PROFESSIONAL DEVELOPMENT AND SCIENTIFIC LITERACY IN SCIENCE CURRICULUM

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ABSTRACT: *This study investigates the correlation between professional development programs and the integration of scientific literacy in science education in selected schools in Agusan del Sur, Philippines. Employing a mixed-method approach, the research involved 151 science teachers and conducted in-depth interviews through a Focus Group Discussion (FGD) with 15 participants. The thematic analysis highlights several areas: the impact of professional development on educators' understanding of scientific literacy, integration of scientific literacy into the curriculum, application of concepts and strategies, collaboration and teacher community development, and student engagement in science. The study proposes the "Modern Science Education Theory," advocating for an integrative approach to modern science education The theory emphasizes improving scientific literacy, expanding literacy strategies, integrating higher-order thinking skills (HOTS), promoting educator collaboration and participation, and incorporating technology. Key findings indicate that factors such as age, gender, teaching experience, and training attendance do not significantly influence science teachers' perceptions of the effectiveness of professional development initiatives. However, a significant relationship exists between grade levels and the effectiveness of these programs in promoting pedagogical changes, teacher engagement, collaboration, and knowledge sharing. Educational attainment also significantly affects the effectiveness of these programs in fostering collaboration and knowledge sharing. Moreover, grade level, teaching experience and educational background significantly influence the implementation of scientific literacy, particularly through assessment strategies The recommendations include increasing funding and access to continuous professional development, customizing programs to meet specific grade-level needs, prioritizing mentorship and advanced training, and ensuring equitable access to professional development in less privileged areas. Rigorous testing and evaluation of the proposed theory through pilot programs and case studies are also recommended to ensure its usability and effectiveness.*

Keywords: *Professional development, Scientific literacy, Science curriculum, Higher Order Thinking Skills, Teaching approaches*

Introduction

The pivotal role of professional development programs in augmenting scientific literacy in science education is emphasized, with particular attention given to customizing these programs to address the distinctive needs and obstacles encountered by teachers in the Agusan del Sur division. This approach aims to generate insights conducive to the seamless integration of scientific literacy into the local science curriculum, benefiting both educators and students in the specified division. Within the study's parameters, evident gaps and limitations emerge. There exists a dearth of research on the effectiveness of professional development programs in specific municipalities in Agusan del Sur, especially in designated schools, which presents a substantial gap in the literature.

Challenges encountered by educators in these educational institutions, particularly regarding the influence of professional development initiatives on teaching practices, remain underexplored due to insufficient resources. The study identifies critical factors such as entrenched traditional teaching methods, limited technological infrastructure, unsuitable school environments, inadequate teacher training, absence of science laboratories and equipment, and a deficiency in orientation toward science resources, underscoring the urgent need for targeted interventions in the realm of science education.

Suwono et al. [1] emphasize the critical role of scientific literacy in shaping the science curriculum. Saro et al. [2] advocate for hands-on experimentation and direct observation to foster students' critical thinking and problem-solving skills in scientific teaching practices. However, teachers face challenges in translating theoretical concepts into engaging classroom activities, highlighting the need for comprehensive professional development initiatives. This study explores the professional landscape, underscoring the importance of such programs in shaping teachers' pedagogical skills and subject knowledge [3]. Various formats, including workshops, seminars, collaborative projects, and online resources, are vital in equipping teachers with effective strategies for engaging students [4,5,6,]. Locally, challenges include entrenched traditional teaching methods hindering critical thinking [7, 8] and resource limitations impeding the transition to student-centered approaches [9]. Disparities in teacher preparation and professional development programs [10] further hinder the adoption of progressive instructional methods, affecting science education quality and students' development of scientific literacy.

Theoretical Framework

This study utilizes the Cognitive Apprenticeship Theory Constructivist Learning Theory, and Diffusion of Innovations Theory as its theoretical framework. The Cognitive Apprenticeship Theory proposed by Collins et al. [11], viewing Viewing learning as an immersive process similar to cultural immersion, they emphasize the role of professional development programs as apprenticeship for educators. Vygotsky's Constructivist Learning Theory, developed in 1978, posits that learners construct knowledge through dynamic interactions with their environment. The Diffusion

of Innovations Theory by Rogers [12] elucidates the predictable adoption of new ideas in education. Professional development programs act as catalysts, raising awareness and offering trial opportunities for innovative instructional approaches to scientific literacy.

