The participants in this study were 15 fifth-grade students from an elementary school in Pati Regency, Central Java, Indonesia. This class was selected purposively because it represented a heterogeneous range of students' learning abilities.

The research instruments consisted of pretests and post-tests with written problem-solving questions in the form of three types of problem packages with HOTS, MOTS, and LOTS levels each consisting of 3 items used to measure students' problem-solving skills and observation sheets used to observe students' activities during the learning process. The classification of these levels was based on Bloom's revised taxonomy, where LOTS includes remembering and understanding (C1-C2), MOTS includes applying and analysing (C3-C4), and HOTS includes evaluating and creating (C5-C6). These questions were designed to assess students' ability to understand problems, determine solution strategies, and evaluate the results of their solutions.

The research data were analysed using method triangulation by comparing the results of written tests and observation sheets to increase the validity and reliability of the research results. The written tests were used to measure students' problem-solving abilities, while the observation sheets were used to record students' learning activities during the implementation of the Problem-Based Learning model integrated with the TaRL approach.

The indicators used to assess students' problem-solving abilities were adapted from Polya's stages of problem-solving (Shodiqin et al., 2020), which include (1) understanding the problem, (2) planning the solution strategy, (3) implementing the solution, and (4) reviewing the results. These indicators were used both the written tests and the observation sheets. The observation data were collected directly by the researcher during the learning process. In the written tests, the indicators were used to analyse students' answers to contextual problems, while in the observation sheets, they were used to observe students' participation during learning activities, such as identifying problems, discussing solution strategies, implementing solutions in group work, and presenting the results of their discussions.

The written test data were analysed using descriptive statistical analysis to describe the improvement in students' problem-solving abilities in IPAS learning. The results were also compared with the Minimum Learning Achievement Criteria (KKTP) for IPAS subjects, which were set at ≥ 75.

Furthermore, the improvement in students' scores was analysed using the normalised gain (N-Gain) formula:

$$(g) = \frac{Post\ test - \Pr e\ test\ score}{Highest\ possible\ score - \Pr e\ test\ score}$$

The interpretation of the N-Gain values was based on Hake's gain index criteria (Fadaei, 2019), which consists of three levels as shown in Table 1.

Table 1 Gain Index Criteria.

Gain Index	Criteria
g > 0,70	High
0,70 ≥ 0,30	Medium
0,30 ≥ g	Low

After calculating the N-Gain score, the results were used to describe the improvement in students' problem-solving abilities. In addition to the written test analysis, observation data were analysed to examine students' problem-solving processes during the learning activities. The results of the analysis were used to describe the data on students' problem-solving abilities. Observation data were analysed based on the development category of Polya's (Shodiqin et al., 2020) problem-solving stages using the indicators presented in Table 2.

Table 2 Problem-solving stage indicators.

Problem Solving Stage	Indicator	Category
Understanding the Problem	Able to mention what is known and asked in the problem using their own words.	Good
	Able to mention what is known and asked in the problem.	Fair
	Not yet able to mention what is known and asked in the problem.	Poor

Making a Solution Plan	Able to explain the solution strategy precisely and lead to the correct answer.	Good
	Able to explain the solution strategy appropriately but has not led to the correct answer.	Fair
	Not yet able to explain the solution strategy appropriately.	Poor
Implementing the Solution Plan	Able to solve the problem by applying the solution strategy made appropriately with correct results.	Good
	Able to solve the problem by applying the solution strategy made appropriately but the results are not yet correct.	Fair
	Not yet able to solve the problem correctly.	Poor
Rechecking and Developing	Able to check the process and answers and draw appropriate conclusions.	Good
	Able to check the process and answer but not yet able to give the right conclusion.	Fair
	Not yet able to check the process and answers and draw conclusions appropriately.	Poor

Adaptation of Putri & Putri (2022)

The written test results were then compared with the observation results to examine the alignment between students' problem-solving performance in the written tests and their participation during the learning process. The comparison was conducted using the same indicators adapted from Polya's problem-solving stages. In the written tests, these indicators were reflected in students' answers when solving contextual problems, while in the observation sheets, they were used to assess students' learning activities during group discussions, problem identification, formulating strategies, implementing solutions, and presenting results. The comparison of these indicators was used to examine the consistency between students' problem-solving abilities and their learning activities during the implementation of the PBL model integrated with the TaRL approach.

Results and Discussion

Before the implementation of learning using the PBL model integrated with the TaRL approach, this study began with giving an initial test to map the initial abilities of students as the basis for grouping in the TaRL approach. The students were grouped into three levels: high with advanced category (HOTS), medium with intermediate category (MOTS), and low with beginner category (LOTS). The initial test results are presented in Table 3.

Table 3. Results of Mapping the Initial Abilities of Students.

Group Type	Category	Number of Students
HOTS	Advanced	3
MOTS	Intermediate	10
LOTS	Beginner	2

The results of the initial test mapping (Table 3) were used as the basis for organising the class into groups. Among the 15 students, five groups were formed: one

HOTS group consisting of three members, three MOTS groups consisting of three, three, and four members, respectively, and one LOTS group consisting of two members. Each group received different learning support according to their level. The LOTS group received more intensive assistance compared to the MOTS and HOTS groups. Students in the LOTS group received more structured guidance such as step-by-step explanations, additional examples, and closer teacher facilitation during problem-solving activities. Meanwhile, students in the MOTS and HOTS groups were encouraged to work more independently through discussion and the exploration of problem-solving strategies. This differentiated support aims to align instruction with students' learning levels, which is the core principle of the TaRL approach.

The next stage was giving a *pretest* to measure students' initial problem-solving abilities, followed by the implementation of the treatment in the experimental class through the implementation of the Problem-Based Learning (PBL) model integrated with the TaRL approach and the administration of a *post-test* containing problem solving questions at the end of learning. Based on the final written test scores, the results presented in Table 4 were obtained.

Table 4. Results of Descriptive Statistical Analysis.

Statistical Data	*Pretest* Results	*Post-test* Results
Number of Students	15	15
Maximum Score	100	100
Highest Score	90	100
Lowest Score	40	60
Average	71.33	84.67
Standard Deviation	15.98	13.02

Table 4 shows an increase in the mean, highest score, and lowest score in the *post-test* results compared to the *pretest* results. The average increase of 13.34% indicates the effectiveness of the implementation of the PBL model integrated with the TaRL approach in IPAS learning in improving problem-solving skills. The results of the *pretest* and *post-test* assessments are presented in Table 5.

Table 5. Frequency Distribution of Students' Written Test Scores.

Interval	Category	Frequency		Description
		Pretest	*Post-test*	
0-75	Low	7	4	Below KKTP
75-89	Medium	5	3	Above KKTP
90-100	High	3	8	Above KKTP

Based on the *post-test* results presented in Table 5, it was found that 11 students were able to exceed the KKTP score of 75. This shows that the Problem-Based Learning model integrated with the TaRL approach influenced students' problem-solving skills as indicated by the increase in the number of students who achieved the minimum criterion compared to the pretest results, in which only eight students achieved the criterion.

Table 6. Frequency and Percentage Distribution Based on N-Gain Categories.

Gain Index	Category	Frequency	Average N-Gain
g > 0,70	High	4	0,56
0,70 ≥ 0,30	Medium	9	
0,30 ≥ g	Low	2	
Total		**15**	

Table 6 shows that four students met high criteria, nine students met medium criteria, and two students were categorised within the low criteria. The average normalised gain was 0.56, which is categorised within the medium criteria. These results indicate that the implementation of PBL integrated with the TaRL approach was moderately effective in improving students' problem-solving skills in IPAS learning for fifth grade students.

Furthermore, the observation results were analysed based on the indicators of the problem-solving stages adapted from Polya. The results of the written test analysis are presented in Table 7.

Table 7. Results of the Problem-Solving Instrument Analysis (*Post-test*).

Problem Solving Stage	Percentage			
	Problem 1	Proble m 2	Problem 3	Average
Understanding the Problem	93,33%	86,67%	86,67%	88,89%
Develop a solution plan	86,67%	86,67%	76,67%	83,34%
Implementing the solution plan	80,00%	76,67%	73,33%	76,67%
Making a Solution Plan	80,00%	73,33%	73,33%	75,55%

(Analysis Result, 2025)

Based on the analysis of the post-test results from three questions containing problem-solving tasks, it was found that most students were able to develop their problem-solving skills. A total of 88.89% of students were able to understand the problems presented. Meanwhile, 83.34% were able to develop a problem-solving plan. In addition, 76.67% and 75.55% of students were able to implement the planned solution strategy and review and evaluate their solutions, respectively.

The results of the written tests and observations show a similar tendency. The written tests indicate students' ability to complete problem-solving tasks, while the observation results show that students were actively involved in the stages of problem-solving during the learning process. Although the indicators measured through written tests and observations were different, both sets of results provide complementary information. The written tests reflect students' cognitive achievement in solving problems, whereas classroom observations describe how students engaged in the problem-solving process during learning activities.

In the learning process, the implementation of the PBL model integrated with the TaRL approach was carried out through contextual problems in IPAS learning for fifth-grade students. For example, students were presented with problems related to environmental issues in their daily lives and were asked to identify the main problem, determine relevant information, and discuss possible solutions in groups. Through the PBL stages, students collaboratively developed solution strategies and presented the results of their discussions.

The TaRL approach enabled teachers to provide learning support according to students' ability levels. Students in the LOTS group received more structured guidance, while students in the MOTS and HOTS groups were encouraged to explore solution strategies more independently. Through this process, students actively engage in the stages of problem-solving, including understanding the problem, planning solutions, implementing strategies, and reviewing the results.

These findings are consistent with previous studies that report that the problem-based learning model can improve students' learning outcomes and problem-solving abilities in science learning (Muchlisin et al., 2023). Other studies also indicate that the integration of PBL and the TaRL approach contributes positively to students' problem-solving abilities (Istiqomah et al., 2024; Ristiyaningtiyas et al., 2024; Widyastuti et al., 2024).

However, the results also show that approximately 26.67% of students continued to experience difficulties in developing problem-solving abilities. Based on classroom observations, some students required more time and guidance, particularly in understanding the problem and formulating solution strategies. In addition, differences in students' initial abilities affected the learning process, especially in managing group discussions and providing appropriate support to each group.

These findings indicate that the implementation of PBL integrated with the TaRL approach presents several challenges in classroom practice. For instance, the need for teacher readiness and creativity in designing meaningful problem situations was observed during the learning process. This finding is consistent with previous studies that report that teacher readiness is a key factor in the successful implementation of PBL (Palmin & Anwar, 2022). Furthermore, time constraints and differences in students' initial abilities were also found to influence the effectiveness of learning activities. These findings are in line with other studies which state that limited time and diverse student abilities can pose challenges in implementing PBL and TaRL (Auliah et al., 2023; Mubarokah, 2022; Satriani et al., 2024). Overall, these findings indicate that the implementation of PBL integrated with the TaRL approach supported students' engagement and contributed to the development of their problem-solving abilities in IPAS learning.

Conclusion

This study aimed to examine the implementation of the Problem-Based Learning (PBL) model integrated with the Teaching at the Right Level (TaRL) approach to support students' problem-solving abilities in IPAS learning for fifth-grade elementary school students. The results show that the implementation of PBL combined with the TaRL approach contributed to the improvement of students' problem-solving abilities. This improvement is indicated by the increase in the average score from 71.33 in the pretest to 84.67 in the post-test, with an average increase of 13.34%. In addition, the number of students who achieved the Minimum Learning Achievement Criteria (KKTP) also increased from 8 to 11 students. The N-Gain score of 0.56 indicates a moderate improvement in students' problem-solving ability after learning intervention.

The analysis based on Polya's problem-solving stages also shows that most students were able to perform the stages of understanding the problem, making a solution plan, implementing the solution plan, and rechecking the results. These findings indicate that the implementation of PBL integrated with the TaRL approach supported students' engagement in problem-solving activities and help them develop systematic strategies for solving problems in IPAS learning.

The findings of this study imply that the integration of the PBL model with the TaRL approach can be used as an alternative instructional strategy for elementary school teachers to facilitate students' problem-solving abilities through contextual learning activities. By grouping students according to their learning levels, teachers can provide more appropriate learning support that helps students to participate more actively in the problem-solving process.

However, this study has not examined in depth the factors influencing students continued to experience difficulties in developing their problem-solving abilities. Therefore, further research is recommended to investigate other factors such as teacher readiness, students' characteristics, learning facilities, and classroom management that may influence the development of students' problem-solving abilities.

References

Ardianti, R., Sujarwanto, E., & Surahman, E. (2021). Problem-based Learning: Apa dan Bagaimana. *DIFFRACTION: Journal for Physics Education and Applied Physics*, *3*(1), 27–35. http://jurnal.unsil.ac.id/index.php/Diffraction

Auliah, F. N., Febriyanti, N., & Rustini, T. (2023). Analisis Hambatan Guru dalam Penerapan Model Problem Based Learning pada Pembelajaran IPS Kelas IV di SDN 090 Cibiru Bandung. *Journal on Education*, *5*(2), 2025–2033. https://doi.org/10.31004/joe.v5i2.846

Bariyyah, K. (2021). Problem solving skills : essential skills challenges for the 21st century graduates. *Jurnal EDUCATIO: Jurnal Pendidikan Indonesia*, *7*(1), 71–80. https://doi.org/https://doi.org/10.29210/120212843

Creswell, J. W. (2023). Research Design Pendekatan Metode Kualitatif, Kuantitatif, dan Campuran. In *Writing Center Talk over Time* (4th ed.). Pustaka Pelajar.

