

Teachers' Preparedness on Pedagogical Practices in K-12 Science Education: Foundations for Crafting an Effective Science Program

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Received June 29, 2024; Revised July 31, 2024; Accepted August 06, 2024

Abstract This study investigates the implications and future works to bolster the preparedness of teachers to pedagogical practices in science teaching. Using a descriptive survey, data were collected from a diverse sample of science teachers to assess their readiness in implementing contemporary pedagogical techniques. The results indicate a sub-optimal level of preparedness among respondents, highlighting significant gaps in their pedagogical practices. The findings suggest a critical need for targeted professional development programs to enhance teachers' skills in modern pedagogical techniques, technology integration, and updated scientific knowledge. Revisions in teacher education curricula, emphasizing practical training and hands-on experiences, are essential to address these gaps. Longitudinal research studies are recommended to monitor the impact of the improved practices on student outcomes and to identify specific barriers faced by the teacher-respondents in science. Additionally, mentorship and collaboration initiatives, along with the integration of educational technology tools, are proposed to support teachers in optimizing their practices. The results draw implications along impacting student learning outcomes, teacher confidence, and retention. Enhancing pedagogical preparedness can bridge achievement gaps, promote educational equity, and lead to policies mandating ongoing professional development. This, in turn, contributes to global competitiveness in STEM fields that fosters a scientifically literate society. Addressing these gaps is crucial for the holistic development of students, teachers, and the broader educational system.

Keywords: *Effective Science Program, K-12 Curriculum, Science Pedagogical Practices, science teaching*

Cite This Article: Wilfredo B. Baniqued, and Romiro G. Bautista, "Teachers' Preparedness on Pedagogical Practices in K-12 Science Education: Foundations for Crafting an Effective Science Program." *American Journal of Educational Research*, vol. 12, no. 8 (2024): 291-297. doi: 10.12691/education-12-8-1.

1. Introduction

Science education in primary and secondary schools holds paramount importance for several reasons. Science education plays a pivotal role in shaping the scientific understanding and critical thinking skills of students. Since 2010, significant researches were conducted to explore various aspects of science education, including pedagogical approaches, curriculum development, and technology integration. One of the key areas of focus has been the shift toward inquiry-based learning as emphasized by Minner, Levy, and Century [1], and Guerrero and Bautista [2]. They investigated the impact of inquiry-based science instruction on student learning outcomes. Their findings highlighted the positive effects of this approach in enhancing students' understanding and interest in science.

This sentiment is echoed in studies like those by Lederman and Lederman [3], emphasizing the need to

foster inquiry-based learning and scientific reasoning in the K-12 education. By engaging students in hands-on experiments and inquiry-based learning experiences, science education stimulates curiosity, encourages analytical thinking, and nurtures a mindset that values evidence-based reasoning. Additionally, according to the National Research Council's report "A Framework for K-12 Science Education," which guides science education reform efforts in the United States, a strong foundation in science is essential for preparing students for future careers, especially in STEM fields. The framework underscores the importance of scientific literacy in addressing societal challenges and making informed decisions. Moreover, scholars like Bybee [4] argued that effective science education does not only foster essential skills for the workforce but also cultivate informed citizens capable of understanding and contributing to discussions on scientific issues. According to the studies of Linn et al. [5] and Anoling et al. [6], integrating engineering practices into science education cultivates problem-solving skills. This integration emphasizes

iterative problem-solving processes and fosters resilience in students when faced with complex challenges.

Another significant development in science education is the integration of technology. The study of Sung, Chang, and Liu [7] examined the effectiveness of incorporating digital tools in science teaching. They found that technology, when used effectively, can facilitate interactive and personalized learning experiences, leading to an improved student engagement and understanding. Furthermore, the role of socio-scientific issues in science education gained attention, as evidenced by the work of Adinda et al. [8] that discusses the role of Socio-Scientific Issues (SSI) in science education. It states that SSI provides opportunities for students to conduct investigations and discussions about social and scientific issues, which can improve students' scientific literacy.

