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## Effectiveness of Professional Development Programs on Science Teachers' Literacy in Basic Education

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### ABSTRACT

Professional development programs are essential for enhancing science educators' teaching competencies. These programs equip teachers with innovative strategies to foster scientific literacy, critical thinking, and student engagement. This study investigates the relationship between professional development programs and the implementation of scientific literacy in selected schools in Agusan del Sur. Adopting a quantitative descriptive-correlational research design, the study surveyed 151 science teachers using complete enumeration sampling (universal sampling). Results show that demographic factors such as age, gender, teaching experience, and training attendance do not significantly affect teachers' perceptions of these programs. However, grade level and educational attainment strongly influence the effectiveness of professional development, particularly in pedagogical approaches, collaboration, and assessment strategies. Based on the findings, the study recommends increasing funding and access to continuous professional development, tailoring programs to specific grade levels, and ensuring equitable opportunities for educators in underprivileged areas. Prioritizing mentorship programs and advanced training can further enhance teacher effectiveness in promoting scientific literacy. Addressing these factors will help strengthen science instruction, ultimately improving students' understanding and application of scientific concepts.

### INTRODUCTION

In the evolving landscape of 21st-century education, science teaching must continuously adapt to ensure that students develop critical thinking skills and engage meaningfully with scientific concepts. Science teachers require robust professional development programs that enhance their pedagogical strategies and subject expertise. These programs provide opportunities for educators to explore innovative teaching methodologies, refine their instructional techniques, and effectively integrate scientific literacy into the curriculum. As Suwono *et al.* (2021) assert, scientific literacy plays a fundamental role in shaping the science curriculum, reinforcing the need for targeted training programs. The study aims to assess the extent to which these initiatives contribute to the enhancement of teachers' competencies, thereby improving the quality of science education in basic education settings.

However, despite the recognized importance of professional development, challenges persist in translating theoretical knowledge into engaging classroom activities. Research indicates that hands-on experimentation and direct observation significantly enhance students' critical thinking and problem-solving abilities (Saro *et al.*, 2023). However, science teachers often struggle with implementing these approaches due to entrenched traditional teaching methods, limited technological resources, and inadequate professional support (Tirol, 2023; Al Sultan *et al.*, 2021). More so, addressing these barriers requires a structured evaluation of professional development programs to determine their effectiveness in fostering scientific literacy among science teachers.

Additionally, professional development programs is further influenced by contextual factors unique to specific educational settings. In the case of Agusan del Sur, disparities in teacher preparation, lack of access to science laboratories, and minimal exposure to emerging educational technologies present significant obstacles to improving science literacy (Palines *et al.*, 2021). Furthermore, professional development initiatives remain underexplored in this locality, leaving a gap in understanding how these programs impact science education at the grassroots level. On the other hand, a critical aspect of this study is its focus on aligning professional development initiatives with the actual needs of science teachers in basic education. As emphasized by DeCoito (2023), effective training programs should address both pedagogical skills and content mastery, ensuring that teachers are well-equipped to deliver high-quality science instruction. The study assessed whether professional development programs adequately enhanced teachers' competencies in scientific literacy and whether they led to measurable improvements in classroom instruction. Additionally, it explored how these programs influenced teachers' confidence in employing student-centered teaching methodologies, thereby fostering a deeper understanding of scientific principles among learners.

This study emphasizes the pivotal role of professional development programs in strengthening science education. Also, the study aims to provide valuable insights into optimizing professional training initiatives within the Agusan del Sur division. The findings contributed

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to the discourse on teacher development, offering and providing recommendations for policymakers, school administrators, and education stakeholders on how to design more impactful training programs. This study aimed to advance the quality of science education and support teachers in cultivating a scientifically literate generation.

## LITERATURE REVIEW

Professional development programs (PDPs) are pivotal in enhancing science teachers' literacy and instructional efficacy in basic education. Recent studies have explored the positive impact of PDPs on teachers' self-efficacy and instructional performance (Quilapio & Callo, 2022; Rajendran *et al.*, 2023). A study by Felix and Abrogena (2023) found that science teachers who participated in continuing professional development activities reported increased confidence in classroom management, instructional strategies, and student engagement. These findings suggest that well-structured PDPs can significantly contribute to the professional growth of science educators.

The design and content of PDPs play a crucial role in their effectiveness. A study by Faikhamta *et al.* (2020) demonstrated that a pedagogical content knowledge-based professional development program positively influenced science teachers' attitudes towards STEM education. Teachers who engaged in hands-on activities and collaborative lesson planning within the program developed a deeper understanding of STEM integration, which translated into improved teaching practices. This highlights the importance of incorporating practical, collaborative elements into PDPs to enhance their impact. Meta-analytical research has further affirmed the benefits of PDPs on teachers' self-efficacy in science instruction. Baysal and Mutlu (2021) conducted a meta-analysis revealing that professional development programs have a moderate positive effect on teachers' beliefs in their science teaching capabilities. The analysis also indicated that factors such as the duration of the program and the sample size influenced the effectiveness of PDPs, suggesting that longer, more comprehensive programs may yield better outcomes. The Department of Education has recognized the need for accredited professional development programs to enhance teachers' competencies. Initiatives such as the Division Training of Trainers of Higher Order Thinking Skills Professional Learning Packages for Grade 7 and 8 Mathematics, Science, and English Teachers have been implemented to address this need. These programs aim to equip teachers with effective strategies to foster critical thinking and improve student learning outcomes.