Fadaei, A. S. (2019). Comparing Two Results: Hake Gain and Dellow Gain, to Analyze FCI Data in Active Learning Process ∗. *US-China Education Review A*, *9*(1), 31–39. https://doi.org/10.17265/2161-623X/2019.01.003

Febriani, A., & Shaliha, S. (2023). *Buku Ajar Mata Kuliah Inti Pemahaman tentang Peserta Didik dan Pembelajarannya*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Halimah, S., Usman, H., & Maryam, S. (2023). Peningkatkan Kemampuan Berpikir Kritis Dalam Pembelajaran IPA Melalui Penerapan Model Pembelajaran Problem-based learning (PBL) di Sekolah Dasar. *JSIM: Jurnal Ilmu Sosial Dan Pendidikan*, *3*(6). https://doi.org/http://dx.doi.org/10.36418/syntax-imperatif.v3i6.207 2721-2246

Hariyanti, A. (2021). Meningkatkan Kemampuan Menulis Teks Prosedur Dengan Menggunakan Model Problem Based Learning (Pbl)Pada Kelas X Dpib 1 Di Smk Negeri 2 Ciamis. *Diksatrasia : Jurnal Ilmiah Pendidikan Bahasa Dan Sastra Indonesia*, *4*(1), 1–14. https://doi.org/10.25157/diksatrasia.v4i1.3285

Hayun, M., & Syawaly, A. M. (2020). Pengaruh Penerapan Model Pembelajaran Problem Based Learning Terhadap Kemampuan Representasi Matematis Siswa Sekolah Dasar. *Instruksional*, *2*(1), 10–16. Diakses pada tanggal 4 Desember 2023

Helyandari, B. H., Hikmawati, H., &

Sahidu, H. (2020). Pengaruh Model Problem Based Learning Terhadap Hasil Belajar Fisika Peserta Didik Ma Darul Hikmah Darek Tahun Pelajaran 2019/2020. *Konstan - Jurnal Fisika Dan Pendidikan Fisika*, *5*(1), 10–17. https://doi.org/10.20414/konstan.v5i1.46

Hermansyah. (2020). Problem Based Learning in Indonesian Learning. *Social, Humanities, and Educations Studies (SHEs): Conference Series*, *3*(3), 2257–2262. https://jurnal.uns.ac.id/shes

Istiqomah, N., Aunurrofiq, M., & Winarti, E. R. (2024). Meningkatkan Kemampuan Pemecahan Masalah Matematis Siswa Kelas XI F-6 SMAN 12 Semarang Melalui Model PBL dengan Pendekatan TaRL Berbantuan Teachmint. *Jurnal Penelitian Tindakan Kelas Universitas Negeri Semarang*, 1062–1070.

Mubarokah, S. (2022). Tantangan Implementasi Pendekatan TaRL (Teaching at the Right Level) dalam Literasi Dasar yang Inklusif di Madrasah Ibtida'iyah Lombok Timur. *BADA'A: Jurnal Ilmiah Pendidikan*, *4*(1), 165–179. https://doi.org/10.37216/badaa.v4i1.582

Muchlisin, M., Wicaksono, V. D., & Handayani, S. (2023). Penerapan Model Problem Based Learning (PBL) dalam Pembelajaran IPAS Kelas IV untuk Meningkatkan Hasil Belajar Peserta Didik SD Negeri Besah II Bojonegoro. *Innovative: Journal of SocialScience Research*, *3*(2), 10051–10059. https://doi.org/10.23969/jp.v8i1.8598

OECD. (2022). Pisa 2022 Result. In *Perfiles Educativos* (Vol. 1). OECD. https://doi.org/10.22201/iisue.24486167e.2024.183.61714

Palmin, B., & Anwar, M. R. (2022). Faktor Penghambat Implementasi Model Problem Based Learning dengan Pendekatan Saintifik Bagi Anak Usia Dini. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *6*(6), 6395–6408. https://doi.org/10.31004/obsesi.v6i6.3166

Putri, S. M. S., & Putri, R. K. (2022). *Profil Pemecahan Masalah Matematika Berdasarkan Teori Polya Ditinjau dari Kemampuan Matematika Siswa*. *06*(02), 1776–1787.

Ramadhani, S. P., Pratiwi, F. M., Fajriah, Z. H., & Susilo, B. E. (2024). Efektivitas Model Problem Based Learning (PBL) untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis terhadap Pembelajaran Matematika. *Prima*, *7*, 724–730.

Rambe, A. Y. F., & Afri, L. D. (2020). Analisis Kemampuan Pemecahan Masalah Matematis Siswa Dalam Menyelesaikan Soal Materi Barisan Dan Deret. *AXIOM : Jurnal Pendidikan Dan Matematika*, *9*(2), 175. https://doi.org/10.30821/axiom.v9i2.8069

Rifai, A., Islam, S. D., & Firdaus, A. (2020). Problem Based Learning Dalam Pembelajaran IPA. *Workshop Nasional Penguatan Kompetensi Guru Sekolah Dasar SHEs: Conference Series*, *3*(3), 2139–2144. https://jurnal.uns.ac.id/shes

Ristiyaningtiyas, A., Purwati, H., Khasanah, U., & Sugiyanti. (2024). Peningkatan Kemampuan Pemecahan Masalah Matematis melalui Model PBL dengan Pendekatan TaRL pada Materi Anuitas. *Edusaintek: Jurnal Pendidikan, Sains Dan Teknologi*, *11*(4), 1997–2013.

Sari, A. R., & Aripin, U. (2018). Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Cerita Bangun

Datar Segiempat Ditinjau Dari Kemampuan Pemecahan Masalah Matematik Untuk Siswa Kelas Vii. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *1*(6), 1135. https://doi.org/10.22460/jpmi.v1i6.p1135-1142

Satriani, Irwan, & H, A. (2024). Pembelajaran dengan Pendekatan TaRL untuk Meningkatkan Hasil Belajar Matematika Peserta Didik Siswa Kelas X TJKT 1 di SMKN 1 Gowa. *Global Journal Education Humanity*, *1*(1), 121–129.

Shodiqin, A., Sukestiyarno, Wardono, Isnarto, & Utomo, P. W. (2020). Profil Pemecahan Masalah Menurut Krulik Dan Rudnick Ditinjau Dari Kemampuanan Wolfram Mathematica. *Prosiding Seminar Nasional Pascasarjana UNNES*, *201920*.

Simarmata, S. M., Sinaga, B., & Syahputra, H. (2022). Analisis Kemampuan Pemahaman Konsep Matematika Siswa Dalam Penerapan Model Discovery Learning Berbantuan Matlab. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *6*(1), 692–701. https://doi.org/10.31004/cendekia.v6i1.1227

Siolimbona, D. R., Juniati, D., & Khabibah, S. (2023). Studi Literatur Proses Metakognisi dalam Pemecahan Masalah Matematika. *Soulmath:Jurnal Ilmiah Edukasi Matematika*, *11*(1), 47–58. https://doi.org/http://dx.doi.org/10.25139/smj.v11i1.5618

Suharyani, S., Suarti, N. K. A., & Astuti, F. H. (2023). Implementasi Pendekatan Teaching At The Right Level (Tarl) Dalam Meningkatkan Kemampuan Literasi Numerasi Anak Di SD IT Ash-Shiddiqin. *Jurnal Teknologi Pendidikan : Jurnal Penelitian Dan Pengembangan Pembelajaran*, *8*(2), 470. https://doi.org/10.33394/jtp.v8i2.7590

Widyastuti, R., Zuhri, M. S., Rifai, A., & Shodiqin, A. (2024). Pengaruh Model Pembelajaran PBL dengan Pendekatan TaRL terhadap Kemampuan Pemecahan Masalah Matematis. *Innovative: Journal of Social Science Research*, *4*(4), 4849–4863. https://doi.org/10.55606/jurrimipa.v3i1.2518

Wulandari, I. S., Januar, H., Rini, A. S., Wijayanti, A., Semarang, U. P., Islam, S. D., & Madina, A. (2024). Penerapan Pendekatan TaRL dalam Meningkatkan Kemampuan Literasi Numerasi Kelas II Pembelajaran Matematika. *INNOVATIVE: Journal Of Social Science Research*, *4*(4), 9529–9538.

2026

SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 6, No: 1, PP: 21-31
www.journal.qitepinscience.org

Research Paper

Open Accsess

Teachers at the Forefront of SDGs: Awareness and Instructional Readiness of Secondary School Teachers in Ibadan Metropolis

S. O. Babalola[1] and Adeniyi Michael Adeduyigbe[2*]

[1]Department of Arts and Social Sciences Education, Faculty of Education, University of Ibadan, Nigeria
[2]Department of Science and Technology Education, Faculty of Education, University of Ibadan, Nigeria
**Corresponding author, e-mail: adeniyiadeduyigbe@gmail.com*

Article history:
Received: April 24, 2025
Revised: September 23, 2025
Accepted: October 10, 2025

Abstract

Sustainable development education has gained global prominence, yet there is limited empirical research on teachers' awareness and readiness in the Nigerian secondary school context. Addressing this gap, the present study investigates the extent to which secondary school teachers in Ibadan Metropolis are aware of and prepared to teach sustainable development concepts. A descriptive survey design was employed using the Teachers' Sustainable Development Awareness and Readiness Questionnaire (TSDARQ). Stratified and simple random sampling techniques were applied to select 300 practising teachers across public and private schools. Findings revealed high levels of awareness (M = 3.40, SD = 0.68) and readiness (M = 3.54, SD = 0.59), both exceeding the benchmark threshold of 2.50. However, systemic support and instructional resources remain insufficient to fully enable classroom integration. These findings provide initial empirical evidence from an under-researched Nigerian context and underscore the need for sustained professional development, provision of adequate instructional resources, and policy alignment. It is recommended that continuous training, curriculum integration, and adequate instructional resources be prioritised to empower teachers as effective drivers of sustainability education.

Keywords: Education for Sustainable Development (ESD), Sustainability, Sustainable Development Goals (SDGs), Teachers' Awareness of SDGs, Teachers' readiness to teach SDGs

Introduction

The world today faces complex and interrelated challenges, including climate change, environmental degradation, resource depletion, and widening social inequalities. These issues pose a serious threat to the well-being of current and future generations, highlighting the urgent need for sustainable development. Sustainable development emphasises a balanced integration of economic growth, environmental protection, and social equity, built on the understanding that long-term progress depends on the stability and resilience of the Earth's life-support systems (Bell, 2017). While universally acknowledged, the concept of sustainability is often interpreted differently depending on the context. For instance, entrepreneurs may view it through the lens of resource efficiency and profitability, whereas educators and policymakers may view it as a means of fostering long-term welfare, equity, and justice. Nonetheless, the core principle remains the same: meeting present needs without compromising the ability of future generations to meet theirs (Browning & Rigolon, 2019; Taylor, 2016).

Recognising the critical role of education in achieving sustainability, the United Nations introduced the 2030 Agenda for Sustainable Development in 2015. This framework outlines 17 Sustainable Development Goals (SDGs), one of which is the promotion of quality education as a means to empower individuals with the skills, values, and knowledge needed for a sustainable future. Central to this is Education for Sustainable Development (ESD), championed by UNESCO, which focuses on integrating sustainability into educational policies, curricula, teacher training, and community initiatives. Teachers, as key facilitators of learning, are instrumental in translating the ideals of sustainability into classroom practice. Their awareness, attitudes, and preparedness significantly influence how learners understand and respond to sustainability challenges (Alkaher & Carmi, 2019; Buchanan & Crawford, 2015; Nation & Feldman, 2021). Scholars agree that education is a vital instrument in addressing global sustainability concerns, as it cultivates critical thinking, responsible citizenship, and lifelong learning (Gough & Scott, 2003; Mensah & Enu-Kwesi, 2018; Thomas, 2015). Teaching sustainability enables students to grasp the interdependence between environmental, economic, and social systems, fostering informed decision-making and ethical responsibility (Kabadayi, 2016; Muthersbaugh & Kern, 2012). However, the successful integration of sustainability into teaching requires teachers to possess a solid understanding of its principles and be confident and prepared to teach them.

Despite the growing emphasis on ESD globally, much of the existing research has focused on pre-service teachers and tertiary-level students (Aydın & Keleş, 2021; Zhukova et al., 2020). However, there is limited empirical data on practising (in-service) teachers, especially within the Nigerian context, where sustainability education is still emerging and inconsistently implemented. This gap is significant, as in-service teachers serve as the primary agents of curriculum delivery and are directly responsible for embedding sustainability concepts in everyday classroom instruction. This, therefore, made teachers' awareness of the SDGs critical. Teachers’ awareness refers to their understanding of sustainable development concepts, such as environmental stewardship, economic viability, social justice, and their recognition of their relevance to teaching (Mensah, 2019; Omisore et al., 2017). Meanwhile, readiness encompasses not only their knowledge and attitudes but also their sense of competence and willingness to implement sustainability education in practice (Fan et al., 2019; Park et al., 2017; Straková, 2015). When teachers are both aware and ready, they are more likely to integrate sustainability meaningfully into their teaching and influence their students’ behaviours and mindsets positively.

Ibadan Metropolis was selected as the study area because it is one of the largest and most diverse urban centres in Nigeria (Ikudayisi & Taiwo, 2022), with both public and private secondary schools that reflect the country’s educational, cultural, and socio-economic diversity. Ibadan, as an educational hub and a city grappling with rapid urbanisation, environmental challenges, and social inequalities (Oyeranmi, 2023; Varghese, 2024), provides a representative context for examining teachers’ awareness and readiness to teach sustainability concepts. Therefore, this study seeks to assess the awareness and readiness of secondary school teachers in Ibadan Metropolis, Nigeria, to teach sustainable development goal concepts. Addressing this gap is essential for informing policy reforms, designing effective teacher training programmes, and developing curricula that align with the goals of sustainable development.

Research Questions

The following research questions were highlighted to guide the focus of the study.

1. What is the level of teachers' awareness of the concepts of Sustainable Development Goals?
2. Are teachers ready to teach the concepts of sustainable development for sustainability?

Methodology

Research Design

The study adopted a descriptive survey design. The target population comprised all secondary school teachers within the metropolis. A stratified random sampling technique was employed to enhance representativeness. First, schools were categorised into public and private strata to ensure proportional inclusion. For each category, a list of schools was compiled, and a random sample was selected using the lottery method. Following the selection of schools, simple random sampling was used to select teachers from the staff lists of the selected schools. This two-stage sampling approach—stratification by school type and random selection of both schools and respondents—was designed to minimise bias and ensure that every teacher had an equal probability of being included in the study, resulting in a total of 300 teachers.