Scope and Limitation of the Study

This study investigated the correlation between the effectiveness of professional development programs and the integration of scientific literacy into science curriculum in selected schools in the Agusan del Sur region during the 2023-2024 school year. The primary objective was to assess how these programs impacted the successful adoption of scientific literacy strategies among science educators in the designated schools of the Agusan del Sur division. To ensure a representative sample, the study utilized purposive sampling, identifying science teachers in the selected schools based on predetermined criteria such as grade levels or teaching experience.

Significance of the Study

The study's results offered a significant context and pertinent insights into the complex interplay between the effectiveness of professional development programs and the integration of scientific literacy into the science curriculum in chosen schools in the Agusan del Sur division, Philippines.

Research Design

This study adopted a mixed methods approach, combining qualitative and quantitative techniques to thoroughly explore the research topic. Descriptive and correlational inquiries were carried out to study variables in their authentic contexts, following Simon's [13] guidance to minimized external influences. Thematic analysis was employed to scrutinize qualitative insights extracted from these interviews, pinpointing recurring themes and patterns as to how science educators viewed the impact of professional development programs on the integration of scientific literacy into the science curriculum, guided by the thematic guidelines outlined by Braun and Clarke [14].

Research Locale

The research was carried out within the Division of Agusan del Sur, with a specific focus on selected districts: Sibagat, Esperanza, San Francisco, Prosperidad, and Talacogon (refer to Figure 2).These districts were chosen based on their number of science teachers and their involvement in various initiatives within the Agusan del Sur division. The study area encompassed only the 15 largest secondary schools in these five districts, including Sibagat National High School of Home Industries, Afga National High School, Esperanza National High School, Guadalupe National High School, Prosperidad National High School, Patin-ay National High School, Agusan del Sur National Science High School, Del Monte National High School, Lucena National High School, Talacogon National High School, Bayugan II National High School, Lapinigan National High School, Sta. Irene National High School, San Vicente National High School, and Mabuhay National High School. The schools were selected based on the number of teachers they employed.

Respondents of the Study

The research targeted prominent secondary schools in the Agusan del Sur division, specifically those in the Sibagat, Esperanza, Prosperidad, San Francisco, and Talacogon districts. These districts were selected based on the number of science teachers they employed and their involvement in various initiatives in the division. Participant selection utilized complete enumeration sampling, ensuring representation from both Junior and Senior High School science departments. Including all science teachers from these schools was essential to gather pertinent data aligned with the research objectives and to ensure the utmost quality and relevance of the study's data collection methods.

RESULTS

Table. 1 Level of Effectiveness of Professional Development Programs for Science Teachers

Parameters	Mean Scores	Remark	Verbal Interpretatio
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 Paradigm	4.46	Strongly Agree	Highly Manifested
OVERALL MEAN	**4.43**	**Strongly Agree**	**Highly Manifested**

Legend: Scale andAdjectival 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

Table 2. Level of Implementation of Scientific Literacy in the Science Curriculum

Parameters	Mean Scores	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
OVERALL MEAN	**4.58**	**Strongly Agree**	**Highly Manifested**

Legend: 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

Table 3. Significant Relationship Between Respondents' Profile and their Assessment on the Effectiveness of

Profile	Professional Development Programs	P-value	Conclusion
Age	Pedagogical Change	0.090	Not Significant
	Teacher Engagement	0.325	Not Significant
	Long-Term Sustainability	0.734	Not Significant
	Student Outcomes	0.828	Not Significant
	Collaboration and Knowledge Sharing	0.406	Not Significant
	Adaptability to Evolving Educational Paradigms	0.257	Not Significant
Sex	Pedagogical Change	0.270	Not Significant
	Teacher Engagement	0.539	Not Significant
	Long-Term Sustainability	0.840	Not Significant
	Student Outcomes	0.692	Not Significant
	Collaboration and Knowledge Sharing	0.836	Not Significant
	Adaptability to Evolving Educational Paradigms	0.596	Not Significant
Grade Level	Pedagogical Change	0.000	Significant
	Teacher Engagement	0.010	Significant
	Long-Term Sustainability	0.110	Not Significant
	Student Outcomes	0.136	Not Significant
	Collaboration and Knowledge Sharing	0.048	Significant
	Adaptability to Evolving Educational Paradigms	0.005	Significant
Length of Teaching Service	Pedagogical Change	0.809	Not Significant
	Teacher Engagement	0.696	Not Significant
	Long-Term Sustainability	0.431	Not Significant
	Student Outcomes	0.567	Not Significant
	Collaboration and Knowledge Sharing	0.440	Not Significant
	Adaptability to Evolving Educational Paradigms	0.336	Not Significant
Educational Attainment	Pedagogical Change	0.117	Not Significant
	Teacher Engagement	0.403	Not Significant
	Long-Term Sustainability	0.295	Not Significant
	Student Outcomes	0.310	Not Significant
	Collaboration and Knowledge Sharing	0.037	Significant
	Adaptability to Evolving Educational Paradigms	0.124	Not Significant
Number of Trainings and Seminars Attended	Pedagogical Change	0.539	Not Significant
	Teacher Engagement	0.672	Not Significant
	Long-Term Sustainability	0.859	Not Significant
	Student Outcomes	0.604	Not Significant
	Collaboration and Knowledge Sharing	0.599	Not Significant
	Adaptability to Evolving Educational Paradigms	0.640	Not Significant