Tzagkaraki *et al.* (2021) highlight the importance of integrating authentic and inquiry-based practices into professional development programs. These practices support the goals of scientific literacy instruction by promoting real-world problem solving, critical thinking, and exploration of scientific phenomena. Teachers who

personally experience instructional methods during professional development are more likely to adopt and adapt them for their classrooms (Oliver *et al.*, 2021). Darling-Takda (2022) emphasize the significance of leadership in facilitating successful professional development. School leaders who prioritize and support ongoing professional development for teachers foster an environment that facilitates the effective implementation of scientific literacy strategies (Kousloglou *et al.*, 2023). Effective leaders have the ability to allocate resources, promote collaboration, and cultivate a culture of continuous improvement. These factors are crucial in order to enhance the impact of professional development. Communities of Practice (CoPs) have emerged as effective platforms for teacher development in the Philippines. Confesor and Belmi (2021) explored the structure and activities of CoPs among secondary science teachers and found that active participation in these communities led to enhanced collaboration, optimism, and adaptability among educators. The study concluded that CoPs foster personal and professional growth, contributing to improved science instruction. A study highlighted that while professional development programs significantly enhance teachers' knowledge, practice, and efficacy, these improvements do not always directly correlate with students' learning outcomes (Padillo *et al.*, 2021). This suggests that factors beyond teacher development, such as student socio-economic status and school resources, also play critical roles in educational achievement. Therefore, a holistic approach that addresses various influencing factors is essential for maximizing the benefits of PDPs. Recent literature indicates that well-designed professional development programs are instrumental in enhancing science teachers' literacy and instructional effectiveness in basic education. Incorporating practical, collaborative elements and fostering communities of practice can further amplify these benefits. However, to fully realize the potential of PDPs, it is crucial to adopt a comprehensive approach that considers the multifaceted factors influencing educational outcomes.

## Research Questions

The goal of the study was to examine the relationship between the effectiveness of professional development programs and science teachers' literacy in the science curriculum in selected secondary schools in the Division of Agusan del Sur, Philippines. Specifically, the study sought to answer the following research questions.

1. What is the profile of the science teacher respondents in terms of age, sex, grade level, length of teaching service, educational attainment, and number of trainings and seminars attended?

2. What is the level of effectiveness of professional development programs for science teachers in terms of pedagogical change, teacher engagement, long-term sustainability, student outcomes, collaboration and knowledge sharing, and adaptability to evolving educational paradigms?

3. What is the level of implementation of scientific literacy among science teachers in the basic education science curriculum in terms of integration into the curriculum, student engagement, assessment strategies, teacher professional learning communities, and real-world applications?

4. Is there a significant difference in the level of effectiveness of professional development programs and the level of implementation of scientific literacy in the basic education science curriculum based on the profile of the science teacher respondents?

5. Is there a significant relationship between the effectiveness of professional development programs and the level of implementation of scientific literacy in the basic education science curriculum?

## MATERIALS AND METHODS

### Research Design

The study employed a quantitative approach, specifically a descriptive-correlational research design. This design allowed for descriptive and correlational inquiries to examine variables in their natural contexts, following Simon's (2011) recommendation to minimize external influences. Additionally, the study adhered to Calderon's (2006) systematic approach to data collection, analysis, categorization, and summarization of existing conditions, practices, processes, and trends. Furthermore, a quantitative descriptive-correlational approach, influenced by Medina's (2010) methodology, was utilized to explore the interrelationships among various factors. Quantitative data were gathered through a structured survey questionnaire distributed to a representative sample of science teachers across selected secondary schools in the Agusan del Sur division.

### Respondents of the Study

The study focused on secondary schools within the Division of Agusan del Sur, specifically in the districts of Sibagat, Esperanza, Prosperidad, San Francisco, and Talacogon. These districts were selected based on the number of science teachers they employed and their active participation in various initiatives, particularly training and workshops within the division. The study utilized complete enumeration sampling, also known as the universal sampling technique, to ensure representation from both Junior and Senior High School science departments. Including all science teachers from these schools was essential for collecting relevant data aligned with the research objectives, ensuring the highest quality and relevance of the study's findings. A total of 15 secondary schools from the five districts were included, with 151 science teachers participating in the study. This sampling approach guaranteed the inclusion of all science teachers from both Junior and Senior High School levels.

### Research Instrument

The research utilized a custom-designed survey questionnaire, structured into distinct sections to

comprehensively address the study's objectives. The first section collected demographic data from science teachers, including age, gender, teaching level, years of experience, educational background, and participation in training and seminars. The second section assessed the effectiveness of professional development programs for science teachers, while the third section examined the extent of scientific literacy integration within the science curriculum. The study aimed to gain insights into the practical implications of incorporating scientific literacy within the educational framework. The questionnaire employed a 5-point Likert scale, with descriptors aligned with established literature (Sozen & Guven, 2019). The mean ranges were clearly defined for each point on the Likert scale to ensure clarity and consistency in respondents' interpretations. This comprehensive design facilitated the collection of detailed and nuanced data, allowing for a deeper understanding of the complex relationship between the effectiveness of professional development programs and the integration of scientific literacy into the science curriculum.

### Statistical Treatment

The data were tabulated, processed, and analyzed based on the research questions presented in the study. Frequency and percentage were used to describe the demographic profile of the respondents, categorized by age, gender, grade level, years of teaching experience, educational attainment, and participation in training and seminars. Weighted Mean analysis was applied to the survey responses, utilizing a 5-point Likert scale to determine the levels of effectiveness of professional development programs and the implementation of scientific literacy in the science curriculum. Correlational analysis was conducted using correlation coefficients, including the chi-square test, to assess the strength and direction of relationships between the effectiveness of professional development programs and the implementation of scientific literacy. Finally, a one-way ANOVA was performed to examine the influence of demographic factors on the effectiveness of professional development programs and the implementation of scientific literacy in the science curriculum among science teachers.

### Ethical Considerations

The study adhered to ethical research principles to ensure the protection and respect of all respondents. Informed consent was obtained from all science teachers before their participation, ensuring they were fully aware of the study's purpose, procedures, and their right to withdraw at any time without consequences. Confidentiality and anonymity were strictly maintained by assigning unique identification codes instead of using personal information, ensuring that responses remained private and untraceable. The collected data were used exclusively for research purposes and securely stored to prevent unauthorized access. Additionally, the study followed ethical guidelines set by relevant institutions and research bodies, ensuring

that the research process upheld integrity, transparency, and respect for the respondents' rights and well-being.