Research Instrument

The research instrument used for this study is the Teachers' Sustainable Development Awareness and Readiness Questionnaire (TSDARQ). The questionnaire consists of three sections: the first section consists of demographic information of the participants; the second section is an awareness scale of 10 items with 4 Likert responses of Great Extent (GE) (4), Some Extent (SE) (3), Little Extent (LE) (2), and Not At All (NAA) (1); and the third section has 10 items that assess Teachers' Readiness to Teach Sustainable Development Goals on a 4 Likert scale with responses of Not ready at all (1), Not too ready (2), Ready (3), Very much ready (4). The validity of the data collection instrument was established by experts in the field of education, who carefully reviewed the items to ensure they were clear, relevant, and aligned with the study's objectives. To assess the reliability of the instrument, internal consistency analysis was conducted using Cronbach's Alpha. The result yielded a reliability coefficient of 0.90, indicating a high level of reliability and suggesting that the items on the instrument consistently measured the intended construct.

Data Analysis

The data collected were analysed using descriptive statistics of frequency count, mean, and standard deviation.

Results

RQ 1: What is the level of teachers' awareness of the concepts of Sustainable Development Goals?

Table 1 Teachers' Awareness of the Concepts of Sustainable Development Goals.

ITEMS	GE	SE	LE	NAA	X	Std
To what extent are you aware of the concept of sustainable development?	200 66.7	74 24.7	22 7.3	4 1.3	3.57	.688
To what extent are you aware that sustainable development satisfies current needs without jeopardising future generations' ability to meet theirs?	194 64.7	84 28.0	18 6.0	4 1.3	3.56	.669
To what extent are you aware of the United Nations SDGs?	159 53.0	117 39.0	20 6.7	4 1.3	3.56	.654
To what extent are you aware that the implementation of the SDGs started in 2015?	190 63.6	91 30.3	15 5.0	4 1.3	3.56	.654
To what extent are you aware that the implementation of the SDGs will end in 2030?	194 64.7	84 28.0	18 6.0	4 1.3	3.56	.669
To what extent are you aware that the SDGs have a teaching and learning component?	163 54.3	110 37.0	19 6.3	7 2.3	3.43	.717
To what extent are you aware that education for sustainable development has been identified by UNESCO as one of the implementation frameworks to enhance the SDGs?	194 64.7	84 28.0	18 6.0	4 1.3	3.56	.654
To what extent are you aware that the SDGs have three components, which are Economic, Environmental, and Social factors?	164 54.7	110 36.7	19 6.3	7 2.7	3.44	.717
To what extent are you aware that, to achieve sustainable development, everyone in the world must have access to quality education?	194 64.7	84 28.0	18 6.0	4 1.3	3.56	.669
Are you aware that education for sustainable development is meant to be taught to students at all levels of education?	159 53.0	117 39.0	20 6.7	4 1.3	3.44	.679

Weighted average: 3.4
Threshold 2.50
Keys: GE (4) - Great Extent, SE (3) - Some Extent, LE (2) - Little Extent, NAA (1) - Not At All, X - Mean, and Std - Standard deviation

Table 1 revealed a generally high level of teachers' awareness of the Sustainable Development Goals (SDGs), with all mean scores above the 2.50 threshold (range: 3.43–3.57; weighted average = 3.40). Awareness of the general concept of sustainable development was the highest (M = 3.57, SD = 0.688), showing strong consensus among teachers, while knowledge of the 2015–2030 SDG timeline also ranked high (M = 3.56, SD = 0.654). However, awareness of the SDGs' teaching and learning component (M = 3.43, SD = 0.717) and their integration into all levels of education (M = 3.44, SD = 0.679) was relatively low, with higher variation suggesting less uniformity in pedagogical understanding compared to conceptual knowledge. These results indicate that while teachers possess a solid and consistent grasp of the broader principles and timeline of sustainable development, there is more variability and uncertainty when linking SDGs to classroom instruction, pointing to a need for targeted professional training in educational applications of sustainability.

RQ 2: Are teachers ready to teach the concepts of sustainable development for sustainability?

Table 2. Teachers' Readiness to Teach Sustainable Development Goals.

ITEMS	4	3	2	1	X	Std
Are you ready to teach your students about sustainable development?	185 61.7	107 35.7	7 2.3	1 0.3	3.59	.557
Do you think you are sufficiently knowledgeable and skilful about sustainable development?	193 64.3	97 23.3	7 2.3	3 1.0	3.60	.590
Are you ready to teach the concept, knowledge, and skills of sustainable development to your students?	183 61.0	101 33.7	7 2.3	9 3.0	3.53	.691
Are you ready to create a well-being atmosphere in school when teaching sustainable development?	188 62.7	100 33.3	5 1.7	7 2.3	3.56	.649
Do you see teaching of sustainable development in schools as a waste of time?	211 70.0	83 27.7	4 1.3	2 0.7	3.68	.535
Are you ready to broaden your knowledge and experience through the teaching of sustainable development?	173 57.7	107 35.7	18 6.0	2 0.7	3.50	.641
Are you ready to teach sustainable development to students, even if the students are not ready to learn it?	170 57.7	120 40.0	8 2.7	2 0.7	3.53	.586
Are you ready to learn new things that can help you learn sustainable development better?	191 63.7	98 32.7	10 3.3	1 1.3	3.60	.573
Do you have the instructional resources required to teach sustainable development to students?	158 52.7	112 37.3	15 5.0	2 0.7	3.51	.626
Are your school management and other stakeholders ready to support and embrace the teaching of education for sustainable development?	157 52.7	112 36.2	14 4.0	2 0.6	3.52	.625

Weighted average: 3.54
Threshold 2.50
Keys: Not ready at all (1), Not too ready (2), Ready (3), Very much ready (4), X - Mean, and Std - Standard deviation

Table 2 revealed that teachers also demonstrated a high level of readiness to teach sustainability concepts, with mean scores ranging from 3.50 to 3.68 and an overall weighted average of 3.54. The highest readiness was observed in teachers' rejection of the belief that teaching SDGs is a waste of time (M = 3.68, SD = 0.535), reflecting strong attitudinal commitment, while many also considered themselves sufficiently knowledgeable (M = 3.60, SD = 0.590) and open to learning new strategies to improve their teaching (M = 3.60, SD = 0.573). Meanwhile, comparatively lower scores with greater variation were recorded in areas such as broadening knowledge through teaching (M = 3.50, SD = 0.641), access to instructional resources (M = 3.51, SD = 0.626), and school management support (M = 3.52, SD = 0.625). These patterns suggest that while teachers are highly motivated, confident, and willing to engage with sustainability education, structural factors such as resource availability and institutional support may constrain effective classroom implementation.

Discussion

The findings of this study indicate that secondary school teachers in Ibadan Metropolis possess a high level of awareness regarding sustainable development concepts. The consistently high mean scores across all awareness items, ranging from 3.43 to 3.57, suggest that these educators are not only familiar with the general concept of sustainable development but also aware of its specific frameworks, such as the Sustainable Development Goals (SDGs), the implementation timeline (2015–2030), and the role of education as a vehicle for achieving these goals. This marked improvement compared to earlier studies, such as Omisore et al. (2017), who reported limited awareness among university staff and students in southwestern Nigeria, could be attributed to several contextual factors. In Ibadan, there has been increasing exposure to SDG-related discourse through radio programmes, advocacy campaigns, social media, and teacher training initiatives organised by governmental and non-governmental agencies. Such platforms have likely played a role in popularising sustainability issues, thereby contributing to heightened teacher awareness. It is also possible that teachers’ responses reflect an element of social desirability bias, as sustainability has become widely recognised as a “good” or socially expected stance.

The role of teachers' awareness in fostering effective sustainability education cannot be overstated. Awareness forms the foundation upon which pedagogical approaches are developed, influencing both the content and delivery of instruction. Ogunyemi et al. (2022) emphasised that familiarity with sustainability concepts significantly affects teachers’ ability to teach such content effectively. Similarly, Aydın and Keleş (2021) observed that awareness levels among pre-service teachers vary by discipline and recommended the integration of sustainability education across all faculties of education. The present findings, showing strong awareness among in-service teachers, support the argument for reinforcing sustainability knowledge at both pre-service and professional development levels. In addition to awareness, the study revealed a high degree of readiness among teachers to implement sustainable development education in their classrooms. The weighted mean score of 3.54 across readiness items reflects strong positive dispositions toward integrating sustainability into teaching practice. Teachers demonstrated a willingness to expand their knowledge base, utilise available instructional resources, and create inclusive classroom environments conducive to sustainability education. Moreover, the teachers' positive attitudes toward the relevance and importance of teaching sustainability, even in the face of student disinterest, highlight a commendable level of professional commitment.

However, a noteworthy contradiction emerges: while teachers report high readiness overall, the lowest mean scores were observed for items relating to the availability of instructional resources and stakeholder support (≈3.51). This indicates a gap between individual readiness and systemic readiness. Teachers appear personally willing and motivated to teach sustainable development; however, institutional structures, such as the provision of teaching materials, administrative support, and broader policy implementation, are lagging. This mismatch suggests that teachers may struggle to translate their readiness into practice without adequate systemic backing. Addressing this gap requires targeted interventions, including the provision of teaching resources, active involvement of school management, and stronger stakeholder engagement.

These findings also align with those of Vukelić (2022), who reported that participation in ESD training programmes significantly enhances teachers' implementation intentions and self-efficacy. Similarly, Alkahtani (2022) asserted that exposure to sustainability pedagogies improves teacher confidence and preparedness. The responses in this study also reflected the four readiness dimensions identified by Manasia et al. (2019)—professional knowledge, practice, engagement, and self-management—demonstrating that these teachers possess not only content knowledge but also the behavioural and motivational readiness to deliver sustainability instruction effectively. Another key insight from this study is the teachers' openness to continuous professional development, particularly their willingness to acquire new knowledge and skills in teaching sustainable development. This resonates with the work of Yang et al. (2024), who noted that teacher motivation and behaviour are critical components of readiness for sustainability education, while pedagogical knowledge requires ongoing enhancement. Mohamed et al. (2017) also emphasised the importance of curriculum familiarity, pedagogical planning, and instructional strategy in shaping teaching readiness, all of which were positively reflected in the teachers' responses.

The findings suggested a positive trajectory in the integration of sustainability education within the Nigerian secondary school context. The combination of high awareness and strong readiness among practising teachers in Ibadan indicated a conducive environment for implementing Education for Sustainable Development (ESD). However, the observed resource and support gaps highlight the need for systemic reforms and teacher readiness. Strengthening school-level support, expanding resource availability, and institutionalising ESD training policies will be crucial in ensuring that the promising individual dispositions of teachers translate into sustainable classroom practices.

Conclusion

In conclusion, this study contributes initial empirical evidence from the under-researched Nigerian secondary school context, showing that teachers in Ibadan Metropolis exhibit both high awareness of sustainable development concepts and strong readiness to teach them. While this demonstrates a promising foundation for advancing Education for Sustainable Development (ESD), the findings also reveal a critical gap: teachers' individual motivation and preparedness are not fully matched by systemic support in terms of resources and stakeholder involvement. This mismatch highlights the need for institutional and policy-level interventions to complement teachers' efforts. By situating these results within the broader literature, the study addresses a gap in African-based ESD research and emphasises that achieving sustainability goals requires not only teacher readiness but also robust systemic support.

Recommendations

The paper concludes with the following recommendations:

- **Professional Development:** Regular training and capacity-building programmes on sustainability and ESD pedagogies should be organised for in-service teachers to deepen their conceptual understanding and instructional skills.
- **Curriculum Integration:** Sustainable development concepts should be systematically embedded into secondary school curricula

across subjects to promote interdisciplinary learning and long-term student engagement.

- **Institutional Support:** Schools and educational authorities should provide the necessary resources, such as teaching aids, instructional materials, and supportive policies, to enable effective sustainability teaching.
- **Policy Enforcement:** Educational policymakers should institutionalise ESD as a mandatory component of teacher education and professional development frameworks nationwide.
- **Further Research:** Future studies should explore regional disparities in teacher awareness and readiness and examine the impact of ESD implementation on student outcomes.

References

Agbedahin, A. V. (2019). Sustainable development, EDUCATION FOR SUSTAINABLE DEVELOPMENT, and the 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT: Emergence, efficacy, eminence, and future. *Sustainable Development*, *27*(4), 669–680. https://doi.org/10.1002/sd.1931

Alabi, H. I., & Sulaiman, M. M. (2019). SENIOR SCHOOL SCIENCE TEACHERS'AWARENESS OF SUSTAINABLE DEVELOPMENT GOALS. Journal of Curriculum and Instruction, 12(1).https://jci-ilorin.org.ng/index.php/jci/article/view/80

Alkaher, I., & Carmi, N. (2019). Is population growth an environmental problem? Teachersí perceptions and attitudes towards including it in their teaching. Sustainability, 11(7), 1994. https://doi.org/doi:10.3390/su11071994

Alkahtani, K.D.F. (2022). Professional Development: Improving Teachers' Knowledge and Self-Efficacy Related to Emotional and Behavioral Disorders. J. Emot. Behav. Disord., 32, 14–23 https://doi.org/10.1177/10634266221130049

Aydın, S., & Keleş, P. U. (2021). Teachers Candidates' Awareness of Sustainable Development. *Shanlax International Journal of Education*, *9*(S1-May), 221–227. https://doi.org/10.34293/education.v9iS1-May.4015

Bell, D. V. J. (2017). *Introduction to Sustainable Development*.

Browning, M., & Rigolon, A. (2019). School green space and its impact on academic performance: A systematic literature review. *International Journal of Environmental Research and Public Health*, 16(3), 429. https://doi.org/10.3390/ijerph16030429

Buchanan, L. B., & Crawford, E. O. (2015). Teaching for sustainability in a social studies methods course: Opportunities and challenges. Social Studies Research and Practice, 10(2), 135ñ158. https://doi.org/10.1108/SSRP-02-2015-B0012

Fan, M.; Leung, L.P.; Hon, S.; Fan, K.L. (2019). Readiness of Hong Kong secondary school teachers for teaching cardiopulmonary resuscitation in schools: A questionnaire survey. Hong Kong J. Emerg. Med., 26 (3) 174–178. https://doi.org/10.1177/1024907918797532

Goller, A., & Rieckmann, M. (2022). What do we know about teacher educators' perceptions of education for sustainable development? A systematic literature review. *Journal* *of Teacher Education for Sustainability, 24*(1), 19-34.