Environmental science, a critical component of science education, has also been a focus, particularly in the context of sustainable education. The research by Stevenson [9] emphasized the importance of teaching environmental science from a sustainability perspective, proposing a pedagogical framework that fosters environmental literacy and responsible citizenship. Additionally, the importance of teacher professional development in science education cannot be understated. Luft, Roehrig, and Patterson [10] provided insights into effective strategies for supporting science teachers, highlighting the necessity of ongoing professional learning to keep pace with scientific advancements and pedagogical changes.

Scientific literacy is vital in today's world, where scientific advancements profoundly impact various aspects of society. The K-12 science education plays a pivotal role in cultivating scientific literacy among students. One of the studies by the National Research Council [11] emphasized the importance of developing scientific literacy to empower individuals to engage thoughtfully in societal discussions and make informed decisions. The research of Scalise et al. [12] highlighted the engagement of students in authentic scientific practices, such as making claims based on evidence and constructing explanation that significantly contributes to the development of scientific literacy. Inquiry-based learning, a cornerstone of science education, stimulates curiosity and encourages students to explore and discover. According to the study of Minner et al. [1], inquiry-based approaches in science education positively influence students' attitudes toward science and increase their interest in pursuing STEM-related fields. The research of Fabiola [13] discussed the use of inquiry-based instructional approaches in science education highlighting the development of research skills and construction of scientific knowledge. It emphasizes the importance of effective teaching strategies and continuous teacher training in implementing open inquiry. The trend toward technology-based serious games and the drive to develop STEM methodologies in the current educational topography are also emphasized.

The landscape of K-12 science education is marked by multifaceted challenges that significantly influence the quality and efficacy of teaching and learning. A fundamental challenge lies in developing a science curriculum that is both comprehensive and aligned with

contemporary scientific advancements while remaining relevant and engaging for students. This requires a delicate balance between incorporating inquiry-based learning methods and meeting standardized testing requirements, as highlighted in the research of Wang et al. [14]. The study emphasized the importance of curriculum alignment with national standards to enhance student engagement and understanding.

Teacher preparedness and ongoing professional development stand out as critical areas requiring attention. Many educators encounter obstacles stemming from inadequate training, limited access to professional development opportunities, and a lack of deep content knowledge. These challenges significantly impact their ability to effectively convey complex scientific concepts and employ innovative teaching strategies. The research of Yerushalmy [15] underscored the necessity of continuous professional development programs focusing on content knowledge enhancement and pedagogical skills development for science educators.

In addition, the shortage of resources and insufficient laboratory facilities impedes the implementation of hands-on, inquiry-based learning experiences. The dearth of proper equipment and materials limits students' practical exposure to scientific experimentation, hindering their deeper understanding of scientific principles. Studies, such as those of Lusterio-Rico et al. [16], stressed the significance of well-equipped science laboratories in fostering effective science learning experiences in schools.

Engaging students and fostering a genuine interest in science poses another significant challenge. Abstract concepts, traditional teaching methods, and a lack of hands-on opportunities often contribute to student disengagement and reduced motivation toward science subjects. Addressing this challenge requires innovative teaching approaches and real-world applications within science education, as advocated by research such as that by Aviso and Manzano [17], emphasizing inquiry-based methods to enhance student engagement and motivation.

Promoting inclusivity and equity in science education remains a challenge, especially in addressing disparities in access to quality education among students from diverse backgrounds. Culturally relevant pedagogies and equitable science education approaches are crucial for ensuring the inclusion of diverse students in the learning process, as emphasized by Francisco and Amparo [18].

Reevaluating assessment practices and adopting more comprehensive evaluation methods is essential. Conventional assessment methods often prioritize memorization over the application and problem-solving skills crucial in science education. The research of Rosel et al. [19] underscored the significance of employing performance-based assessments and formative evaluation methods to accurately gauge students' understanding and practical application of scientific concepts. Hence, this study aims to investigate the preparedness and practices of K-12 science teachers along student-centered pedagogy, hands-on learning, scaffolding, assessment and feedback, and professional development toward the development of a proposed science program. This is expected to leverage the current status of science education in response to the results of world ranking studies.