## RESULTS AND DISCUSSIONS

### Profile Data

Table 1 presents the distribution of the respondents according to profile. As can be gleaned from the table, the majority of the respondents are 20-30 years old, accounting for 36.42% of the total number of

participants. This suggests that most teachers in the said locale are predominantly young. On the other hand, the fewest participants belong to the age group 51-60, making up only 11.92% of the respondents. In terms of gender distribution, there is a notable skew towards female respondents, comprising 71.52% of the total, compared to 28.48% who are male. This aligns with the global trend where teaching is predominantly a female-dominated profession.

**Table 1:** Demographic Profile of the Respondents

Profile	Category	Frequency (n)	Percentage (%)
Age	20 - 30 years old	55	36.42
	31 - 40 years old	40	26.49
	41 - 50 years old	38	25.17
	51 - 60 years old	18	11.92
Sex	Male	43	28.48
	Female	108	72.52
Grade Level Taught	Grade 7	8	5.30
	Grade 8	3	1.99
	Grade 9	18	11.92
	Grade 10	55	36.42
	Grade 11	35	23.18
	Grade 12	32	21.19
Length of Teaching Service	6 - 10 years	22	14.57
	11 - 15 years	13	8.61
	16 - 20 years	33	21.85
	21 - 25 years	26	17.22
	26 - 30 years	39	25.83
	31 years and above	18	11.92
Educational Attainment	Bachelor's Degree Graduate	31	20.53
	Master's Degree Units	39	25.83
	Master's Degree CAR	19	12.58
	Master's Degree Graduate	18	11.92
	Doctorate Degree Units	3	1.99
	Doctorate Degree CAR	18	11.92
	Doctorate Degree Graduate	23	15.23
Number of Trainings Attended	0 - 9	55	36.42
	10 - 19	49	32.45
	20 - 29	28	18.54
	30 - 39	15	9.93
	40 and above	4	2.65
<b>Total</b>		<b>151</b>	<b>100</b>

Regarding the grade levels taught, the highest number of respondents teach Grade 10 (36.42%), followed by Grade 11 (23.18%) and Grade 12 (21.19%). Notably, the smallest number of participants who taught Grade 8 level was recorded, comprising only 3 or 1.99% of the total respondents. Concerning the length of teaching experience, respondents with 26-30 years of experience represent the largest group at 25.83%, followed closely

by those with 16-20 years at 21.85%. This indicates a seasoned workforce, with a significant portion of respondents having substantial experience in the educational field. On the lower end, teachers with 11-15 years of experience are the smallest group, comprising 13 or 8.61% of the respondents. Moreover, the largest group in the educational attainment profile are those who have completed some units towards a Master's Degree, with

39 or 25.83% of the participants. Conversely, the least number of respondents belong to those individuals who garnered units in doctorate degrees, with only three listed participants. Lastly, the number of training attended by respondents shows a concentration in the lower range, with 36.42% attending between 0 to 9 training sessions and 32.45% attending between 10 to 19 sessions. This could reflect ongoing professional development efforts. However, the relatively smaller numbers in the higher training categories (20 trainings and above) may indicate limited access to or availability of more intensive professional development opportunities.

**Level of Effectiveness of Professional Development Programs**

Table 2 displays an overall mean of 4.43, indicating a “Strongly Agree” rating and a “Highly Manifested”

interpretation of the level of effectiveness of professional development programs among science teachers. Among the parameters, Long-Term Sustainability received the highest mean score (4.49), suggesting that professional development initiatives are perceived as sustainable over time. More so, Collaboration and Knowledge Sharing (4.45) and Adaptability to Evolving Educational Paradigms (4.46) were also highly rated, highlighting the teachers’ strong engagement in continuous learning and adaptation to educational advancements. While all parameters scored within the “Highly Manifested” range, Student Outcomes (4.36) had the lowest mean, though still reflecting a “Strongly Agree” rating. These findings suggest that professional development programs are effectively supporting pedagogical improvements, fostering teacher engagement, and ensuring long-term sustainability in enhancing science education.

**Table 2:** Effectiveness of Professional Development Programs for Science Teachers in the Division of Agusan del Sur

Parameters	Mean Scores	Verbal Description	Verbal Interpretation
Pedagogical Change	4.41	Strongly Agree	Highly Manifested
Teacher Engagement	4.39	Strongly Agree	Highly Manifested
Long-Term Sustainability	4.49	Strongly Agree	Highly Manifested
Student Outcomes	4.36	Strongly Agree	Highly Manifested
Collaboration and Knowledge Sharing	4.45	Strongly Agree	Highly Manifested
Adaptability to Evolving Educational Paradigms	4.46	Strongly Agree	Highly Manifested
<b>Overall Mean</b>	<b>4.43</b>	<b>Strongly Agree</b>	<b>Highly Manifested</b>

Note: Scale and Adjectival Rating; 1.00 – 1.79, Strongly Disagree; 1.80 – 2.59, Disagree; 2.60 – 3.39, Moderately Agree; 3.40 – 4.19, Agree; 4.20 – 5.00, Strongly Agree