**Significant at 0.05*

Table 4. Significant Relationship Between the Respondents' Profile Professional Development Programs for Science Teachers and the Level of Implementation of Scientific Literacy in the Science Curriculum

Profile	Scientific Literacy	P-value	Conclusion
Age	Integration into Curriculum	0.232	Not Significant
	Student Engagement	0.596	Not Significant
	Assessment Strategies	0.293	Not Significant
	Teacher Professional Learning Communities	0.522	Not Significant
	Real-World Applications	0.150	Not Significant
Sex	Integration into Curriculum	0.127	Not Significant
	Student Engagement	0.255	Not Significant
	Assessment Strategies	0.379	Not Significant
	Teacher Professional Learning Communities	0.477	Not Significant
	Real-World Applications	0.481	Not Significant
Grade Level	Integration into Curriculum	0.135	Not Significant
	Student Engagement	0.330	Not Significant
	Assessment Strategies	0.050	Significant
	Teacher Professional Learning Communities	0.457	Not Significant
	Real-World Applications	0.373	Not Significant
Length of Teaching Service	Integration into Curriculum	0.000	Significant
	Student Engagement	0.000	Significant
	Assessment Strategies	0.000	Significant
	Teacher Professional Learning Communities	0.000	Significant
	Real-World Applications	0.081	Not Significant
Educational Attainment	Integration into Curriculum	0.000	Significant
	Student Engagement	0.000	Significant
	Assessment Strategies	0.000	Significant
	Teacher Professional Learning Communities	0.000	Significant
	Real-World Applications	0.092	Not Significant
Number of Trainings and Seminars Attended	Integration into Curriculum	0.706	Not Significant
	Student Engagement	0.725	Not Significant
	Assessment Strategies	0.523	Not Significant
	Teacher Professional Learning Communities	0.493	Not Significant
	Real-World Applications	0.943	Not Significant

**Significant at 0.05*

Influence of Professional Development Programs on Educators' Understanding of Scientific Literacy and Its Integration into the Science Curriculum

The thematic analysis of responses from fifteen teachers about their experiences with professional development programs provides comprehensive insights into the influence of these programs on enhancing scientific literacy and its integration into the science curriculum.

Theme One: Deepening Scientific Literacy and Pedagogical Skills

As noted by multiple respondents, deepening Scientific Literacy and Pedagogical Skills emerged as a significant theme. For instance, Respondent 1 stated that professional development programs "*help me to motivate, enhancing my capability in helping students to develop critical thinking and skills in science concepts.*" This theme underscores the role of professional development in enriching teachers' pedagogical strategies, particularly in fostering critical thinking and problem-solving skills, which are crucial components of scientific literacy. Respondent 4 further emphasized this by noting the programs' impact on understanding diverse student needs and enhancing problem-solving skills in the science curriculum. These experiences signify that professional development serves to impart knowledge and deepen the pedagogical skills necessary for effective teaching and learning in science education [15].