2. Methodology

The Descriptive Survey design was used in this study. This employed a structured survey or questionnaire to gather quantitative data on the respondents' preparedness in various pedagogical practices. Questions covered aspects of student-centered pedagogy, hands-on learning, scaffolding, assessment and feedback, and professional development.

This study was conducted in a Schools Division of the Department of Education in the Philippines. This site is documented to be in the realm of improving science education across all levels with the provisions of inquiry-based learning and Lesson Study (LS): all at the helm of improving science instruction through a Community of Practice (CoP) in a sustained culture of LS [2,20,21,22].

On the other hand, the respondents of this study were the science teachers in the elementary and secondary. They were chosen based on the idea that an effective science education shall start in the foundation level. Thus, their standpoints are necessary in developing better programs that can bolster the practices and procedures in science education.

The total number of science teachers in the research locale was requested from the Schools Division Office. The sample of 190 from a total population of 373 was determined using the Raosoft sample size calculator using a level confidence of 95% and an error of 5%. After this, the Stratified Random Sampling (SRS) technique was employed to ascertain the representativeness of the population per strata.

The instrument used to gather the needed data was a validated researcher-made questionnaire. It covered the following concepts: student-centered pedagogy, hands-on learning, scaffolding, assessment and feedback, and professional development. Indicators of the known parameters were formulated based on the frames of the identified theory, Constructivist Learning Theory. Three experts were consulted to check on the consistency of the indicators sought. Thereafter, the questionnaire was field tested to 30 respondents who were outside the research locale. Test of reliability, particularly the unidimensionality of the items, through Cronbach's alpha was employed. The instrument has an alpha of .849. According to Taber [23], an alpha of at least .7 suggests acceptability. Hence, a valid and reliable instrument.

Descriptive statistics were employed in determining the conformity of the respondents on the formulated problems of the study. These became the basis of the formulated plan to bolster the science teaching in the K-12 program.

3. Results and Discussion

3.1. Preparedness of Science Teachers on the Various Pedagogical Practices in Science Education

As presented in Table 1, the respondents agreed in all the parameters of pedagogical practices in science which are interpreted as *much prepared*, a mean range of 2.50 to 3.25. These imply that the respondents are in the process

of progressing in advancing their pedagogical practices in science which require more for them to advance and move further in response to the newer psychology of learning in science.

Table 1. General Preparedness of Science Teachers on the Various Pedagogical Practices in Science Education

	Pedagogical Practices	Mean	SD	Description	Interpretation
1	Student-centered pedagogy	2.89	.652	Agree	Much prepared
2	Hands-on learning	2.93	.671	Agree	Much prepared
3	Scaffolding	2.86	.661	Agree	Much prepared
4	Assessment and feedback	2.91	.656	Agree	Much prepared
5	Professional development	2.92	.682	Agree	Much prepared

The effective integration of standards into science education requires a holistic approach that encompasses curriculum development, teacher training, and student assessment. Nadelson and Seifert [24] explored how teacher perceptions and understandings of standards, such as the NGSS, impact their implementation. They found that teacher attitudes toward these standards significantly influence how they are integrated into classroom practice, highlighting the need for comprehensive professional development that addresses both content and pedagogy. The influence of standards on student outcomes is another critical area of research.

Banilower et al. [25] conducted a large-scale study examining the impact of standards-based teaching on student achievement in science. Their findings indicate that adherence to standards correlates with an improved student understanding and achievement in science, underscoring the importance of standards in driving educational effectiveness. Standards also play a crucial role in addressing equity in science education. Lee and Buxton [26] discussed how well-designed standards can help bridge the achievement gap in science education by providing clear expectations and consistent educational experiences for all students. However, they also cautioned academicians and planners that this requires careful attention to the diverse needs of students, particularly those from historically underrepresented groups. The evolution of science standards over time reflects changes in our understanding of how students learn science. Duschl and Grandy [27] examined the shift from content-focused standards to those that integrate scientific practices and crosscutting concepts, arguing that this evolution represents a more holistic view of science education that mirrors how science is practiced in the real world. Challenges in aligning assessment with standards are also a significant concern. Reyes [28], Discipulo and Bautista [29], and Ligado et al. [30] discussed the complexities of developing assessments that accurately reflect standards, particularly those that emphasize higher-order thinking and scientific inquiry. They argued for a new generation of assessments that are aligned with the cognitive demands of the standards. Despite the potential benefits of standards in science education, concerns have been raised about their implementation. Tadem [31] and Bagay et al. [32] noted that without adequate support,

resources, and professional development, the implementation of standards can become a superficial checklist rather than a meaningful change in science education.