Additionally, the table presents the level of effectiveness of professional development programs for science teachers, revealing a highly positive perception across various parameters. Among these, “Long-Term Sustainability” emerged as the highest-rated aspect, with a mean score of 4.49, indicating a strong consensus among respondents on its effectiveness. This suggests that science teachers perceive these programs as equipping them with essential skills and knowledge for long-term success in teaching. The findings highlight the ability of these initiatives to address practical needs, instill confidence in consistent implementation, and align with evolving educational trends. As noted by Meesuk *et al.* (2021) and Saro *et al.* (2023), teachers expect these programs to have a lasting influence, fostering a culture of continuous improvement and adaptability. Additionally, this aligns with the argument by Ancho and Arrieta (2021), who emphasized the importance of professional development programs that not only provide immediate benefits but also nurture long-term impact, thereby enhancing the sustainability and growth of educators’ careers in science teaching. On the other hand, “Student Outcomes” recorded the lowest mean score of 4.36, which, despite being the lowest among the parameters, still falls within the “Strongly Agree” category. This suggests that while professional development programs effectively foster pedagogical change, teacher engagement, collaboration,

and adaptability, there may be further opportunities to refine strategies that directly enhance student outcomes. The consistently high mean scores across all parameters, culminating in an overall mean of 4.43, emphasizes the strong effectiveness of these programs in addressing the multifaceted needs of science teachers. This effectiveness translates to improved teaching practices, greater job satisfaction, and increased adaptability, as supported by Budirahayu and Saud (2023). Moreover, students are also expected to benefit from more immersive and impactful learning experiences, leading to enhanced academic performance and long-term educational success, as highlighted by Anis (2024).

**Extent of Scientific Literacy Implementation among Science Teachers**

Table 3 shows that the implementation of scientific literacy among science teachers is highly manifested, with an overall mean score of 4.58, categorized under “Strongly Agree.” This indicates that science teachers perceive the integration of scientific literacy into their teaching practices as significantly effective. The findings suggest that teachers actively incorporate scientific literacy principles, fostering critical thinking, inquiry-based learning, and interdisciplinary connections in their classrooms. This high level of implementation reflects the strong commitment of science educators to

enhancing students' scientific understanding, aligning with contemporary educational goals that emphasize the development of scientifically literate individuals capable of making informed decisions in real-world contexts.

**Table 3:** Implementation of Scientific Literacy among Science Teachers

Parameters	Mean Scores	Verbal Description	Verbal Interpretation
Integration into Curriculum	4.54	Strongly Agree	Highly Manifested
Student Engagement	4.55	Strongly Agree	Highly Manifested
Assessment Strategies	4.63	Strongly Agree	Highly Manifested
Teacher Professional Learning Communities	4.56	Strongly Agree	Highly Manifested
Real-World Applications	4.60	Strongly Agree	Highly Manifested
<b>Overall Mean</b>	<b>4.58</b>	<b>Strongly Agree</b>	<b>Highly Manifested</b>

Note: Scale and Adjectival Rating; 1.00 – 1.79, Strongly Disagree; 1.80 – 2.59, Disagree; 2.60 – 3.39, Moderately Agree; 3.40 – 4.19, Agree; 4.20 – 5.00, Strongly Agree

Among the parameters, "Assessment Strategies" received the highest mean score of 4.63, signifying that teachers place a strong emphasis on evaluating students' scientific literacy skills through varied and effective assessment methods. This highlights the importance of using diverse assessment tools to measure students' ability to analyze, interpret, and apply scientific knowledge. "Real-World Applications" followed closely with a mean score of 4.60, indicating that teachers effectively connect scientific concepts to practical, everyday situations, reinforcing students' understanding and relevance of science in their lives. Similarly, "Teacher Professional Learning Communities" (4.56) and "Student Engagement" (4.55) reflect a strong collaborative culture and an interactive learning environment, promoting both peer-to-peer knowledge sharing and active student participation. "Integration into Curriculum" recorded the lowest mean score at 4.54, though still categorized as "Highly Manifested," suggesting that while scientific literacy is effectively embedded within the curriculum, there may be areas for further enhancement, such as refining curriculum frameworks to provide more structured guidelines for implementation. Overall, these findings imply that strengthening assessment methods, reinforcing real-world applications, and sustaining professional learning communities can further support the continuous improvement of scientific literacy integration among science teachers.

Sewagegn and Diale (2020) assert that such a methodological shift facilitates a deeper engagement with scientific concepts as it promotes the development of essential scientific skills, such as problem-solving, critical thinking, and analytical reasoning. The strong emphasis on varied and comprehensive assessment strategies, as reflected in the survey results, supports a more robust and inclusive learning environment and aligns with contemporary educational goals to prepare students for real-world challenges, as per Aqdu (2023). This alignment suggests that the curriculum is effectively fostering the acquisition of scientific knowledge and the essential skills needed in today's science-driven society (Sermona *et al.*, 2022). Meanwhile, Yilmaz (2023) emphasizes the need for further enhancement in the integration of scientific literacy into the curriculum, particularly by

incorporating more technology, interactive elements, and interdisciplinary connections to ensure a well-rounded science education. Additionally, the University of New Brunswick (2024) highlights the importance of real-world applications and varied assessment methods in fostering students' ability to apply scientific knowledge practically and creatively. Finally, Valladares (2021) posits the significance of collaborative teaching efforts in sustaining the continuity of scientific literacy across different subjects and grade levels, ultimately contributing to a more scientifically literate student body capable of addressing complex real-world challenges.

According to Dela Cruz *et al.* (2022), the integration of scientific literacy in the Philippine education system has been instrumental in enhancing students' critical thinking and analytical skills, aligning with the Department of Education's push for competency-based learning. Reyes and Bautista (2021) emphasized that assessment strategies play a crucial role in ensuring that students grasp scientific concepts beyond rote memorization, fostering deeper comprehension and application. Gonzales (2023) highlighted the importance of real-world applications in science education, noting that hands-on and inquiry-based learning approaches significantly improve student engagement and retention. Moreover, Ramos and Santiago (2020) asserted that professional learning communities among teachers contribute to the sustained success of scientific literacy initiatives, as collaborative efforts enable the exchange of best practices and innovative teaching strategies. Finally, based on the findings of Villanueva (2024), the strong emphasis on student engagement in scientific literacy programs across Philippine schools suggests a shift towards more student-centered and interactive pedagogical approaches, ensuring that learners are well-equipped with the skills necessary for scientific inquiry and problem-solving.