Table 5. Significant Relationship Between Effectiveness of Professional Development Programs and Implementation of Scientific Literacy in the Science Curriculum

Professional Development Programs	Scientific Literacy	r	p-value	Conclusic
Pedagogical Change	Integration into Curriculum	0.071	0.389	Not Signific
	Student Engagement	0.039	0.631	Not Signific
	Assessment Strategies	-0.004	0.958	Not Signific
	Teacher Professional Learning Communities	-0.005	0.950	Not Signific
	Real-World Applications	-0.001	0.995	Not Signific
Teacher Engagement	Integration into Curriculum	0.031	0.708	Not Signific
	Student Engagement	-0.010	0.903	Not Signific
	Assessment Strategies	-0.031	0.706	Not Signific
	Teacher Professional Learning Communities	-0.020	0.804	Not Signific
	Real-World Applications	-0.023	0.776	Not Signific
Long-Term Sustainability	Integration into Curriculum	0.032	0.700	Not Signific
	Student Engagement	-0.004	0.858	Not Signific
	Assessment Strategies	-0.031	0.709	Not Signific
	Teacher Professional Learning Communities	-0.026	0.754	Not Signific
	Real-World Applications	-0.038	0.641	Not Signific
Student Outcomes	Integration into Curriculum	0.042	0.606	Not Signific
	Student Engagement	0.001	0.990	Not Signific
	Assessment Strategies	-0.017	0.831	Not Signific
	Teacher Professional Learning Communities	-0.019	0.815	Not Signific
	Real-World Applications	-0.031	0.703	Not Signific
Collaboration and Knowledge Sharing	Integration into Curriculum	0.041	0.616	Not Signific
	Student Engagement	0.004	0.960	Not Signific
	Assessment Strategies	-0.030	0.710	Not Signific
	Teacher Professional Learning Communities	-0.018	0.827	Not Signific
	Real-World Applications	-0.032	0.701	Not Signific
Adaptability to Evolving Educational Paradigms	Integration into Curriculum	0.048	0.559	Not Signific
	Student Engagement	-0.005	0.950	Not Signific
	Assessment Strategies	-0.025	0.765	Not Signific
	Teacher Professional Learning Communities	-0.025	0.762	Not Signific
	Real-World Applications	-0.039	0.638	Not Signific

**Significant at 0.05*

Theme Two: Integrating Modern Methods and Real-life Contexts

Integrating Modern Methods and Real-life Contexts was another theme that illustrating the shift toward contemporary educative strategies. Respondent 2's experience highlighted integrating "*21st-century teaching methods so learners may understand more about the science curriculum*," reflecting a trend toward modernizing teaching approaches to improve student engagement and comprehension. This is corroborated by Respondent 10, who mentioned the practical application of these methods, providing "*knowledge about real-life situations as an example of scientific interactions*." This theme coincides with the assertion of Padillo et al. [16] that professional development programs are pivotal in equipping teachers with the tools to make science education more applicable and relatable to students' lives, enhancing the learning experience.

Theme Three: Enhancing Real-World Relevance of Scientific Literacy

The theme Enhancing Real-World Relevance of Scientific Literacy focuses on applying scientific knowledge to real-world scenarios. Respondent 3 pointed out the importance of moving beyond mere information retention to "*help children develop scientific literacy*," which includes critical thinking and the ability to scrutinize scientific data. This perspective is crucial for students to apply scientific concepts outside the classroom and in real-life contexts, as also seen in Respondent 5's remarks on programs demonstrating "*effective strategies in integrating scientific literacy into the curriculum.*" According to Santos & Reyes [17], through such training and programs, teachers learn how to design and implement curriculum and activities that not only cover scientific theories but also demonstrate their practical applications, thereby enabling students to see the tangible impact of science in everyday life and to develop the skills needed to evaluate and use scientific data effectively in real-world contexts.

Theme Four: Addressing Disparities and Enhancing Teacher Performance

Addressing Disparities and Enhancing Teacher Performance reflects on the challenges and goals in less privileged contexts. Respondent 7 highlighted that "*Scientific literacy has minimal influence to those who are in the far-flung areas,*" suggesting a disparity in the impact of professional development based on geographic and socioeconomic factors. Meanwhile, Respondent 14 discussed how a goal-oriented learning experience "*strengthens learning and development and ultimately helps improve teacher's performance and productivity*," indicating the broader aspirations of professional development in enhancing educational outcomes. The findings corroborate the statement provided by Smith [18], in which she emphasizes that professional development programs play a crucial role in addressing educational disparities in rural areas by implementing specific strategies and policy changes tailored to overcome the unique challenges teachers and students face.