3.2. Proposed Plan to Bolster the Pedagogical Practices in Science Education

Title: Enhancing Teacher Preparedness in the K-12 Science Education: Comprehensive Professional Development and Support Program

RATIONALE:

The quality of science education in K-12 schools significantly impacts students' understanding, interest, and career choices in science, technology, engineering, and mathematics (STEM) fields. The preparedness of science teachers to employ effective pedagogical practices is crucial in fostering a conducive learning environment that stimulates students' curiosity and critical thinking skills.

Research has shown that student-centered pedagogy, hands-on learning, scaffolding, assessment and feedback, and continuous professional development are integral components of effective science teaching. However, many teachers face challenges in implementing these practices due to the following: lack of resources, training, and institutional support. This program aims to address these gaps by providing comprehensive professional development, fostering collaboration, updating curriculum, and ensuring adequate resource allocation.

By enhancing teachers' preparedness, the program seeks to improve science education quality, increase student engagement and motivation, and prepare students for future STEM careers. The program aligns with contemporary educational standards and responds to the needs identified in the study of teachers' preparedness on various pedagogical practices in science education.

Professional development indirectly affects the implementation of pedagogical practices through its impact on teacher preparedness. As teachers receive more training, their increased preparedness leads to better application of student-centered pedagogy, hands-on learning, scaffolding, and effective assessment and feedback practices.

The interaction effect between teacher preparedness and the grade level taught by the teacher needs to be explored. Research results indicate that while preparedness is crucial at all levels, the specific needs and applications of pedagogical practices vary. For example, hands-on

learning might be more prominent in elementary settings, whereas scaffolding might be more critical at higher grade levels where concepts are more complex.

The analysis highlighted that professional development has a varying impact depending on the years of teaching experience. Less experienced teachers benefit significantly from professional development as it boosts their preparedness more substantially compared to their more experienced counterparts who might already possess a high level of preparedness.

Another critical pathway is from teacher preparedness through pedagogical practices to student outcomes. Teachers who are better prepared and effectively implement student-centered pedagogy, hands-on learning, and scaffolding can significantly improve student engagement, understanding, and retention of scientific knowledge.

Promoting inclusivity and equity in science education remains a challenge, especially in addressing disparities to the access to quality education among students from diverse backgrounds. Culturally relevant pedagogies and equitable science education approaches are crucial for ensuring the inclusion of diverse students in the learning process.

Re-evaluating assessment practices and adopting more comprehensive evaluation methods are essential. Conventional assessment methods often prioritize memorization over the application and problem-solving skills crucial in science education. Researches underscored the significance of employing performance-based assessments and formative evaluation methods to accurately gauge students' understanding and practical application of scientific concepts.

GOALS:

1. To improve teachers' knowledge and skills in contemporary pedagogical practices.
2. To foster a collaborative culture among teachers for sharing best practices.
3. To ensure teachers have access to updated curriculum and necessary teaching resources.
4. To implement diverse and effective assessment and feedback strategies.
5. To create engaging and inclusive learning environments for students.
6. To advocate for policies that support continuous professional development and resource allocation.