**Significant Difference between Respondents' Profile and Their Assessment of Professional Development**

The findings indicate that age, sex, length of teaching service, educational attainment, and the number of training sessions attended do not significantly influence teachers' assessment of professional development (PD)

effectiveness in basic education. The p-values for these variables across all parameters were above the 0.05 significance threshold, leading to the failure to reject the null hypothesis. This suggests that professional development experiences and perceived effectiveness are not determined by demographic or background factors but may instead be influenced by other elements such as institutional support, teaching context, or personal motivation. The non-significance of age and teaching

experience implies that newer and more seasoned teachers perceive PD effectiveness similarly, emphasizing the universal nature of professional development programs. Additionally, the lack of significance concerning sex suggests that male and female teachers assess PD with similar perspectives, reinforcing the idea that gender-related teaching experiences do not heavily shape their views on professional growth.

**Table 4:** Significant Difference between Respondents' Profile and Their Assessment of PD Effectiveness in Basic Education

Profile	Parameters	P-value	Decision	Conclusion
Age	Pedagogical Change	0.090	Failed to reject null Hypothesis	Not Significant
	Teacher Engagement	0.325	Failed to reject null Hypothesis	Not Significant
	Long-Term Sustainability	0.734	Failed to reject null Hypothesis	Not Significant
	Student Outcomes	0.828	Failed to reject null Hypothesis	Not Significant
	Collaboration and Knowledge Sharing	0.406	Failed to reject null Hypothesis	Not Significant
	Adaptability to Evolving Educational Paradigms	0.257	Failed to reject null Hypothesis	Not Significant
Sex	Pedagogical Change	0.270	Failed to reject null Hypothesis	Not Significant
	Teacher Engagement	0.539	Failed to reject null Hypothesis	Not Significant
	Long-Term Sustainability	0.840	Failed to reject null Hypothesis	Not Significant
	Student Outcomes	0.692	Failed to reject null Hypothesis	Not Significant
	Collaboration and Knowledge Sharing	0.836	Failed to reject null Hypothesis	Not Significant
	Adaptability to Evolving Educational Paradigms	0.596	Failed to reject null Hypothesis	Not Significant
Grade Level Taught	Pedagogical Change	0.000	Reject null Hypothesis	Significant
	Teacher Engagement	0.010	Reject null Hypothesis	Significant
	Long-Term Sustainability	0.110	Failed to reject null Hypothesis	Not Significant
	Student Outcomes	0.136	Failed to reject null Hypothesis	Not Significant
	Collaboration and Knowledge Sharing	0.048	Reject null Hypothesis	Significant
	Adaptability to Evolving Educational Paradigms	0.005	Reject null Hypothesis	Significant
Length of Teaching Service	Pedagogical Change	0.809	Failed to reject null Hypothesis	Not Significant
	Teacher Engagement	0.696	Failed to reject null Hypothesis	Not Significant
	Long-Term Sustainability	0.431	Failed to reject null Hypothesis	Not Significant
	Student Outcomes	0.567	Failed to reject null Hypothesis	Not Significant
	Collaboration and Knowledge Sharing	0.440	Failed to reject null Hypothesis	Not Significant
	Adaptability to Evolving Educational Paradigms	0.336	Failed to reject null Hypothesis	Not Significant
Educational Attainment	Pedagogical Change	0.117	Failed to reject null Hypothesis	Not Significant
	Teacher Engagement	0.403	Failed to reject null Hypothesis	Not Significant
	Long-Term Sustainability	0.295	Failed to reject null Hypothesis	Not Significant
	Student Outcomes	0.310	Failed to reject null Hypothesis	Not Significant
	Collaboration and Knowledge Sharing	0.037	Reject null Hypothesis	Significant
	Adaptability to Evolving Educational Paradigms	0.124	Failed to reject null Hypothesis	Not Significant
Number of Trainings Attended	Pedagogical Change	0.539	Failed to reject null Hypothesis	Not Significant
	Teacher Engagement	0.672	Failed to reject null Hypothesis	Not Significant
	Long-Term Sustainability	0.859	Failed to reject null Hypothesis	Not Significant
	Student Outcomes	0.604	Failed to reject null Hypothesis	Not Significant

	Collaboration and Knowledge Sharing	0.599	Failed to reject null Hypothesis	Not Significant
	Adaptability to Evolving Educational Paradigms	0.640	Failed to reject null Hypothesis	Not Significant

Note: Significant at 0.05

However, the grade level taught was found to have a significant impact on pedagogical change ( $p = 0.000$ ), teacher engagement ( $p = 0.010$ ), collaboration and knowledge sharing ( $p = 0.048$ ), and adaptability to evolving educational paradigms ( $p = 0.005$ ). This implies that teachers working at different grade levels perceive PD effectiveness differently, particularly in areas related to instructional strategies and collaboration. Teachers in lower grade levels might require more concrete strategies for engaging younger students, whereas those in higher grades might focus on subject depth and critical thinking approaches. This finding highlights the necessity for differentiated PD programs designed to the specific instructional needs of teachers handling different grade levels. A one-size-fits-all approach to PD may not be effective, reinforcing the need for specialized training that addresses the pedagogical and engagement demands of different educational stages.

On the other hand, educational attainment had a significant influence on collaboration and knowledge sharing ( $p = 0.037$ ), suggesting that teachers with higher academic qualifications may engage more in collaborative efforts and professional learning communities. This could be due to their increased exposure to research-based teaching strategies and advanced educational theories, making them more inclined toward sharing knowledge and fostering collegiality. This finding emphasizes the importance of encouraging all teachers, regardless of academic credentials, to actively participate in collaborative learning environments. Schools and educational institutions should consider creating platforms where teachers with varying levels of educational attainment can share best practices and mentor one another, thus fostering and cultivating a culture of continuous learning and knowledge exchange. The study's implications suggest that while demographic factors may not significantly shape teachers' perceptions of PD effectiveness, contextual and academic factors such as grade level taught and educational attainment play a role. These findings highlight the importance of designing PD programs that are responsive to the needs of teachers across different grade levels and fostering a culture of collaboration among educators. School administrators and policymakers should consider these insights when crafting PD initiatives, ensuring that they are not only inclusive but also tailored to specific teaching contexts. Furthermore, since PD effectiveness is not determined by the number of training sessions attended, there is a need to evaluate the quality and relevance of these trainings rather than merely focusing on frequency. Ensuring that PD programs are meaningful, engaging, and aligned with teachers' instructional needs will be crucial in enhancing their effectiveness and long-term impact.