Gough, S., & Scott, W. (2003). Sustainable development and learning: Framing the issues. Routledge. https://doi.org/10.4324/9780203464625

Ikudayisi, A. E., & Taiwo, A. A. (2022). Accessibility and inclusive use of public spaces within the city-centre of Ibadan, Nigeria. Journal of Place Management and Development, 15(3), 316-335. https://doi.org/10.1108/JPMD-08-2020-0077

Kabadayi, A. (2016). A suggested in-service training model based on Turkish preschool teachersí conceptions for sustainable development. Journal of Teacher Education for Sustainability, 18(1), 5-15. https://doi.org/10.1515/jtes-2016-0001

Malik, M. S. K., Qi, Z., Iqbal, M., Zamir, S., & Malik, B. F. (2022). Education for sustainable development: Secondary school teacher's awareness and perception of integration. Sustainable Development, 31(3), 1515-1525. https://doi.org/10.1002/sd.2463

Manasia, L., Ianos, M. G., & Chicioreanu, T. D. (2019). Pre-Service Teacher Preparedness for Fostering Education for Sustainable Development: An Empirical Analysis of Central Dimensions of Teaching Readiness. *Sustainability*, *12*(1), 166. https://doi.org/10.3390/su12010166

Mensah, J., & Enu-Kwesi, F. (2018). Implication of environmental sanitation management in the catchment area of Benya Lagoon, Ghana. *Journal of Integrative Environmental Sciences*, 16 (1) 23-43 https://doi.org/10.1080/1943815x.2018.1554591

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences*, *5*(1), 1653531. https://doi.org/10.1080/23311886.2019.1653531

Mohamed, Z., Valcke, M., & De Wever, B. (2017). Are they ready to teach? Student teachers' readiness for the job with reference to teacher competence frameworks. *Journal of Education for Teaching*, *43*(2), 151–170. https://doi.org/10.1080/02607476.2016.1257509

Muthersbaugh, D., & Kern, A. (2012). Pre-service teachers use of images in integrating environmental sustainability lessons. Journal of Teacher Education for Sustainability, 14 (1) 67-79. https://doi.org/10.2478/v10099-012-0006-8

Nation, M. T., & Feldman, A. (2021). Environmental education in the secondary science classroom: How teachersí beliefs influence their instruction of climate change. Journal of Science Teacher Education, 32(5), 481-499. https://doi.org/10.1080/1046560X.2020.1854968

Ogunyemi, B., Ifegbesan, A., Benedict, H. T., Ogunsanya, A. O., Iyunade, O. T., Olubela, A., Itasanmi, B., & Edewor, K. (2022). Knowledge, Perceptions and Readiness of Nigeria's Beginning Teachers for Sustainability Education. *Journal of Teacher Education for Sustainability*, *24*(2), 180–194. https://doi.org/10.2478/jtes-2022-0024

Omisore, A. G., Babarinde, G. M., Bakare, D. P., & Asekun-Olarinmoye, E. O. (2017). Awareness and knowledge of the sustainable development goals in a University Community in

Southwestern Nigeria. *Ethiopian Journal of Health Sciences*, *27*(6), 669. https://doi.org/10.4314/ejhs.v27i6.12

Oyeranmi, S. (2023). Environmental management and sustainable development of cities: a case study of Ibadan, Nigeria. Ethics International Press. https://books.google.com.ng/books?hl=en&lr=&id=VRflEAAAQBAJ&oi=fnd&pg=PR8&dq=ibadan+is+an+educational+hub+and+a+city+grappling+with+rapid+urbanisation,+environmental+challenges,+and+social+inequalities,&ots=-CER-odeKS&sig=ot-37EupcI3xrMIpzbAXeM3D2q4&redir_esc=y#v=onepage&q&f=false

Öztürk Demirbaş, Çağrı. (2015). "Sustainable Development Awareness Levels of Teachers Pre-Service." Marmara Coğrafya Dergisi, no. 31, pp. 300-316. https://hdl.handle.net/20.500.12513/2024

Park, M.H.; Dimitrov, D.M.; Patterson, L.G.; Park, D.Y. (2017). Early childhood teachers beliefs about readiness for teaching science, technology, engineering, and mathematics. J. Early Child. Res., 15 (3) 275–291. https://doi.org/10.1177/1476718X15614040

Rodriguez, V., Lynneth Solis, S., Mascio, B., Kiely Gouley, K., Jennings, P. A., & Brotman, L. M. (2020). With Awareness Comes Competency: The Five Awarenesses of Teaching as a Framework for Understanding Teacher Social-Emotional Competency and Well-being. *Early Education and Development*, *31*(7), 940–972. https://doi.org/10.1080/10409289.2020.1794496

Straková, Z. (2015). The perception of readiness for teaching profession: A case of pre-service trainees. J. Lang. Cult. Educ., 3(1) 32–42.

Sundh, S. (2020). Establishing Sustainable Teacher Education with Weekly School Practice: Identifying Teacher Students' Experiences of Didactic Dilemmas in the Swedish Primary School Classroom. *Journal of Teacher Education for Sustainability, 22*(1), 37-48.

Taylor, S. J. (2016). *A review of sustainable development principles: Centre for environmental studies*. South Africa: *University of Pretoria*.

Thomas, C. F. (2015). Naturalizing Sustainability Discourse: Paradigm, Practices and Pedagogy of Thoreau, Leopold, Carson and Wilson: Ph.D Thesis: *Arizona State University*

Tjarve, B., & Zemīte, I. (2016). The Role of Cultural Activities in Community Development. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 64(6) 2151–2160 https://doi.org/10.11118/actaun201664062151

UNESCO. (2021). Berlin Declaration on Education for Sustainable Development. https://en.unseco.org/events/ESDfor2030

VARGHESE, T. (2024). NAVIGATING THE PATH OF PROGRES:" A COMPREHESIVE STUDY OF IBADAN'S DEVELOPMENTAL GROWTH AND LIVABILITY" (Doctoral dissertation, St. Teresa's College (Autonomous) Ernakulam). http://117.239.78.102:8080/jspui/bitstream/123456789/4723/1/Teena%20Varghese-%20Project-1.pdf

Vukelić, N. (2022). Student Teachers' Readiness to Implement Education for Sustainable Development. *Education Sciences*, *12*(8), 505.

https://doi.org/10.3390/educsci12080505

Yang, W., Chinedu, C. C., Chen, W., Saleem, A., Ogunniran, M. O., Ñacato Estrella, D. R., & Vaca Barahona, B. (2024). Building Capacity for Sustainability Education: An Analysis of Vocational Teachers' Knowledge, Readiness, and Self-Efficacy. *Sustainability*, *16*(9), 3535. https://doi.org/10.3390/su16093535

Zhukova, O., Fjodorova, I., & Iliško, D. (2020). Novice Teachers' Beliefs and Knowledge about Education for Sustainable Development. *Acta Paedagogica Vilnensia*, *44*, 34–44. https://doi.org/10.15388/ActPaed.44.3

2026

SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 6, No: 1, PP: 32-45
www.journal.qitepinscience.org

Research Paper

Open Accsess

Managing Practical Work in Secondary Schools' Science Education: An Assessment of Teachers' Practices

Baraka Peter Sanjito[1*], Denis Hyams-Sekasi[2]

[1] Department of Education, UNICAF University in Malawi, Malawi
[2]Department of Education, UNICAF University in Malawi, Malawi
[*]Corresponding author, e-mail: bsanjito@gmail.com

Article history:
Received: August 20, 2025
Revised: February 9, 2026
Accepted: February 19, 2026

Abstract

This paper examined how science teachers manage practical work in middle secondary schools in Tanzania and how they design, prepare, implement, assess, and evaluate laboratory work. A descriptive survey design with classroom-structured observations was used. Questionnaires and observation checklists were used to gather data on 64 science teachers, and SPSS was used to analyse the data using descriptive statistics. The results showed that the strongest element was the implementation of practical work: 100% of the observed teachers could explain the steps of a procedure step-by-step, and 83.3% could relate the practical activities to the theoretical ones. Conversely, 33.3% of teachers consistently provided safety instructions and encouraged inquiry-based learning, and 41.7% used formative assessment strategies during practical sessions. In general, there were higher scores on practical implementation (75%) than on practical assessment (65.5%), indicating an imbalance in the administration of laboratory learning. The research also found that although teachers had high procedural competence, the safety practices, inquiry facilitation, and formative assessment were weak, restricting the efficacy of practical work. The results indicate the need for specific professional training, better laboratory staffing, and administrative support to facilitate safe, inquiry-based, and assessment-driven practical science teaching in public Tanzanian secondary schools.

Keywords: Inquiry-based Learning, Laboratory Safety, Practical Work, Science Education, Science Practices.

Introduction

Global Perspectives on Practical Work in Science Education

The extensive use of practical work is commonly acknowledged as one of the key elements of successful science education in most parts of the world. It will allow learners to interact directly with scientific phenomena, thereby advancing conceptual, investigative, and scientific reasoning. Using practical exercises, students can observe, measure, experiment, and apply abstract scientific knowledge in practical settings (Oliveira & Bonito, 2023). When properly planned, organised, and guided by teachers, practical work is also a crucial means of developing inquiry, critical thinking, and problem-solving skills (Chen, 2024; Afyusisye & Gakuba, 2022).

Although it is a powerful pedagogical method, its inclusion in the curriculum does not ensure its effectiveness in practical work. Research in other educational settings reveals that the effectiveness of practical activities largely depends on teachers' ability to regulate laboratory and outdoor activities, particularly in their preparation, organisation, classroom control, assessment, and safety (Apeadido et al., 2024). Therefore, there has been a growing focus on quality rather than on the availability of practical activities.

Practical Work in Tanzanian Science Education

In Tanzania, science practical work is a compulsory subject in the secondary school curriculum in Physics, Chemistry, and Biology. The documents on the national education policy emphasise the importance of laboratory investigations as the primary means by which students are supposed to learn science, gain practical skills, and develop positive attitudes towards science (Kinyota, 2020). The curriculum also promotes students' experimentation that fosters meaningful learning and better performance in science subjects.

As part of the Secondary Education Development Plan (SEDP), Tanzania has invested heavily in establishing laboratory facilities in secondary schools, which is part of its policy to ensure sufficient access to science laboratories across the country. However, severe inequalities in resource access persist, especially in rural areas. Although laboratory infrastructure is irreplaceable, empirical evidence indicates that quality empirical instruction occurs through teachers' pedagogical activities (Acharya & Subedi, 2023). Studies have also reported that a significant number of teachers place importance on completing the mandated practical exercises as per examination requirements, suggesting a limited scope of being able to get involved and develop higher-order thinking skills in the long term (Kinyota, 2020).

Nevertheless, an empirical study of Tanzanian secondary schools demonstrates that there are severe problems with the implementation of practical science teaching, which are lack of laboratory infrastructure, equipment, materials, insufficient laboratory time, and large classes (Mokoro, 2020). Consequently, most science teachers are accustomed to applying teacher-centred methods through instruction, including demonstrations and theoretical explanations, and do not involve students in practical experiments (Ajani, 2023). Despite high-level policy promoting practical science instruction, the extent to which classroom practices reflect these goals remains debatable.

Gaps in Existing Literature

The literature review of previous research in Tanzania has focused chiefly on identifying general concerns related to science education, including curriculum implementation, teacher qualifications, and student performance. Although these studies are illuminating, the empirical research on practical work management practices by science teachers in the context of available resource constraints is relatively scarce. There is restricted information on how teachers plan, design, implement, assess, and evaluate practical activities, as well as on how these management practices relate to the available facilities to support laboratories' impact on practical science teaching quality.

Although the application of laboratories is recognised as the key to successful practical work (Catherine, 2022), there is a lack of context-based information on how the number of laboratories, spatial planning, material accessibility, and safety statements influence the organisation and efficacy of practical work in the Tanzanian secondary schools. Those gaps underscore the need for empirical research that goes beyond policy idealism to examine real-life classroom practices and contextual realities.

Purpose of the Study

This study aims to examine the effectiveness of the practical work management practices of science teachers in public secondary schools in Tanzania. In particular, the research focused on two significant issues. First, it evaluated the sufficiency and accessibility of science laboratory facilities in terms of the number of laboratories, laboratory spatial distribution, and the number that could accommodate actual science work. Second, it examined the effectiveness of practical work management practices among science teachers, particularly in the preparation and design of science practical work, its implementation and assessment, and compliance with safety procedures.

The research, by addressing these questions, aims to offer empirical evidence on the relationship between laboratory infrastructure and teacher management practices in the delivery of practical science education. It is expected that the findings will guide curriculum developers, institutions of teacher education, administrators of learning institutions, and policymakers to enhance the quality and consistency of practical science teaching in Tanzanian state secondary schools.

Theoretical Framework

Constructivist and experiential approaches of learning were the basis of this study, focusing on the active engagement of the learner and the creation of knowledge through first-hand experience. The concept of learning in science education has been interpreted as involving students in practical tasks, such as experimentation, reflection, and the application of the idea in real situations. Laboratories in schools offered opportunities for such learning, provided there was sufficient infrastructure, equipment, and materials to support teaching and assessment (Allen, 2022). In the absence of laboratory facilities or resources, the experiential learning cycle could be disrupted, leading to fewer opportunities for students to actively participate in scientific processes and gain more effective practical learning (Nwuke, 2024).

Constructively, the teacher is vital in guiding learners in the field of practical work by providing support within the Zone of Proximal Development—a set of tasks that can be handled by learners with the assistance of instructors (Efgivia et al., 2021). This assistance may be observed in real lessons in planning and showing the processes, overseeing experiments, and helping reflect on and discuss the outcomes. Well-managed laboratories are beneficial for teachers in structuring these stages to facilitate inquiry, collaboration, and theory-practice connections (Jegstad, 2023). Building on the principles of constructivist and experiential learning, the most effective practical work management practices should be based on the plan, preparation, implementation, assessment, and evaluation of activities (Chen, 2024; Chuene and Teane, 2024; El Masri et al., 2023). These parts of this study informed the research design, the development of an instrument, and the discussion of the research findings in Tanzanian public secondary schools.