Table 2. Proposed Plan to Bolster the Pedagogical Practices in Science Education

Key Result Area	Objective	Activities	Output	Outcome
Professional Development	Enhance teachers' knowledge and skills	- Organize workshops and seminar - Provide access to online courses and webinars - Conduct expert sessions - Implement hands-on training sessions - Develop and distribute instructional material - Create a professional development portal with resources and forums	- Regular workshops and seminar - Online courses and webinars - Expert sessions - Hands-on training materials - Instructional materials - Professional development portal	- Improved teacher knowledge and skills - Enhanced teaching practices - Increased confidence in teaching complex scientific concepts
Collaboration and Knowledge Sharing	Foster a collaborative culture among teachers	- Establish Professional Learning Communities (PLCs) - Implement mentorship	- PLCs - Mentorship programs - Peer observation report - Online resource platform	Increased collaboration and sharing of best practices among teachers

Key Result Area	Objective	Activities	Output	Outcome
		programs - Schedule regular peer observation and feedback sessions - Create an online platform for sharing resources and ideas - Organize annual science education conferences and symposiums	Annual conferences and symposiums	- Strengthened professional networks - Continuous improvement in teaching strategies
Curriculum Development	Update curriculum to include contemporary scientific advancements and inquiry-based learning	- Revise and update science curriculum - Ensure resource provision - Integrate latest scientific research and technology - Develop interdisciplinary projects - Pilot new curriculum modules in select schools	- Updated curriculum - Access to teaching materials and equipment - Interdisciplinary project guidelines - Pilot program reports	- Enhanced curriculum - Better equipped classrooms - Increased relevance and engagement of science lessons - Feedback-driven curriculum improvements
Assessment and Feedback	Implement diverse and effective assessment and feedback strategies	- Promote varied assessment methods (rubrics, quizzes, observations) - Train teachers on providing constructive feedback - Develop self-assessment and peer-assessment tools - Create a database of assessment examples and templates - Conduct regular assessment review and improvement workshops	- Varied assessment methods - Constructive feedback training - Self-assessment and peer-assessment tools - Assessment database - Workshop reports	- Improved assessment practice - Better student understanding and performance - Enhanced student self-awareness and peer learning
Student Engagement and Motivation	Create engaging and inclusive learning environments	- Create interactive learning environments - Incorporate real-world applications in curriculum - Use gamification and digital tools to enhance learning - Develop project-based learning modules - Organize science fairs and competitions	- Interactive learning environments - Real-world science projects - Gamified learning modules - Project-based learning guidelines - Science fair and competition events	- Increased student engagement and motivation - Enhanced learning experiences - Higher student achievement in science - Greater interest in STEM careers
Inclusivity and Equity	Promote culturally responsive teaching and support for diverse learners	- Train teachers in culturally responsive teaching - Provide additional support for diverse learners - Develop inclusive curriculum materials - Implement universal design for learning (UDL) strategies - Establish support groups for students with special needs	- Culturally responsive teaching practices - Support resources for diverse learners - Inclusive curriculum materials - UDL strategy guidelines - Support group sessions	- More inclusive and equitable science education - Improved student outcomes across diverse groups - Greater teacher awareness and responsiveness to student needs
Leadership and Policy Support	Engage school administrators and advocate for supportive policies	- Engage administrators in professional development - Advocate for supportive educational policies - Develop leadership training programs for school leaders - Organize policy forums and roundtable discussions - Create policy briefs and advocacy materials	- Administrative support - Policy recommendations - Leadership training programs - Policy forum reports - Advocacy materials	- Stronger support for professional development and innovative teaching practices - Enhanced leadership in science education - Improved policy environment for science education

following implications:

1. Develop and implement targeted professional development programs to enhance teachers' skills and knowledge in science teaching;
2. Assess and revise the teacher education curricula to ensure comprehensive coverage of effective science teaching practices by incorporating more practical training and hands-on experiences;
3. Conduct longitudinal studies to monitor the impact

4. Conclusion and Future Works

The science teachers in the locale of this study are much prepared to carry out the various pedagogical practices in science education along student-centered pedagogy, hands-on learning, scaffolding, assessment and feedback, and professional development. This draws the

of the improved pedagogical practices on student learning outcomes in science

4. Establish mentorship programs where experienced science teachers can guide less prepared teachers to foster collaboration among teachers in sharing their best practices and resources;
5. Explore the integration of educational technologies including the Internet of Things (IoT) that can support and enhance science teaching.

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