The study's findings align with previous research emphasizing the importance of contextualized professional development for teachers across different grade levels. Schwartz (2023) highlighted that effective professional development programs allow teachers to grow their knowledge and sharpen their skills, ultimately leading to improved student outcomes. Stanley (2023) emphasized that pedagogical strategies introduced in training programs must be applicable to specific grade levels to ensure relevance and effectiveness. The significance of continuous professional development in keeping educators updated on emerging educational trends, technologies, and curriculum advancements was also supported by Manlapaz (2022), reinforcing the idea that engagement in such programs varies depending on teachers' instructional needs. Furthermore, Abdelaziz *et al.* (2023) emphasized that adaptability to evolving educational paradigms differs across grade levels, necessitating a differentiated approach in professional development initiatives. These citations collectively strengthen the argument that tailoring professional development programs to address teachers' unique instructional contexts is crucial for maximizing their effectiveness.

**Significant Difference between Respondents' Profile and Their Assessment of Scientific Literacy Implementation**

The findings in Table 5 reveal that the respondents' profiles had varying influences on their assessment of scientific literacy implementation in basic education. More so, age, sex, and the number of trainings and seminars attended showed no significant difference across all parameters, suggesting that these demographic factors do not substantially shape perceptions of scientific literacy implementation. This result implies that scientific literacy is generally viewed consistently across different age groups and genders, highlighting a universal understanding of its importance regardless of personal characteristics. Additionally, the lack of significant difference in training and seminar attendance suggests that while professional development is essential, its impact on perceptions of scientific literacy implementation may not be as profound as other factors such as teaching experience and educational attainment. This may indicate that one-time training sessions do not necessarily translate into noticeable changes in how scientific literacy is perceived within the curriculum.

Conversely, the grade level taught exhibited a significant difference in assessment strategies ( $p = 0.050$ ), implying that teachers at different grade levels perceive and implement assessment strategies in scientific literacy in distinct ways. This could be due to the varying

complexity of scientific concepts at different grade levels, requiring different assessment methods tailored to students' cognitive abilities. Elementary teachers may rely more on formative assessments, while secondary educators might emphasize summative evaluations or performance-based assessments. This finding suggests a need for professional development programs that equip teachers with differentiated assessment strategies aligned with students' learning needs at various grade levels. By strengthening teachers' ability to design and implement effective assessment techniques, educational stakeholders can enhance the overall effectiveness of scientific literacy programs across all levels.

Moreover, the length of teaching service and educational attainment both showed significant differences in multiple parameters, including integration into the curriculum, student engagement, assessment strategies, and teacher professional learning communities ( $p = 0.000$ ). This indicates that teachers with longer teaching experience and higher educational qualifications tend to have a more nuanced understanding of scientific literacy implementation. Experienced teachers likely draw from extensive classroom exposure and pedagogical insights, leading to a more critical assessment of how scientific literacy is integrated and applied. Moreover, those with advanced degrees may possess

a deeper theoretical and practical grasp of scientific literacy frameworks, influencing their perspectives on curriculum effectiveness. These findings underscore the importance of sustained professional development and higher education opportunities for teachers, as these factors significantly contribute to the successful implementation of scientific literacy in schools.

The implications of these findings highlight the need for targeted interventions in professional development, curriculum design, and teacher education programs. Since experienced teachers and those with higher education levels perceive scientific literacy implementation differently, school administrators and policymakers should consider designing differentiated training programs that cater to teachers at various career stages. Additionally, the significant variation in assessment strategies across grade levels suggests the need for a more standardized yet flexible approach to evaluating students' scientific literacy skills. Lastly, the non-significant differences in age, sex, and training participation emphasize the importance of institutional and structural factors over personal characteristics in shaping teachers' perceptions. These results provide valuable insights for enhancing scientific literacy programs, ensuring that they are effectively implemented across diverse educational settings.

**Table 5:** Significant Difference between Respondents' Profile and Their Assessment of Scientific Literacy Implementation in Basic Education

Profile	Parameters	P-value	Decision	Conclusion
Age	Integration into Curriculum	0.232	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.596	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	0.293	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	0.522	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	0.150	Failed to reject null Hypothesis	Not Significant
Sex	Integration into Curriculum	0.127	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.255	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	0.379	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	0.477	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	0.481	Failed to reject null Hypothesis	Not Significant
Grade Level Taught	Integration into Curriculum	0.135	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.330	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	0.050	Reject null Hypothesis	Significant
	Teacher Professional Learning Communities	0.457	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	0.373	Failed to reject null Hypothesis	Not Significant
Length of Teaching Service	Integration into Curriculum	0.000	Reject null Hypothesis	Significant
	Student Engagement	0.000	Reject null Hypothesis	Significant
	Assessment Strategies	0.000	Reject null Hypothesis	Significant
	Teacher Professional Learning Communities	0.000	Reject null Hypothesis	Significant
	Real-World Applications	0.081	Failed to reject null Hypothesis	Not Significant

Educational Attainment	Integration into Curriculum	0.000	Reject null Hypothesis	Significant
	Student Engagement	0.000	Reject null Hypothesis	Significant
	Assessment Strategies	0.000	Reject null Hypothesis	Significant
	Teacher Professional Learning Communities	0.000	Reject null Hypothesis	Significant
	Real-World Applications	0.092	Failed to reject null Hypothesis	Not Significant
Number of Trainings and Seminars Attended	Integration into Curriculum	0.706	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.725	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	0.523	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	0.493	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	0.943	Failed to reject null Hypothesis	Not Significant

Note: Significant at 0.05

The study's findings aligns with previous research suggesting that demographic factors do not always directly influence teaching practices (Graham *et al.*, 2020). However, the findings contrast with Quilapio and Callo (2022), who emphasized the importance of professional training in improving science education. The lack of significant impact from training attendance raises concerns about the effectiveness of existing professional development programs. Irvine (2019) argues that merely attending training sessions does not guarantee enhanced instructional implementation; rather, the content, delivery, and applicability of training must be evaluated. This suggests a need for education policymakers to reassess the structure and focus of professional training programs, ensuring that they translate into meaningful improvements in teaching scientific literacy.