In conclusion, teachers' experiences reveal that professional development programs are instrumental in enhancing teachers' pedagogical capabilities, modernizing teaching practices, making science education more relevant to real-world problems, and addressing educational disparities. This evidence confirms the claim proposed by Washington [19], saying these programs are vital in promoting a deeper, more practical understanding of scientific literacy and fostering an enriched learning environment for teachers and students.

Challenges Encountered in Integrating Scientific Literacy into the Curriculum Following Professional Development and Strategies for Overcoming Them

Theme One: Modernizing Teaching Approaches

The respondents prepared "*differentiated instructions to meet the needs of all learners*," a strategy that helps bridge the gap between new teaching methods and traditional expectations, as claimed by Ferlazzo (2023). Respondent 5 further mitigated resistance by incorporating "*interactive and engaging activities such as hands-on experiments and real-world problem-solving tasks*," demonstrating scientific literacy's practical relevance and importance.

Theme Two: Systemic Adaptation and Resource Management

Respondent 4, who listed "*teacher knowledge gaps, standardized testing, insufficient materials*" as significant obstacles. . As Holvio [20] asserted, these teacher knowledge gaps can lead to inadequate instruction, limiting students' understanding and mastery of subject matter, ultimately hampering their academic performance and intellectual growth. Meanwhile, in the article report of Baron [21], he exposes that the shortage of learning materials is also a manifestation of a failed education system.

Theme Three: Resource Innovation and Local Adaptation

Respondents 8 and 10 discussed the lack of functional scientific instruments, which they countered by "*innovating contextually*" and localizing lessons to best use available resources. This enhances the applicability of scientific concepts and ensures that students can engage with the curriculum meaningfully. This aligns with the insights provided by Maffea [22], who asserts that by innovating in their specific contexts, teachers manage resource limitations effectively and enhance educational delivery and outcomes.

Theme Four: Technological Adaptation in Science Education

Respondent 13, who described themselves as a "*digital alien*" struggling with the rapid pace of technological change. Such observation aligns with the narrative report from Alibang [23], who exposes that teachers in the Philippines are struggling with web challenges that affect their teaching methods and the quality of education for countless students.

In conclusion, the successful integration of scientific literacy into the curriculum following professional development hinges on a balanced approach that includes adapting to modern educational demands, managing resource limitations, leveraging technological advancements, and fostering collaborative environments, per Suliman et al. [24].

Direct Application of Concepts and Strategies from Professional Development Programs to Enhance Scientific Literacy in Science Lessons

Theme One: Implementing Active Learning and Critical Thinking

Respondent 1 and Respondent 6 highlighting inquiry-based learning and the Socratic method. These strategies encourage students to engage directly with scientific content through

experiments, group presentations, and critical discussions, fostering a deeper understanding and retention of scientific concepts [25]. For instance, Respondent 5 specifically noted the use of inquiry-based learning to "*encourage critical thinking and problem solving in my science lessons*," illustrating how such approaches stimulate active exploration and analysis of scientific ideas. Such finding goes in accordance with the idea of Bulba [26] as she revealed that in this sense, students have opportunities to explore possible solutions, develop explanations for the phenomena under investigation, elaborate on concepts and processes, and evaluate or assess their understandings in the light of available evidence.

Theme Two: Contextualizing Science Education

Respondent 2 described this approach as applying localization "*for proper comprehension of the learners*," ensuring students are more engaged by relating content to their experiences. As implied by Pandolpho [27], teachers can significantly boost student engagement by connecting learning materials to the student's experiences.

Theme Three: Integrating Technology and Hands-on Learning

Respondent 5, for example, utilized "*technology tools learned in these programs for interactive simulations and real time data analysis*," which helps make abstract concepts more tangible and engaging. Adler and Bhatia [28] described that these technology-enabled simulations provide a visual and interactive way to explore complex scientific concepts, making abstract ideas more concrete and understandable. Respondent 9 emphasized the role of "*visualizations, multimedia, and technology tools*" in enhancing student engagement and understanding, demonstrating the broad use of technology in science education. Abdulrahaman et al. [29] testified that by integrating these tools, teachers can create more engaging, understandable, and inclusive learning experiences that enhance academic performance and prepare students for future challenges and opportunities.

Theme Four: Strengthening Assessment and Feedback Practices

As Respondent 3 and Respondent 4 have adopted refined assessment strategies to evaluate better and support students' learning progress. These professional development programs often introduce teachers to advanced assessment techniques beyond traditional tests and quizzes. Differentiated instructions and targeted assessments allow teachers to address individual learning needs and provide feedback that guides further improvement, ensuring a comprehensive approach to building scientific literacy.