Linkage between Theoretical Framework, Constructs, and Measured Variables

The theoretical framework was used to identify key constructs based on constructivist and experiential learning theories, and to operationalise them into measurable variables. This agreement matched the theory, the research design, and the data collection tools, as abstract theoretical principles were correlated with observable, measurable characteristics of practical science teaching and learning. Table 1 provides an overview of the connections between the underlying theories, core constructs, their operational definitions, and application indicators in questionnaires and observation checklists.

Table 1. Relationship between Theory, Constructs, Operational Definitions, and Measured Variables.

Theory	Construct	Operational Definition	Measured Variables
Constructivist Learning Theory	Teacher Scaffolding	Structured guidance provided by teachers to support learners' progression within the Zone of Proximal Development during practical work.	Clarity of instructions; demonstration of procedures; supervision during experiments; feedback and guidance
	Inquiry-Based Learning	The extent to which practical activities promote learners' questions, explorations, collaborations, and active participation.	Student participation; group work; opportunities for questioning; learner autonomy
Experiential Learning Theory	Practical Work Planning	Advance organisation of practical activities aligned with curriculum objectives and available resources.	Practical objectives in lesson plans, syllabus alignment, and time allocation
	Practical Work Preparation	Teacher readiness through the organisation of materials, equipment testing, and laboratory setup.	Availability of materials; functionality of equipment; laboratory readiness
	Practical Work Implementation	Facilitation of hands-on activities enabling concrete experience and active experimentation.	Learner-centred approaches; supervision; student engagement
	Assessment and Evaluation	Use of formative and summative strategies to assess understanding and skills gained through practical work.	Practical reports; oral questioning; feedback on performance

	Safety Management	Enforcement of laboratory safety procedures during practical activities.	Adherence to safety rules, availability of safety equipment, and teacher supervision
Contextual Enabling Factors	Laboratory Infrastructure	Availability and adequacy of physical facilities and resources supporting practical work.	Number of laboratories, spatial layout, availability, and condition of equipment

Methodology

Research Design

This study employed a descriptive survey design to assess the effectiveness of science teachers' practical work management practices in public secondary schools. The quantitative component consisted of a structured questionnaire administered to 64 science teachers, while the qualitative component involved structured laboratory observations and practical science lessons. Quantitative and qualitative data were collected concurrently, analysed separately, and then the results were combined for a comprehensive understanding. This method was adopted as it supported the study's validity by using various data collection methods and helped to connect statistical findings with real-world education (Ming, 2023; Adhikari & Timsina, 2024).

Participants of the Study

This study involved a total of 64 science teachers selected from public secondary schools in the Nyamagana and Magu districts in the Mwanza region. The targeted participants were diverse in terms of size and geography, providing different groups of respondents to the survey. Schools were sampled using a stratified random sampling method, where both urban and rural settings were included in the study. In the sampled schools, science teachers were recruited through purposive sampling because they often have special skills and are directly involved in laboratory instruction, which is crucial to the research objectives of this study. In the case of the student population, simple random sampling was utilised to remove selection bias, as well as to encourage the representativeness and fairness of the sample.

Instrumentation and Data Collection Procedures

Teacher Questionnaire

A structured questionnaire was developed using the constructivist and experiential learning theories and administered to gather data on teachers' practical work management practices. The questionnaire was designed to comprise five domains: plan, preparation, implementation, assessment, and evaluation of practical work. Responses were measured on a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree to indicate teachers' self-reported practice in the domains.

To establish instrument validity, the questionnaire was also reviewed by experts in science education who assessed its relevance, clarity, and correspondence with the study's goals. A pilot study was done with the science teachers in the non-primary schools, which were public secondary schools. The pilot study provided feedback that was necessary to revise ambiguous items and wording. The questionnaire's reliability was assessed using Cronbach's alpha, which yielded satisfactory levels of reliability (α =

0.70) across all domains, indicating the instrument was reliable for data collection.

Observation Checklist

Data on the actual implementation of the practical work during laboratory sessions were collected using a structured observation checklist. The checklist included observable points on lesson preparation, clarity of instructions during teaching, learner attention, inquiry-based activities, assessment practices, and safety management. The constructs measured by the questionnaire were matched to the checklist to enable a direct comparison of self-reported with observed practices.

Inter-rater reliability was also determined to increase the reliability of the observation data. Two trained observers observed selected practical lessons and recorded the observations using the checklist. The percentage of agreement and Cohen's kappa coefficient (0.84) indicated a satisfactory level of consistency. Discrepancies were discussed and resolved through consensus to improve the accuracy of the observations, indicating a satisfactory level of agreement.

Data collection was performed in three distinct steps. First, all science teachers in the sampled public secondary schools completed the questionnaire. Second, direct classroom observations of practical science lessons were conducted using an observation checklist. These observations offered the possibility of systematically recording teachers' teaching behaviours and provided the scope to make them comparable to self-reported data (Kholifah & Sofwan, 2024). This step provided the necessary background to explain how physical resources could impact the implementation of practical work in science teaching.

Data Analysis

The survey questionnaire and observation checklist provided a detailed dataset that was subjected to statistical analysis. The percentages, frequencies, and mean scores were obtained to measure prevalence. Meanwhile, the effect of different practical work management practices was subjectively rated. Self-reported data were compared with the corresponding observer-based data to determine the alignment or discrepancy between the reported and actual instructional practices in the classroom setting.

Research Ethics

The UNICAF University Research Ethics Committee and the Tanzania Commission for Science and Technology (COSTECH) provided ethical approval for this study. Every respondent participating in this study was informed about the purpose of the study and provided written consent. Anonymity and confidentiality were maintained throughout the study period. All data collected was kept safe and used only for educational purposes.

Results

Availability of Science Laboratories

Adequate provision of practical science instruction in secondary schools is impossible without science laboratories. Teachers were asked whether their schools had functional science laboratories. The responses are summarised in Table 2.

Table 2. Reported Availability of Science Laboratories by Teachers.

Respondent group	Laboratory availability	Frequency (n)	Percentage (%)
Teachers	Yes	64	100.00
	No	00	00.00

The findings in Table 2 indicated that science laboratories were widely available in the participating public secondary schools, with 100% of the teachers confirming their presence.

Science Laboratory Infrastructure and Resource Sufficiency

Teachers also prepared reports on the number of laboratories, laboratory organisation, and the sufficiency of resources. Table 3 and Figure 1 provided the results.

Table 3. Teachers' Responses on Science Laboratory Structure and Resource Adequacy.

Aspect	Category	Frequency (n)	Percentage (%)
Number of Laboratories	One	23	35.90
	Two	08	12.50
	Three	33	51.60
	More than three	00	00.00
Total		**64**	**100**
Laboratory Organisation	One lab for each science subject	33	51.60
	One shared lab for all science subjects	31	48.40
Total		**64**	**100**
Laboratory Resource Sufficiency	Resources are adequate	35	54.70
	Resources are inadequate	29	45.30
Total		**64**	**100**

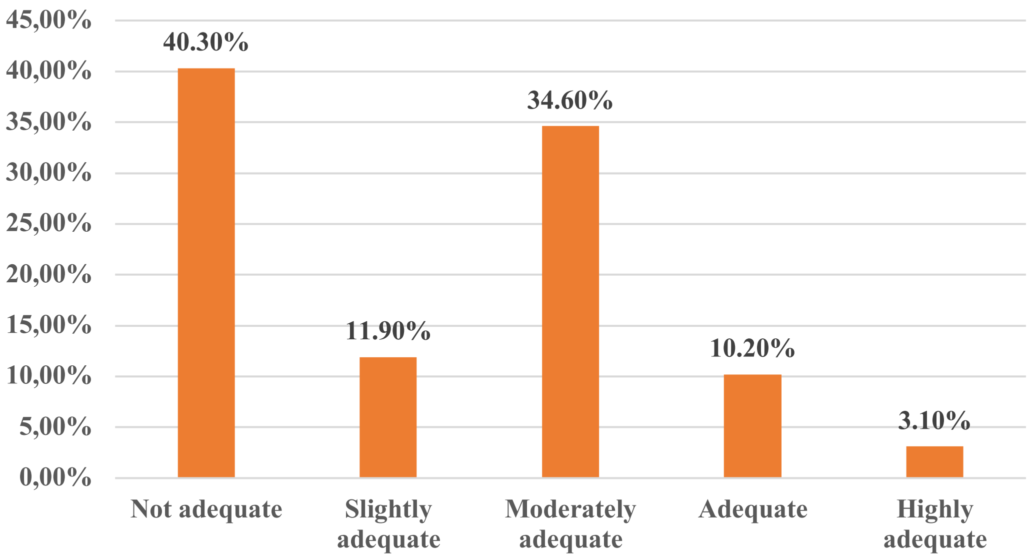

Figure 1. Teachers' Responses to the Adequacy of Laboratory Resources.

The findings revealed differences in the laboratory infrastructure across schools. A slight majority of the teachers (51.60) stated that they had individual labs for each science, whereas 48.40 percent used shared labs. Resource-wise, 54.70% of teachers reported adequate laboratory resources, while 45.30% said otherwise.

Effectiveness of Science Teachers' Practical Work Management Practices

Teachers indicated their participation in five elements of practical work management practices: design, preparation, implementation, assessment, and evaluation. These components had mean ratings given in Figure 2.

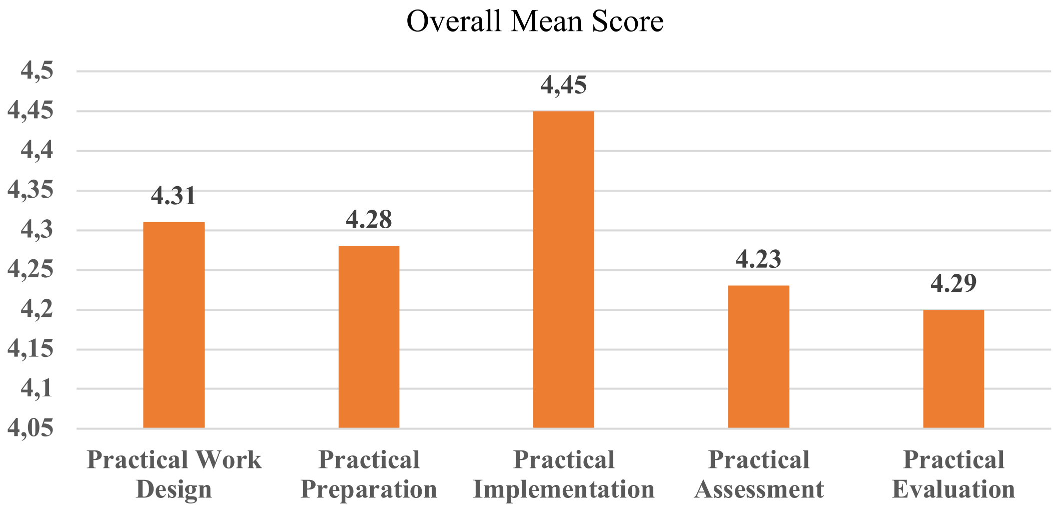

Figure 2. Teachers’ Mean Ratings across Five Practical Work Management Practices.

The results in Figure 2 indicated that among the dimensions of science practical work management practices, implementation received the highest mean score (M = 4.45), followed by design (M = 4.31), evaluation (M = 4.29), preparation (M = 4.28), and assessment (M = 4.23).

Observed Laboratory Practices

A structured checklist was utilised to conduct classroom observations to assess teachers' self-reported practices. Table 4 summarises the observed practices.

Table 4. Observed Teachers' Practical Work Management Practices (n =12).

Criteria	Frequency (n)		Percentage (%)	
Practical Implementation	**Yes**	**No**	**Yes**	**No**
The teacher provides step-by-step explanations of experimental procedures.	12	0	100	0
Teacher links practical work to theoretical lessons	10	2	83.30	16.70
The teacher conducts a trial of practicals before students perform them.	10	2	83.30	16.70
Clear safety instructions are given before starting experiments	4	8	33.30	66.70

Overall percentage			75.00	25.00
Practical Assessment	**Yes**	**No**	**Yes**	**No**
The teacher observes students during experiments to assess their understanding of the material.	9	3	75	25
The teacher monitors students during experiments to ensure adherence to safety measures	10	2	83.30	16.70
The teacher supervises students throughout the practical session	9	3	75	25
The teacher encourages inquiry-based learning during practicals (e.g., asking questions, concluding)	4	8	33.30	66.70
Formative assessments (e.g., observations, questioning) are used during practicals	5	7	41.70	58.30
Students are encouraged to take responsibility for their learning during practical activities	9	3	75	25
Students are asked to write laboratory reports after practical activities.	9	3	75	25
Overall percentage			**65.50**	**34.50**

Source: Sanjito, 2025, field data

The use of a structured checklist in classroom observations ensured that teachers had practice in managing their work. The teachers explained the experimental procedures in steps (100%), but 83.30% integrated practical activities with theoretical lessons and conducted practice runs before the students. Only 33.30% of people provided clear safety instructions, 75% focused on students' knowledge and the sessions they were going through, and 83.30% monitored safety during the assessment. However, 33.30% promoted inquiry-based learning, and 41.70% employed formative evaluation. In 75% of the sessions, student autonomy was noted in the writing of the laboratory report. In general, the practical implementation was 75%, and the assessment was 65.50%. These findings suggested that teachers consistently offered procedural guidance and supervision of practical activities, whereas assessment practices, inquiry facilitation, and safety instructions were less uniform in observed lessons.