Meanwhile, the study reveals that grade levels taught significantly affect assessment strategies, reinforcing the need for grade-specific pedagogical approaches. According to Klemencic *et al.* (2023), different educational levels require varied assessment strategies to match students' cognitive abilities and learning progressions. This supports the idea that teachers should be equipped with tailored assessment tools to enhance scientific literacy across different grade levels. Additionally, the significant relationships between teaching experience, educational attainment, and scientific literacy implementation highlight the crucial role of professional expertise in science education. Call (2018) and Grove (2019) assert that experienced and highly educated teachers are more adept at engaging students in scientific literacy activities, as they possess refined teaching methodologies and deeper content knowledge. Furthermore, Ventista and Brown (2023) emphasize that veteran teachers contribute significantly to professional learning communities, fostering collaboration and mentoring less experienced educators. This emphasizes the importance of continuous professional development and advanced education in enhancing scientific literacy implementation in the Science curriculum.

### Significant Relationship between PD Effectiveness and Scientific Literacy Implementation in the Science Curriculum

The findings from the correlational analysis indicate that there is no statistically significant relationship between professional development programs and the implementation of scientific literacy across all examined parameters. The computed r-values are all very close to zero, and the corresponding p-values exceed the 0.05 significance threshold, leading to the failure to reject the null hypothesis in every case. This suggests that factors such as pedagogical change, teacher engagement, long-term sustainability, student outcomes, collaboration and knowledge sharing, and adaptability to evolving educational paradigms do not exhibit a measurable correlation with the integration of scientific literacy components like curriculum integration, student engagement, assessment strategies, teacher professional learning communities, and real-world applications. These findings imply that while professional development programs play a role in teacher competence, they may not directly impact the extent to which scientific literacy is effectively implemented in educational settings.

One possible interpretation of these results is that external factors beyond professional development programs might have a more substantial influence on the successful integration of scientific literacy. These factors could include institutional policies, administrative support, availability of resources, or the overall teaching culture within the schools. The lack of significant correlation may also indicate that while teachers participate in professional development programs, these activities may not be explicitly designed to translate into measurable improvements in scientific literacy implementation. More so, if training programs focus more on theoretical knowledge rather than practical applications, their direct impact on classroom instruction and student engagement may be limited. Additionally, the variation in teaching styles and instructional strategies used by different educators could dilute the observable effects of professional development efforts on scientific literacy outcomes.

The implications of these findings suggest the need for a more targeted approach to professional development that directly addresses the practical integration of scientific literacy into teaching methodologies. It may be necessary to restructure existing training programs to include more hands-on activities, real-world applications, and classroom-based assessments that align with scientific literacy objectives. Furthermore, professional development initiatives should be supplemented with strong institutional support, ensuring that teachers receive the necessary tools, resources, and guidance to effectively implement scientific literacy in their instruction. Future research could also explore whether longitudinal professional development models those that provide continuous training and mentoring rather than one-time workshops would yield a stronger impact on scientific literacy outcomes.

Lastly, while the study did not find significant correlations, it does not necessarily mean that professional development programs are ineffective. Instead, it highlights the complexity of educational reform and suggests that professional development should be part of a broader, multi-faceted strategy for improving scientific literacy. Collaboration between policymakers, educators, and curriculum designers is essential to bridge the gap between teacher training and classroom implementation. Moreover, further studies could investigate alternative variables that

may serve as mediators or moderators in the relationship between professional development programs and scientific literacy implementation. Moreover, by refining teacher training strategies and aligning them with the practical demands of scientific literacy instruction, educational institutions can ensure a more robust and meaningful integration of scientific concepts into the curriculum.

The lack of significant correlations suggests that the effectiveness of the currently designed and implemented professional development programs may not directly influence specific aspects of scientific literacy in the curriculum. This implies that, while these programs might be valuable in other areas, they need to be more precisely tailored to enhance scientific literacy practices directly. These results contrast with the findings of Kartal *et al.* (2019), who reported that professional development programs for science had effectively improved teachers' practices and successfully integrated scientific literacy into their teaching.

Moreover, the findings indicate a disconnect between the content and focus of professional development programs and the practical needs of teachers in implementing scientific literacy. These results underscore the importance of evaluating and redesigning professional development programs based on based on teacher feedback to ensure they effectively address the areas that will enhance scientific literacy (Schaefer, 2023).