In conclusion, applying concepts and strategies from professional development programs has significantly enhanced how scientific literacy is taught and integrated into the science curriculum. Because of this, Asiyah et al. [30] reported that teachers have effectively implemented active learning techniques, contextualized education to fit student needs, utilized modern technologies to make learning engaging, and strengthened assessment practices to ensure effective learning outcomes.

Extent of Professional Development Programs in Fostering Collaboration and Teacher Community Development for Effective Integration of Scientific Literacy

Theme One: Strengthening Teacher Collaboration

Respondent 4 highlighted the impact of "*collaborative learning, peer mentoring, and coaching and workshops*," which allow teachers to learn from one another and collectively refine their teaching strategies. This notion is further supported by Respondent 9, who emphasized the support of communities of practice, where teachers "*collaborate regularly and share learnings, solve problems and support each other in professional growth*." As per Rajendran et al. [31], participating in these forms of collaborative professional development exposes teachers to a broader array of pedagogical techniques and strategies, which can lead to more effective and diverse teaching practices.

Theme Two: Implementing Collaborative Educational Projects

Respondent 1 mentioned the involvement of the local government and school science departments in funding student research and providing necessary equipment, which not only enhances student learning but also integrates scientific literacy into tangible research activities. Similarly, Respondent 10 described how "*all teachers in a community can conduct scientific exhibits,*" which caters to students' outputs and hands-on learning, demonstrating the real-world application of scientific concepts. These findings are consistent with the observations made by Almulla & Al-Rahmi [32], in which she emphasized that the engagement of multiple stakeholders in educational projects enriches the learning environment by bringing diverse resources and perspectives.

Theme Three: Enhancing Professional Growth Through Collaboration

Respondent 5 cited the "*teacher learning and leadership program in Canada*," emphasizing collaborative inquiry among teachers to improve science teaching practices. This kind of collaborative professional development ensures that teachers are not only recipients of knowledge but also active participants in generating and disseminating educational innovations [33].

In conclusion, professional development programs have been instrumental in creating collaborative, supportive environments that enhance scientific literacy. These programs encourage sharing best practices, joint problem-solving, and the development of communal educational projects, thereby strengthening the educational ecosystem.

Impact of Professional Development on Student Engagement in Science Concerning Scientific Literacy

Theme One: Enhancing Engagement through Project-Based Learning

Respondent 5 noted the use of project-based learning to "*enhance student engagement and scientific literacy as evidenced by projects where students apply scientific principles to real-world problems.*" This method has proven effective in fostering creativity and critical thinking as

students analyze data and interpret findings, similar to the projects described by Respondent 1. Such educational practices emphasize the application of knowledge, enhancing students' ability to relate theoretical concepts to practical situations, thereby boosting their engagement and enthusiasm for learning science [34].

Theme Two: Cultivating Deeper Understanding and Engagement

Respondent 3, who remarked that professional development focused on scientific literacy "*has a significant impact on student engagement in science*." By providing teachers with the knowledge and tools to create more engaging and relevant science experiences, professional development programs help to cultivate a more profound understanding among students, making the learning experience both informative and appealing [35]. Respondent 4 echoed this, stating that such programs equip teachers with "*innovative learning methods*," which are critical in captivating students' interests and improving their scientific literacy.

Theme Three: Encouraging Practical Applications and Environmental Awareness

Respondent 12 shared an example where "*STEM students joined different contests...that showcase the knowledge and skills of our STEM students*," highlighting how competitive environments motivate students to apply and extend their scientific knowledge. Even more than that, Respondent 13 discussed how enhanced awareness of scientific concepts led students to "*practice correct application in day-to-day living*," including adopting healthy diets and engaging in environmental protection. This theme underscores the value of scientific literacy as a tool for empowering students to make informed decisions that affect their lives and the environment [36].