Discussion

Availability of Science Laboratories

The availability of universal science laboratories in sampled public secondary schools indicates significant progress in enforcing national policies that place greater emphasis on practical science learning in Tanzania. This observation is consistent with findings from other sub-Saharan African settings, where education reforms have increased access to laboratory services (AbiDoye et al., 2022). Nevertheless, the availability of a laboratory does not guarantee a successful practical teaching period, as the results of the current study later show the inadequacy of equipment and organisation in the laboratories. In terms of experiential learning, competent hands-on learning requires access to laboratories and well-equipped functional environments to facilitate experimentation and inquiry. This finding indicates that the policy's intervention should go beyond infrastructure delivery to include sustained provision of laboratory facilities and maintenance, with a view to improving the quality and effectiveness of practical sciences instruction.

Science Laboratory Infrastructure and Resource Sufficiency

The results of the science laboratory infrastructure and resource adequacy indicate significant variation among schools and essential implications for the management and quality of instruction in practical sciences. Though only a slight majority (51.60) of the teachers reported having independent laboratories for each science subject, a large percentage (48.40) utilised shared laboratories, which could limit opportunities for subject-specific practical work and flexibility in scheduling. Although teachers had a relatively small majority (54.70) in their assessment of whether the available lab resources were adequate, the comparatively high number of teachers who reported inadequacy (45.30) indicates critical discrepancies in the allocation of equipment and consumables. This contradictory image helps clarify the disparities observed between teachers' self-reported practices and their classroom observations reported in other parts of the research. Teachers in better-equipped or subject-specific laboratories would also be more likely to report sufficient provision and effective practical management.

In contrast, teachers in shared or under-equipped laboratories may over-report positive practices to meet curricular requirements, despite practical constraints. The problem of resource scarcity, in particular, directly influences teacher behaviour, commonly leading to increased use of demonstrations, lower rates of student-led experimentation, and less frequent use of inquiry learning, especially when consumables and safety gear are insufficient. This is one of the reasons some practices, such as the procedure explanation, are rated highly. Meanwhile, more resource-intensive practices, such as inquiry-based engagement or safe, hands-on experimentation, are not always applied. Altogether, the findings indicated that the state of infrastructure was not enough. Long-term investment in the laboratory facilities, fair distribution, and teacher assistance was required to convert policy intentions into effective and learner-centred practical science learning as sustainable as the theories of experiential and constructivist learning (AbiDoye et al., 2022; Mokoro, 2020; Efgivia et al., 2021).

Effectiveness of Science Teachers' Practical Work Management Practices

The results revealed that science teachers in the sampled public secondary schools were highly competent in their applications of practical work, as the mean scores in the five management dimensions (plan, preparation, implementation, assessment, and evaluation) were high. The highest scores were consistently obtained in implementation, indicating that teachers were confident in their abilities to conduct experiments, oversee students, and discuss procedures during practical lessons. This trend was consistent with the existing literature, which highlighted that educators were more focused on the performance aspect of practising tasks, as it was most strongly correlated with syllabus coverage, examination requirements, and pre-service training expectations (El Masri et al., 2023; Manyilizu, 2023). Conversely, the relatively lower scores in preparation and assessment indicated that less attention was paid to activities such as advanced planning, risk anticipation, formative assessment, and post-practical reflection, even though they were all important for meaningful learning.

This difference between the generally favourable self-reports of the teachers and the relatively lower observational ratings can be partially attributed to contextual limitations in schools. Self-reported data can be based on what teachers want to or should do, but observations are based on what is practically implemented within an existing state of affairs. Those practices that were rated consistently high, including explaining procedures step-by-step and making connections between experiments and theory, mainly rely on teachers' pedagogical knowledge rather than on material resources. These are well instilled in teacher training courses and curriculum manuals, and this is one of the reasons why they perform uniformly. Conversely, the practices with low scores, such as explicit safety instruction, inquiry-based facilitation, formative assessment, and laboratory reporting, tend to include sufficient equipment, safety gear, adequate time, and manageable class sizes. In situations where laboratories are shared, equipment is limited, or consumables are scarce, teachers can limit student autonomy, cut down on inquiry activities, or favour getting experiments done rather than more thorough assessment and reflection.

The lack of resources thus influences teachers' behaviour in significant ways. In poorly equipped laboratories, educators might minimise practical work to reduce safety issues, thereby limiting the potential for questioning, research, and formative evaluation. On the same note, the reduced focus on inquiry-based tasks and laboratory reports can also indicate time pressure and workload, especially in institutions with less access to laboratories. On the one hand, the overall practical implementation scored relatively high. On the other hand, the low score in assessment and inquiry reveals a tendency to prioritise completing procedures over developing scientific reasoning, reflection, and communication skills. These results indicated that pedagogical training was insufficient to enhance the management of practical work. Specialised professional learning should be supported by improved facilities in terms of laboratories and institutional facilities, realistic safety, and assessment to ensure that teachers can transform high-level procedural competence into inquiry-based, reflective, and safe learning of practical science as part of constructivist and experiential learning principles (Chen, 2024; El Masri et al., 2023).

Results and Discussion

This study analysed the practical work management practices among science teachers in public secondary schools in Tanzania across the design, preparation, implementation, assessment, and evaluation stages. In general, the results indicated that the teachers exhibited high levels of procedural competence, especially in the application of practical lessons, student monitoring, and connecting experiments to theoretical material. However, classroom observations indicated that certain practices were not consistently applied, such as explicit safety instruction, inquiry-based scaffolding, formative assessment, and systematic laboratory reporting. These lapses indicated that teachers were occupied with the practical lessons underway, while cognitive involvement and official safety and evaluation procedures had not yet been deeply integrated into everyday practice. Moreover, differences in schools' laboratory facilities (including the number of subject-specific laboratories) limited uniformity and the quality of practical work.

The research is unique in its approach to the study, as it triangulated teachers' self-reported data with classroom observations, thereby exposing differences between reported practices and classroom implementation. This body of mixed evidence shows the influence of structural factors, such as resource availability and the organisation of the laboratory, on the teacher's behaviour during a practical lesson. Based on these results, the research suggests specialised professional training that would include inquiry-based teaching, formative evaluation, laboratory safety, and scientific reporting, as well as policy-level work to mitigate inequity in infrastructure and harmonise the principles for managing practical work. Further studies should examine how increased capacity and laboratory resources for teachers can lead to quantifiable benefits in student engagement and the development of scientific skills.

Acknowledgements

We sincerely appreciate God for His help and support during our research. Many thanks to UNICAF University for its support in education and to COSTECH for granting ethical clearance, as well as to all the teachers, students, and school heads who participated in this study.

References

AbiDoye, F., AdebiSi, A. M., RiHanat, A. A., & AliYu, M. Z. (2022). Availability of Laboratory Facilities on Students' Performance In Upper Basic Schools In Kwara State, NIGERIA. *International Journal of Educational Research Review*, *7*(4), 262–267. https://doi.org/10.24331/ijere.1151372

Acharya, K. P., & Subedi, R. R. (2023). Exploring Experiences of Science Education Teachers on Professional Development. *Orchid Academia Siraha*, *2*(1), 33–41. https://doi.org/10.3126/oas.v2i1.65600

Adhikari, R., & Timsina, T. P. (2024). An Educational Study Focused on the Application of Mixed Method Approach as a Research Method. *OCEM Journal of Management, Technology & Social Sciences*, *3*(1), 94–109. https://doi.org/10.3126/ocemjmtss.v3i1.62229

Afyusisye, A., & Gakuba, E. (2022). The effect of the chemistry practicals on the academic performance of Ward Secondary School students in Momba District in Tanzania. *Journal of Mathematics and Science Teacher*, *2*(2), em019. https://doi.org/10.29333/mathsciteacher/12397

Ajani, O. A. (2023). Challenges of school resources management for curriculum delivery in South African Rural High Schools: Principals' perceptions on the way forward. *International Journal of Research in Business and Social Science (2147- 4478)*, *12*(6), 275–285. https://doi.org/10.20525/ijrbs.v12i6.2709

Allen, A. (2022). An Introduction to Constructivism: Its Theoretical Roots and Impact on Contemporary Education. *Journal of Learning Design and Leadership,* 1 (1) 1- 11

Apeadido, S., Opoku-Mensah, D., & Mensah, G. O. (2024). Enhancing Science Process Skills and Academic Performance in Biology: The Impact of Practical Work. *Integrated Science Education Journal*, *5*(1), 34–41. https://doi.org/10.37251/isej.v5i1.854

Catherine, A. (2022). Adequacy of STEM Resources and Academic Achievement in STEM Subjects: Case of Selected Secondary Schools in Western Kenya. *Asian Journal of Education and Social Studies*, 10–29. https://doi.org/10.9734/ajess/2022/v34i1719

Chen, X. (2024). Effectiveness of Practical Teaching Participation for Improving the Students' Employability. *International Journal of Sociologies and Anthropologies Science Reviews*, *4*(3), 475–490. https://doi.org/10.60027/ijsasr.2024.4276

Chuene, D. M., & Teane, F. M. (2024). Resource inadequacy as a barrier to effective curriculum implementation by life sciences teachers in South Africa. *South African Journal of Education*, *44*(2), 1–10. https://doi.org/10.15700/saje.v44n2a2387

Efgivia, M. G., Adora Rinanda, R. Y., Suriyani, Hidayat, A., Maulana, I., & Budiarjo, A. (2021). *Analysis of Constructivism Learning Theory:* 1st UMGESHIC International Seminar on Health, Social Science and Humanities (UMGESHIC-ISHSSH 2020), Gresik, Indonesia. https://doi.org/10.2991/assehr.k.211020.032

El Masri, Y. H., Erduran, S., & Ioannidou, O. (2023). Designing practical science assessments in England: Students' engagement and perceptions. *Research in Science & Technological Education*, *41*(1), 190–210. https://doi.org/10.1080/02635143.2021.1872519

Jegstad, K. (2023). Inquiry-based chemistry education: A systematic review. *Studies in Science Education*, *null*, null. https://doi.org/10.1080/03057267.2023.2248436

Kholifah, E. R., & Sofwan, M. (2024). Comparison of Data Collection Methods: Advantages and Disadvantages. *Jurnal Kepemimpinan Dan Pengurusan Sekolah*, *9*(4), 519–525. https://doi.org/10.34125/jkps.v9i4.628

Kinyota, M. (2020). The status of and challenges facing secondary science teaching in Tanzania: A focus on inquiry-based science teaching and the nature of science. *International Journal of Science Education*, *42*(13), 2126–2144. https://doi.org/10.1080/09500693.2020.1813348

Lestari, W., Surtikanti, H. K., & Rahman, T. (2023). Science Teacher's Professionalism In Planning Practical Learning Activities. *Syntax Literate ; Jurnal Ilmiah Indonesia*, *8*(9), 5054–5069. https://doi.org/10.36418/syntax-literate.v8i9.11443

Manyilizu, M. C. (2023). Effectiveness of virtual laboratory vs. Paper-based experiences to the hands-on chemistry practical in Tanzanian secondary schools. *Education and Information Technologies*, *28*(5), 4831–4848. https://doi.org/10.1007/s10639-022-11327-7

Ming, G. K. (2023). Measuring Reliability and Validity of Questionnaire on Teacher Digital Professional Development: A Rasch Model Analysis. *International Journal of Academic Research in Progressive Education and Development*, *12*(4), Pages 304-312. https://doi.org/10.6007/IJARPED/v12-i4/19662

Mokoro, D. (2020). Adequacy of Laboratory Facilities for Effective Implementation of Competence-Based Curriculum in Public Secondary Schools in Arumeru District, Tanzania. *East African Journal of Education and Social Sciences*, *1*(2), 141–149. https://doi.org/10.46606/eajess2020v01i02.0029

Nwuke, T. J. (2024). Provision and Utilization of Physical Resources for Effective Teaching and Learning Effectiveness in Public Universities in Rivers State. *International Journal of Applied and Scientific Research*, *2*(2), 227–244. https://doi.org/10.59890/ijasr.v2i2.1412

Oliveira, H., & Bonito, J. (2023). Practical work in science education: A systematic literature review. *Frontiers in*

Education, *8*, 1151641. https://doi.org/10.3389/feduc.2023.1151641

2026
SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 6, No: 1, PP: 46-57
www.journal.qitepinscience.org
Research Paper
Open Accsess

Integrating Solar Cells, Arduino, and Sensors for Vocational Science Education: A Scoping Review

M. Raynaldo Sandita Powa[1*]

[1] *Faculty of Teacher Training and Education, University of Bengkulu, Bengkulu 38371A, Indonesia*
[*]*Corresponding author, e-mail: raynaldo.sandita@gmail.com*

Article history:
Received: March 26, 2025
Revised: March 13, 2026
Accepted: May 04, 2026

Abstract

Vocational science learning requires contextual, hands-on experiences that reflect real-world technological applications. Solar cell systems integrated with Arduino and various sensors represent low-cost technological platforms with strong potential to be adapted as learning media for renewable energy topics in vocational education. Numerous studies have developed solar-Arduino-sensor systems for monitoring, tracking, acquiring data, and experimenting in a laboratory; however, these developments have not been systematically mapped from an educational perspective. This study employed a scoping review to map the landscape of existing research on solar cell–Arduino–sensor system designs. The initial literature research was conducted using Publish or Perish (PoP) based on Google Scholar indexing, followed by iterative searching and reference tracking during the review process. A total of 20 articles published between 2015 and 2025 were selected for data charting and thematic analysis. The results revealed several major clusters of system development, including solar tracking mechanisms, sensor-based photovoltaic monitoring, Internet of Things (IoT) architectures, portable photovoltaic laboratory instruments, and immersive solar education technologies. Although most studies were conducted in engineering and monitoring contexts, the identified designs demonstrated strong potential to be adapted as contextual science learning media aligned with the characteristics of vocational education. This mapping provides a comprehensive overview of technological designs that can support the development of vocational science learning tools based on solar cells, Arduino, and sensor integration.

Keywords: Arduino, Scoping Review, Sensor Integration, Solar Cell, Vocational Science Education.