**Table 6:** Correlational Analysis of Professional Development Programs and the Implementation of Scientific Literacy

Professional Development Programs	Scientific Literacy Implementation	Computed r	P-value	Decision	Conclusion
Pedagogical Change	Integration into Curriculum	0.071	0.389	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.039	0.631	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	-0.004	0.958	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	-0.005	0.950	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	-0.001	0.995	Failed to reject null Hypothesis	Not Significant
Teacher Engagement	Integration into Curriculum	0.031	0.708	Failed to reject null Hypothesis	Not Significant
	Student Engagement	-0.010	0.903	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	-0.031	0.706	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	-0.020	0.804	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	-0.023	0.776	Failed to reject null Hypothesis	Not Significant
Long-Term Sustainability	Integration into Curriculum	0.032	0.700	Failed to reject null Hypothesis	Not Significant
	Student Engagement	-0.004	0.858	Failed to reject null Hypothesis	Not Significant

	Assessment Strategies	-0.031	0.709	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	-0.026	0.754	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	-0.038	0.641	Failed to reject null Hypothesis	Not Significant
Student Outcomes	Integration into Curriculum	0.042	0.606	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.001	0.990	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	-0.071	0.831	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	-0.019	0.815	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	-0.031	0.703	Failed to reject null Hypothesis	Not Significant
Collaboration and Knowledge Sharing	Integration into Curriculum	0.041	0.616	Failed to reject null Hypothesis	Not Significant
	Student Engagement	0.004	0.960	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	-0.030	0.710	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	-0.018	0.827	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	-0.032	0.701	Failed to reject null Hypothesis	Not Significant
Adaptability to Evolving Educational Paradigms	Integration into Curriculum	0.048	0.559	Failed to reject null Hypothesis	Not Significant
	Student Engagement	-0.005	0.950	Failed to reject null Hypothesis	Not Significant
	Assessment Strategies	-0.025	0.765	Failed to reject null Hypothesis	Not Significant
	Teacher Professional Learning Communities	-0.025	0.762	Failed to reject null Hypothesis	Not Significant
	Real-World Applications	-0.039	0.638	Failed to reject null Hypothesis	Not Significant

Note: Significant at 0.05

### Bridging Professional Development and Scientific Literacy: Implications for Science Education in Basic Education

The findings of this study suggest that the effectiveness of professional development programs in enhancing science teachers' literacy in basic education is not directly measurable through the parameters examined. Despite the expectation that professional development programs would lead to significant improvements in the implementation of scientific literacy, the correlational analysis revealed no statistically significant relationships. This lack of significance implies that while professional development programs may provide teachers with knowledge and strategies, they may not always translate into immediate or observable improvements in scientific literacy. One possible implication is that professional

development initiatives may require more sustained implementation, follow-up support, and contextual alignment with classroom practices to yield meaningful results. Additionally, this finding raises concerns about the structure and content of existing training programs, suggesting that they may not be effectively designed to address the real-world challenges faced by science teachers in basic education.

Another key implication is that professional development programs should be designed with a stronger focus on practical application and ongoing mentorship rather than isolated training sessions. The results indicate that a one-size-fits-all approach to teacher training may not be sufficient in fostering scientific literacy among educators. Instead, programs should be adaptive, incorporating active learning strategies, classroom-based assessments,

and collaborative learning experiences that allow teachers to immediately apply new concepts in their teaching. Schools and educational institutions should consider implementing professional learning communities (PLCs) where teachers can share experiences, reflect on their teaching practices, and receive continuous support. Furthermore, integrating technology-enhanced learning into professional development can provide teachers with more accessible, engaging, and interactive ways to enhance their scientific literacy, also improving student outcomes.

Moreover, the study's findings emphasize the need for a holistic approach to teacher professional development that includes institutional support, policy alignment, and resource allocation. Scientific literacy implementation may not solely depend on teacher training but also on factors such as curriculum design, school leadership, availability of teaching materials, and student engagement. If professional development programs are not aligned with national education policies and school initiatives, their impact on teachers' literacy may remain limited. Educational policymakers should work closely with school administrators and teacher training providers to ensure that professional development programs are structured to meet the specific needs of science teachers. Additionally, providing incentives such as career advancement opportunities or recognition for teachers who actively apply scientific literacy strategies in their classrooms could encourage more meaningful engagement with professional development efforts.

Finally, while the findings indicate no direct correlation, this does not mean that professional development programs are ineffective; rather, it suggests that their impact may be more complex and influenced by multiple variables. Future research should explore additional factors that might mediate or moderate the effectiveness of professional development programs, such as teacher motivation, student demographics, or institutional culture. Longitudinal studies could also provide deeper insights into whether sustained professional development leads to gradual improvements in scientific literacy over time. Also, these findings highlight the importance of continuously evaluating and refining professional development initiatives to ensure they are responsive to the evolving needs of science teachers and contribute meaningfully to the advancement of scientific literacy in basic education.

## CONCLUSION

In conclusion, while professional development programs for science teachers have proven effective in fostering essential skills and promoting educational advancements, their direct influence on the implementation of scientific literacy remains limited. This emphasizes the need for more targeted training initiatives that bridge the gap between theoretical knowledge and classroom application. Furthermore, the significance of teaching experience and educational attainment in enhancing scientific literacy suggests that professional development programs should be designed to accommodate varying

levels of expertise among educators. More so, addressing challenges in less privileged areas by prioritizing resource accessibility, innovative instructional strategies, and real-world applications will further strengthen the impact of these programs. Thus, refining professional development efforts to align with practical teaching needs will enhance scientific literacy and improve student engagement in science education.

## Recommendations

From the abovementioned conclusions, the researcher forwards the following recommendations:

1. It is recommended that authorities in the academe allocate more resources to continuous professional development programs to address the limited opportunities available, particularly for young and inexperienced science teachers. Expanding access to training initiatives will enhance educators' competencies and ensure long-term professional growth.

2. It is suggested that professional development programs integrate more strategies that directly improve student engagement and performance. Also, by focusing on innovative curriculum designs that embed scientific literacy across subjects, these programs can better equip teachers to facilitate meaningful learning experiences.

3. It is recommended that professional development programs be designed to meet the distinct needs of teachers at different grade levels. Addressing the specific challenges faced in elementary and secondary science instruction will enhance the practical applicability of these programs and improve overall teaching effectiveness.

4. It is suggested that professional development programs emphasize mentorship initiatives and advanced training opportunities. Leveraging experienced educators as mentors can help bridge the knowledge gap, allowing for the transfer of best practices and hands-on strategies to less experienced teachers.

5. It is recommended that professional development programs be designed with direct input from educators to ensure relevance and practical applicability. These programs can be better aligned with real-world classroom challenges and foster more effective implementation of scientific literacy.

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