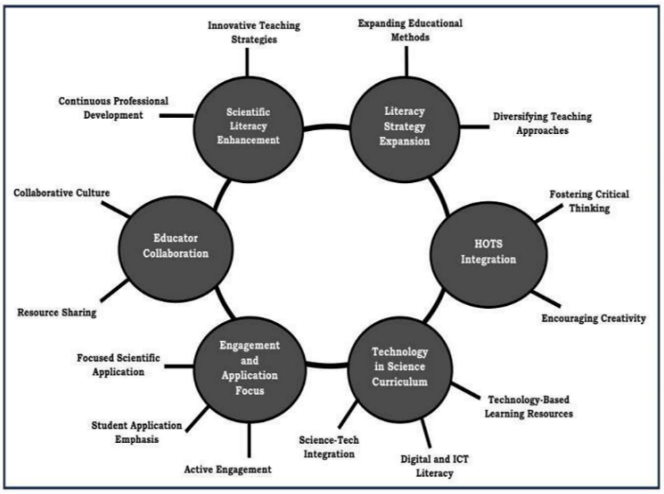

Figure 3. Modern Science Education Theory

Theme Four: Linking Science Education to Students' Lives and Futures

Respondent 15 mentioned that professional development impacts students by "*applying their learnings in scientific concepts like doing scientific experiments, research, or even applied in real-world scenarios*." This relevance to everyday life and future careers enhances students' engagement and interest in science, providing them with a clear understanding of how science directly impacts their lives and society [2].

Proposed Theory: Modern Science Education Theory

Table .6 Proposed Modern Science Education Theory

Domains	Descriptions	Key Components
Domain One	Scientific Literacy Enhancement	• Continuous Professional Development • Innovative Teaching Strategies
Domain Two	Literacy Strategy Expansion	• Expanding Educatior Methods • Diversifying Teachinç Approaches
Domain Three	HOTS Integration	• Fostering Critical Thinking • Encouraging Creativi
Domain Four	Educator Collaboration	• Collaborative Culture • Resource Sharing
Domain Five	Engagement and Application Focus	• Active Engagement • Student Applications Emphasis • Focused Scientific Application
Domain Six	Technology in Science Curriculum	• Science-Tech Integration • Technology-Based Learning Resources • Digital and ICT Litera

****Legend: Six Domains of Modern Science Education Theory*

The theory provides emphasis on the expansion of learning and teaching strategies for scientific literacy integration, such as interdisciplinary connections, inquiry-based instruction, and technology integration. Additionally, differentiating instruction and providing opportunities for peer collaboration can support scientific literacy development and promote equitable learning opportunities for all students. Even so, the proposed theory addresses challenges in scientific literacy by advocating for equitable access to resources, teacher preparation, curriculum alignment, and assessment practices.

The Continuous Professional Development (CPD) is a key component, providing educators with ongoing training, resources, and opportunities for growth.

Domain One: Scientific Literacy Enhancement

The Modern Science Education Theory is a framework for enhancing science education in a modern classroom. Its Domain One, Scientific Literacy Enhancement, is crucial for improving both science teachers' or educators and students' understanding and application of scientific concepts.

Domain Two: Literacy Strategy Expansion

The Modern Science Education Theory provides a complex framework for enhancing science education in contemporary classrooms.

Domain Three: HOTS Integration

The domain three focused on HOTS Integration emphasizes on integrating Higher Order Thinking Skills (HOTS) into teaching practices, fostering critical thinking, and encouraging creativity among students.

Domain Four: Educator Collaboration

The Domain Four of the proposed "Modern Science Education Theory" focuses on Educator Collaboration.

Domain Five: Engagement and Application Focus

The domain five on Engagement and Application Focus is one of the domain of the theory that emphasizes the importance of actively involving students in the learning process and focusing on the practical application of scientific concepts.

Domain Six: Technology in Science Curriculum

The proposed theory, the "Modern Science Education Theory" for modern science education, with Domain six focusing on the integration of technology in the science curriculum.

CONCLUSION

The findings suggest that the professional development programs are highly effective in addressing the diverse needs of science teachers. These programs foster pedagogical innovation, sustain teacher engagement, promote collaborative learning environments, ensure adaptability to evolving educational paradigms, and prioritize long-term impact.

The proposed "Modern Science Education Theory" is an integrative approach to contemporary science education. It focuses on enhancing scientific literacy, expanding literacy strategies, integrating higher-order thinking skills (HOTS), fostering educator collaboration and engagement, and incorporating technology. This theory aims to prepare students for 21st-century challenges and opportunities, fostering a scientifically literate citizenry capable of thriving in a complex and rapidly evolving world. Efficient professional development programs are crucial for implementing this theory, ensuring that educators can successfully enhance student learning and success in the science curriculum.

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