Introduction

The demand for electrical energy continues to increase over time. This has resulted in high consumption of electrical energy sources, particularly fossil fuels, as the primary energy source for power plants. Fossil fuels have a direct negative impact on the environment. This has driven humanity to innovate continuously in developing electrical energy sourced from renewable energy, one of which is solar energy converted into electricity using solar cells. Solar cells operate by harnessing photons from sunlight and converting them into electrical energy in the form of current and voltage (Fonash, 2015). Generally, there are four stages in the photovoltaic conversion process of solar cells (Conibeer & Willoughby, 2014): (1) transfer of solar photons to the active part of the system; (2) absorption of the photons and energy transfer to the electronic system; (3) selective extraction of electrons to contacts (at least two); (4) the transfer of e-free energy to a useful load whose impedance is adjusted.

Solar cell systems involve measurable electrical parameters, such as voltage, current, and power, that vary with environmental conditions and system configurations. These characteristics allow solar cells to function as observable physical systems rather than abstract concepts, making them suitable for exploration through direct interaction. In vocational and science education contexts, learning activities that engage students with tangible systems have been shown to support conceptual understanding and the development of practical skills through hands-on experiences.

In the context of Technical and Vocational Education and Training (TVET), such hands-on activities are not merely practical exercises but represent core pedagogical principles. Vocational learning is grounded in work-based learning, where knowledge is constructed through activities that resemble real technical work (Sudira, 2017). This perspective is closely related to life-based learning and work-integrated learning, in which learning occurs through meaningful interactions with tools, systems, and real-world technologies. Solar cell systems integrated with microcontrollers and sensors reflect the techno-scientific learning environment, as students engage in assembling systems, measuring physical parameters, interpreting data, and directly observing system performance. These characteristics position solar cell–embedded system designs within the fundamental framework of TVET pedagogy rather than as merely technological devices.

Several studies have demonstrated the use of immersive technologies, portable photovoltaic laboratory instruments, Arduino-based monitoring systems, and wireless sensor architectures in learning-related or exploratory contexts involving solar energy systems, as conducted by Machado et al. (2025), Zahra et al. (2023), and Khalid et al. (2024). Nevertheless, these studies are commonly situated within engineering, monitoring, or system optimisation contexts rather than being explicitly discussed from an educational perspective. As a result, the educational potential of these technological designs, especially for vocational science learning, has not yet been systematically mapped. To address this gap, a mapping of existing research is required to understand what types of solar cell–Arduino–sensor systems have been developed, how these systems are instrumented, and how they could be adapted as contextual science learning media.

Based on this objective, the study is guided by the following research questions: (1) What types of solar cell–Arduino–sensor systems have been developed in existing studies? (2) What physical parameters are measured, and how are these systems instrumented? (3) In what contexts are these systems applied (engineering, monitoring, laboratory, or educational settings)? (4) What educational potentials can be inferred for vocational science learning from these technological designs?

Methodology

This study employed a scoping review methodology following the framework proposed by Arksey and O'Malley (2005) and further refined by Levac et al. (2010) to map the landscape of technological designs that integrate solar cells, Arduino, and sensors. This scoping review was conducted through the following: (1) Identifying the research question; (2) Identifying relevant studies; (3) Selecting the studies; (4) Charting the data; and (5) Collating, summarising, and reporting the results. The consultation stage was not conducted, as the review focused on mapping published technological designs rather than stakeholder validation.

The initial literature search was conducted using the Publish or Perish (PoP) software based on Google Scholar indexing with the keyword query "solar cell, Arduino, science, vocational education". Following the scoping review approach, the searching process was iterative, and additional relevant articles were incorporated through complementary searches and reference tracking during the review process. After identifying core studies from the initial search, additional relevant articles were incorporated through reference tracking and complementary searches to ensure a comprehensive mapping of solar cell–Arduino–sensor system designs.

To determine the eligibility of studies included in this scoping review, predefined inclusion and exclusion criteria were applied. In line with the scoping review approach, these criteria emphasised topic relevance and system characteristics rather than database indexing, journal quartile, or access type. The inclusion and exclusion criteria used in this study are summarised in Table 1.

Table 1 Inclusion and Exclusion Criteria.

No	Criteria	Inclusion	Exclusion
1.	Period	2015–2025	Before 2015
2.	Language	English	Not English
3.	Topic Relevance	Discuss solar cell systems integrated with embedded systems, microcontrollers, or sensors	Not related to solar–Arduino–sensor systems
4.	System Focus	Present system design, monitoring, tracking, data acquisition, or laboratory applications	Pure theoretical discussion without system implementation
5.	Application Context	Engineering, monitoring, laboratory, or educational context	Unrelated application context
6.	Educational Potential	Demonstrates potential for experimental or learning media adaptation	No potential for experimental or learning use

Results and Discussion

The initial literature search produced a broad set of studies relevant to solar cell systems integrated with embedded platforms and sensors. Using Publish or Perish (PoP) with the keyword combination "solar cell, Arduino, science, vocational education," the search captured studies spanning technological, experimental, and educational contexts. Although the initial query emphasised the term "Arduino," subsequent screening and mapping revealed that many relevant studies employed other microcontrollers and embedded systems (e.g., ESP8266, ESP32, Raspberry Pi) with similar functional roles in solar cell monitoring and experimentation. Based on these findings, the scope of the review was broadened to include solar cell systems integrated with various embedded platforms and sensors.

This search yielded approximately 200 articles from various sources and criteria. These records served as the starting point for identifying relevant studies. VOSviewer was utilised only as a visual tool to explore keyword relationships within the initial records, supporting the understanding of research trends rather than serving as a formal screening instrument.

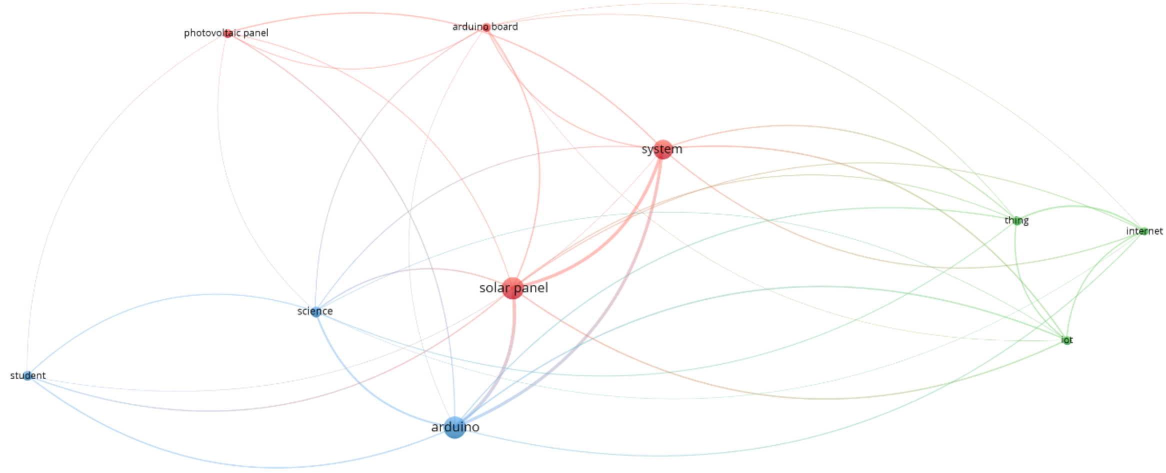

Figure 1. VOSviewer Keyword Screening.

The keyword visualisation indicated strong relationships between solar panels, Arduino, sensors, monitoring systems, and IoT-related terms, illustrating the technological focus of the initial literature landscape. In particular, explicit educational terms such as "vocational education" were not dominant in the keyword network. The study selection process followed the stages of identifying relevant studies, screening based on eligibility criteria (Table 1), and charting the data as described in the scoping review framework. The initial search returned approximately 200 records, which served as the starting point for identifying relevant studies. These records were screened based on title and abstract relevance, resulting in 60 articles for full-text review. Rather than limiting the selection based on database indexing or access type, the screening focused on identifying studies that presented relevant solar cell–embedded system–sensor system designs. During the full-text review and data charting process, additional relevant articles were identified through reference tracking and complementary searches. This iterative process resulted in a final set of 20 articles utilised for mapping and thematic analysis.

Table 2. Selected Article.

No	***Author & Year***	***Criteria***				
		Language	**Topic Relevance**	**System Focus**	**Application Context**	**Educational Potential**
1	Abichandani et al. (2019)	English	Solar–VR learning environment	Virtual PV simulation system	Education	Immersive PV learning media
2	Organtini & Tufino (2022)	English	Arduino-based lab apparatus	Experimental lab instrumentati-on	Education	Inquiry-based lab tool
3	Mayub et al. (2024)	English	Solar power bank with Arduino	Solar charging prototype	Education	Solar kit for literacy

4	AlQallaf et al. (2024)	English	VR solar system design	Immersive solar training system	Education	Immersive solar training
5	Belik et al. (2025)	English	PV parameter measuremen t	Portable PV laboratory stand	Laboratory	PV instrumentati-on kit
6	Muñoz et al. (2024)	English	PV I–V characterisat i-on	Arduino I–V tracer	Laboratory	PV characterisati-on tool
7	Machado et al. (2025)	English	PV panel characterisat i-on	Arduino I–V curve tracer	Laboratory	Low-cost PV tracer
8	Baouche et al. (2022)	English	Solar tracking mechanism	Arduino tracker prototype	Engineerin g	Replicable tracker model
9	Laseinde & Ramere (2019)	English	Multi-axis solar tracking	Arduino tracking design	Engineerin g	Low-cost tracker design
10	Morón et al. (2017)	English	Dual-axis solar tracking	Arduino mechanical–electronic tracker	Engineerin g	Mechanical tracker model
11	Zahra et al. (2023)	English	PV monitoring system	Arduino-based battery charging monitoring	Monitoring	Monitoring system model
12	García et al. (2022)	English	PV fault detection	ESP-based PV diagnosis	Monitoring	Sensor-based PV diagnosis
13	Oberloier & Pearce (2018)	English	Power monitoring	Arduino data logger	Monitoring	Open-source monitoring tool
14	Beltrán Castañón et al. (2025)	English	Wireless PV monitoring	Arduino Nano monitoring system	Monitoring	Wireless monitoring model

15	Salamone et al. (2015)	English	Wireless solar control	Arduino ZigBee control	IoT / Monitoring	PV control architecture
16	Hameed & Kurnaz (2024)	English	Long-range PV monitoring	LoRaWAN PV monitoring	IoT / Monitoring	Long-range monitoring model
17	Khalid et al. (2024)	English	IoT PV SCADA system	Arduino + ESP32 SCADA	IoT / Monitoring	SCADA learning model
18	Panagopou -los & Argiriou (2022)	English	PV data acquisition	ESP32 MQTT DAQ system	IoT / Monitoring	IoT data architecture
19	Paredes-Parra et al. (2018)	English	Standard PV monitoring	Arduino + Raspberry PV system	Monitoring	IEC-compliant monitoring
20	Cámara-Díaz et al. (2021)	English	PV electronic behaviour	Low-cost PV electronic design	Engineerin g	PV behaviour model

The mapping of the reviewed studies revealed five dominant clusters of system development: (1) solar tracking mechanisms; (2) sensor-based photovoltaic monitoring systems; (3) IoT-based monitoring architectures; (4) portable photovoltaic laboratory instruments; and (5) immersive solar education technologies. These clusters represent recurring patterns in the integration of solar cell systems with embedded platforms and sensors. The thematic mapping derived from the data charting process answers the first research question regarding the types of developed systems.

Table 3. Thematic Mapping of Solar-Embedded System Designs.

No	Cluster	Focus of Design	Representative Studies	Application Context	Educational Affordance
1	Solar Tracking Mechanisms	Light sensors, actuators, and microcontrollers for dynamic panel orientation	Baouche et al. (2022); Laseinde & Ramere (2019); Morón et al. (2017)	Engineering	System assembly, sensor calibration, actuator control, and performance comparison between fixed and tracked panels

2	Sensor-Based PV Monitoring Systems	Measurement of V, I, P, temperature, and light intensity using low-cost sensors and Arduino	Zahra et al. (2023); Oberloier & Pearce (2018); Beltrán Castañón et al. (2025); García et al. (2022)	Monitoring	Real-time measurement practices, data logging, and observation of environmental influence on PV output
3	IoT-Based Monitoring Architectures	Wireless transmission of PV data via MQTT, HTTP, LoRaWAN, ZigBee, SCADA	Khalid et al. (2024); Panagopoulos & Argirio (2022); Hameed & Kurnaz (2024); Salamone et al. (2015)	IoT / Monitoring	Integration of hardware-software systems, remote data observation, and network configuration and verification
4	Portable PV Laboratory Instruments	I–V curve tracing, Voc, Isc, MPP measurement, portable PV test stands	Belik et al. (2025); Muñoz et al. (2024); Machado et al. (2025); Paredes-Parra et al. (2018); Cámara-Díaz (2021)	Laboratory	Experimental characterisation of PV behaviour, controlled measurement, and interpretation of electrical parameters
5	Immersive and Explicit Educational Technologies	VR solar simulation, Arduino-based lab learning, solar prototype kits	Abichandani et al. (2019); Organtini & Tufino (2022); Mayub et al. (2024); AlQallaf et al. (2024)	Education	Direct manipulation of systems, conceptual visualisation, and inquiry-based experimental learning

Cluster 1: Solar Tracking Mechanisms

In the studies by Baouche et al. (2022), Laseinde and Ramere (2019), and Morón et al. (2017), solar panels are treated as parts of systems that move and respond to light. Light sensors, actuators, and microcontrollers are integrated into a single unit that continuously adjusts the panel's position in response to the direction of incoming sunlight. The assembly process requires careful attention to both mechanical and electronic aspects, including frame construction, sensor placement, and actuator control. System performance is tested by comparing energy output between fixed panel positions and light-following positions. These stages involve direct observation, adjustment, and repeated testing. The sequence of activities follows a workflow commonly encountered in a laboratory practicum.

Cluster 2: Sensor-Based Photovoltaic Monitoring Systems

Zahra et al. (2023), Oberloier and Pearce (2018), Beltrán Castañón et al. (2025), and

García et al. (2022) present approaches focused on continuous measurement of electrical and environmental parameters. A relatively consistent system structure appears: the solar panel is connected to sensors, data are processed by a microcontroller, and the results are displayed or recorded. The main attention is directed toward acquiring real-time data and observing photovoltaic behaviour directly. In this context, the solar panel becomes an object whose performance can be interpreted through measured values. The instruments used are simple and easy to reassemble, allowing experiments to be repeated at any time. The workflow reflects measurement activities commonly carried out in physics experiments.

Cluster 3: IoT-Based Monitoring Architectures

Khalid et al. (2024), Panagopoulos and Argiriou (2022), Hameed and Kurnaz (2024), and Salamone et al. (2015) extend monitoring systems into data communication networks. Information from sensors is not limited to local displays; instead, it is transmitted to servers or dashboards through various communication protocols. Users engage in tasks that include sensor installation, configuration of communication modules, and setup of data-receiving software. The system consists of multiple interconnected layers, ranging from hardware components to digital interfaces. Its construction requires an understanding of how these parts interact within the system. Throughout the process, testing and parameter verification remain essential steps.

Cluster 4: Portable Photovoltaic Laboratory Instruments

Belik et al. (2025), Muñoz et al. (2024), Machado et al. (2025), Paredes-Parra et al. (2018), and Cámara-Díaz et al. (2021) position solar panels as test objects similar to laboratory samples. The developed devices enable full I–V curve measurement to examine the electrical characteristics of the panel. The equipment typically includes automated load control and measurement displays within portable frames. The primary focus lies in observing electrical characteristics in detail rather than energy utilisation. Users operate these devices in the same way laboratory instruments are used during practicum. The testing environment is arranged in a controlled manner so that measurement results can be carefully analysed.

Cluster 5: Immersive and Educational Technologies

Abichandani et al. (2019), Organtini and Tufino (2022), Mayub et al. (2024), and AlQallaf et al. (2024) directly bring solar energy systems into learning activities. Students interact with the devices, make observations, and interpret the results obtained. Some studies employ virtual simulations, while others utilise Arduino-based physical devices. Learning takes place through the manipulation of equipment and examination of measured parameters. The activity pattern resembles what is found in engineering and monitoring clusters. The difference lies in the explicit intention to support learning from the outset.

Dominance of Arduino as an Experimental Platform

The mapping results indicated that Arduino appeared more frequently than other embedded platforms, including ESP8266, ESP32, and Raspberry Pi, across the included studies. In the mapped dataset, Arduino-based systems were reported in a larger proportion of studies compared to other platforms. Its simplicity, mature ecosystem of libraries, low cost, and ease of programming make it practical for a wide range of system designs. Sensors can be connected using basic circuits. Moreover, libraries are easily accessible, and the system can be rebuilt quickly when needed. This condition supports repeated testing without requiring complex equipment. Arduino is therefore often used as a medium for exploring physical parameters rather than merely as a device controller.

Educational Potential Across Non-Educational Studies

Many studies situated in engineering, monitoring, and laboratory contexts display workflows that closely resemble a vocational science practicum. Users assemble devices, install sensors, perform measurements, record data, and evaluate system performance. These sequences represent the core components of experimental learning. Although the authors rarely frame their work in educational terms, the system designs themselves already form learning-oriented processes. The practicum structure is embedded within the technological designs. From this perspective, an opportunity emerges that has not been widely discussed within educational contexts.

From a vocational education standpoint, experiential learning is widely recognised as a foundational pedagogical approach, as it emphasises learning through direct engagement with real-world systems and tools (Sudira, 2017). This emphasis is particularly relevant in the context of TVET, where previous studies have identified persistent challenges related to overly theoretical learning practices that are insufficiently connected to authentic work processes, resulting in graduates who are not fully prepared to meet industry demands (Suharno et al., 2020). In response to these challenges, hands-on and practice-oriented learning environments are known to support the development of procedural skills, conceptual understanding, and problem-solving abilities by enabling learners to connect abstract concepts with observable system behaviour. Learning activities that involve constructing, testing, and refining physical systems further foster iterative reasoning and reflective thinking, which are essential components of scientific and technical competence. Consequently, system designs that naturally require learners to engage in measurement, experimentation, and evaluation align closely with the pedagogical goals of vocational science education.

Although most of the reviewed non-educational studies did not explicitly report instructional designs or learning outcomes, their underlying system architectures demonstrate characteristics that are pedagogically transferable to educational settings. The modular construction, sensor-based measurement, and iterative testing processes observed across studies provide a practical foundation for designing vocational science learning activities grounded in experiential learning principles. This perspective is consistent with recent vocational education research emphasising that engagement with emerging technologies and authentic technological systems plays a critical role in cultivating students' professional skills and higher-order thinking skills in vocational contexts (Li & Zhang, 2024). At the same time, the absence of explicit educational framing across the reviewed studies highlights a gap between technological development and pedagogical application. This gap suggests an opportunity for future work to deliberately adapt and evaluate such system designs as structured learning media within vocational science classrooms, thereby transforming implicit educational potential into explicitly designed instructional practice.

Conclusion

This scoping review mapped existing studies that integrate solar cell systems with embedded platforms and sensors to identify their technological characteristics and educational relevance for vocational science learning. In response to the first research question, the review found that a wide range of solar cell-embedded system designs have been developed, with Arduino-based platforms appearing most frequently across the literature. Other platforms–including ESP8266, ESP32, and Raspberry Pi–were also employed, but Arduino's accessibility and suitability for experimental system development contributed to its dominance.

The reviewed studies commonly measured photovoltaic electrical and environmental parameters such as voltage, current, power, temperature, and light intensity. These measurements were obtained through sensor-based data acquisition systems integrated with microcontrollers, enabling real-time monitoring, logging, and analysis of photovoltaic behaviour under varying conditions. Many systems were designed as portable laboratory instruments or experimental setups that support direct observation and parameter characterisation.

The application contexts of these systems were primarily situated in engineering, monitoring, laboratory, and system development settings. Only a limited number of studies explicitly framed their designs within educational contexts. Nevertheless, the workflows involved in system assembly, sensor integration, measurement, data interpretation, and performance evaluation closely resemble activities commonly found in a vocational science practicum.

This review identified substantial educational potential across non-educational studies. Although explicit instructional designs and learning outcomes were rarely reported, the underlying system architectures demonstrate characteristics that are pedagogically transferable to vocational science education. The modular construction, sensor-based measurement, and iterative testing processes align with experiential and practice-oriented learning principles central to TVET. At the same time, the lack of explicit educational framing highlights a gap between technological development and pedagogical application. This gap indicates an opportunity for future research to intentionally adapt and evaluate solar cell–embedded system designs as structured learning media, thereby transforming implicit educational potential into explicitly designed instructional practice within vocational science classrooms.

References

Abichandani, P., McIntyre, W., Fligor, W., & Lobo, D. (2019). Solar Energy Education through a Cloud-Based Desktop Virtual Reality System. *IEEE Access*, *7*, 147081–147093. https://doi.org/10.1109/ACCESS.2019.2945700

AlQallaf, N., AlQallaf, A., & Ghannam, R. (2024). Solar Energy Systems Design Using Immersive Virtual Reality: A Multi-Modal Evaluation Approach. *Solar*, *4*(2), 329–350. https://doi.org/10.3390/solar4020015

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a Methodological Framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Baouche, F. Z., Abderezzak, B., Ladmi, A., Arbaoui, K., Suciu, G., Mihaltan, T. C., Raboaca, M. S., Hudișteanu, S. V., & Țurcanu, F. E. (2022). Design and Simulation of a Solar Tracking System for PV. *Applied Sciences (Switzerland)*, *12*(19). https://doi.org/10.3390/app12199682

Belik, M., Rubanenko, O., Hunko, I., Rubanenko, O., Baraban, S., & Semenov, A. (2025). Tools for Researching the Parameters of Photovoltaic Modules. *Electronics (Switzerland)*, *14*(9), 1–27. https://doi.org/10.3390/electronics14091885

Beltrán Castañón, N. J., Chura Acero, F., Ramos Cutipa, J., Chayña Velásquez, O., Shuta Lloclla, H., & Cruz Ticona, E. (2025). A Low-Cost Wireless Monitoring System for Photovoltaic Systems: Performance Analysis and Potential Application in Direct-Current Nanogrids. *Energies*, *18*(9), 1–15. https://doi.org/10.3390/en18092279

Cámara-Díaz, L., Ramírez-Faz, J., López-Luque, R., & Casares, F. J. (2021). A cost-effective and efficient electronic design for photovoltaic systems for solar hot water production. *Sustainability (Switzerland)*, *13*(18), 1–21.

https://doi.org/10.3390/su131810270

Conibeer, G., & Willoughby, A. (2014). *Solar Cell Materials: Developing Technologies*. John Wiley & Sons Ltd. https://doi.org/10.1002/9781118695784

Fonash, S. J. (2015). *Introduction to Light Trapping in Solar Cell and Photo-detector Devices*. Academic Press.

García, E., Ponluisa, N., Quiles, E., Zotovic-Stanisic, R., & Gutiérrez, S. C. (2022). Solar Panels String Predictive and Parametric Fault Diagnosis Using Low-Cost Sensors. *Sensors*, *22*(1). https://doi.org/10.3390/s22010332

Hameed, B. H., & Kurnaz, S. (2024). Secure low-cost photovoltaic monitoring system based on LoRaWAN network and artificial intelligence. *Discover Computing*, *27*(1). https://doi.org/10.1007/s10791-024-09475-0

Khalid, W., Jamil, M., Khan, A. A., & Awais, Q. (2024). Open-Source Internet of Things-Based Supervisory Control and Data Acquisition System for Photovoltaic Monitoring and Control Using HTTP and TCP/IP Protocols. *Energies*, *17*(16). https://doi.org/10.3390/en17164083

Laseinde, T., & Ramere, D. (2019). Low-cost automatic multi-axis solar tracking system for performance improvement in vertical support solar panels using Arduino board. *International Journal of Low-Carbon Technologies*, *14*(1), 76–82. https://doi.org/10.1093/ijlct/cty058

Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: Advancing the Methodology. *Implementation Science*, *5*(69), 1–9.

Li, K., & Zhang, L. (2024). Dual-line Cultivation of Students ' Professional Skills and Creative Thinking in Vocational Education in the Context of Emerging Technologies. *Applied Mathematics and Nonlinear Sciences*, *9*(1), 1–17. https://doi.org/https://doi.org/10.2478/amns-2024-2371

Machado, P. L. O., Fachini, L. V. G., Tiuman, E. T., Barchi, T. M., Stevan, S. L., Siqueira, H. V., Szmoski, R. M., & Antonini Alves, T. (2025). A Low-Cost Arduino-Based I–V Curve Tracer with Automated Load Switching for PV Panel Characterization. *Applied Sciences (Switzerland)*, *15*(15), 1–23. https://doi.org/10.3390/app15158186

Mayub, A., Delima, E. M., Nursa'adah, E., Fahmizal, & Lazfihma. (2024). Solar cell based power-bank prototype as a media to increase students' scientific literacy. *International Journal of Applied Power Engineering*, *13*(4), 989–1004. https://doi.org/10.11591/ijape.v13.i4.pp989-1004

Morón, C., Ferrández, D., Saiz, P., Vega, G., & Díaz, J. P. (2017). New prototype of photovoltaic solar tracker based on arduino. *Energies*, *10*(9), 1–13. https://doi.org/10.3390/en10091298

Muñoz, J. V., Nieto, L. M., Canalejo, J. F., Montes-Romero, J., Gonzalez-Rodriguez, A. G., & Gulkowski, S. (2024). Novel Indoor Educational I-V Tracer for Photovoltaic Modules. *Electronics (Switzerland)*, *13*(24), 1–12. https://doi.org/10.3390/electronics13244932

Oberloier, S., & Pearce, J. M. (2018). Open source low-cost power monitoring system. *HardwareX*, *4*. https://doi.org/10.1016/j.ohx.2018.e00044

Organtini, G., & Tufino, E. (2022). Effectiveness of a Laboratory Course with Arduino and Smartphones. *Education Sciences*, *12*(12). https://doi.org/10.3390/educsci12120898

Panagopoulos, O., & Argiriou, A. A. (2022). Low-Cost Data Acquisition System for Solar Thermal Collectors. *Electronics*

(Switzerland), *11*(6). https://doi.org/10.3390/electronics11060934

Paredes-Parra, J. M., Mateo-Aroca, A., Silvente-Niñirola, G., Bueso, M. C., & Molina-García, Á. (2018). PV module monitoring system based on low-cost solutions: Wireless raspberry application and assessment. *Energies*, *11*(11). https://doi.org/10.3390/en11113051

Salamone, F., Belussi, L., Danza, L., Ghellere, M., & Meroni, I. (2015). An open source low-cost wireless control system for a forced circulation solar plant. *Sensors, 15*(11), 27990-28004. https://doi.org/10.3390/s151127990

Sudira, P. (2017). TVET Abad XXI: Filosofi, Konsep, dan Strategi Pembelajaran Vokasional. *UNY Press*, 1689–1699.

Suharno, Pambudi, N. A., & Harjanto, B. (2020). Vocational education in Indonesia: History, development, opportunities, and challenges. *Children and Youth Services Review*, *115*(January), 105092. https://doi.org/10.1016/j.childyouth.2020.105092

Zahra, M. M. A., Sharif, H., Alazi, K. M. A., Mohammed, N. Q., Ali, A. A., Tariq, H., & Mohammed, M. Q. (2023). Battery Charging Monitoring System Using PZEM 004t Sensor and DC Voltage Sensor. *International Journal of Renewable Energy Research*, *13*(2), 666–672. https://doi.org/10.20508/ijrer.v13i2.14152.g8736

SciEd
SEAQIS Journal of Science Education

SEAMEO Regional Centre for QITEP in Science

Kompleks Balai Besar Guru dan Tenaga Kependidikan (BBGTK) Provinsi Jawa Barat,
Gedung B, Jl. Dr. Cipto No. 9, Bandung, West Java 40171, Indonesia

+62 22 421 8739 secretariat@qitepinscience.org www.qitepinscience.org

+62 821 2345 0630 @seaqis QITEP in Science

Qitep in Science SEAMEO QITEP in Science

ISSN 2964-7533
9 772964 753001

ISSN 2987-8101
9 772987 810002

#Daretoinnovate