LEVERAGING RESEARCH BASED INSTRUCTIONS IN NURTURING ACTIVE LEARNING ENGAGEMENT AND SCIENTIFIC LITERACY AMONG GRADE 9 STUDENTS

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ABSTRACT

This study evaluated the effectiveness of research-based instruction—specifically Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL)—in enhancing active learning engagement and scientific literacy among Grade 9 students in Mauban, Quezon. Motivated by persistent challenges in science education, the study investigated how these instructional approaches influenced students' engagement in terms of interest, interaction, and active cognitive processing. A quasi-experimental design using cluster sampling was employed, involving 64 Grade 9 students from Manuel S. Enverga Memorial School of Arts and Trades. Data were gathered through pre- and post-assessments, formative assessments, a Likert-scale survey, and a criteria-based performance assessment. Paired and independent samples t-tests were used to analyze the data. Results indicated that both PBL and IBL positively influenced active learning engagement and improved scientific literacy, particularly in the domains of creativity and collaboration. While PBL demonstrated slightly higher engagement outcomes, it did not produce a statistically significant effect on critical thinking. No significant differences were observed between the post-assessment performances of the two instructional groups. These findings suggest that both PBL and IBL are effective in promoting active learning and developing key components of scientific literacy among secondary students. Future research should explore contextual factors that may influence the implementation and outcomes of research-based instructional strategies.

Keywords: Active Learning Engagement, Inquiry-Based Learning (IBL), Problem-Based Learning (PBL), Research Based Instructions, and Scientific Literacy

INTRODUCTION

Science educators in the early twenty-first century face numerous challenges, particularly as students in some countries continue to have significant gaps in scientific achievement, notably in Europe and Asia (National Center for Education Statistics, 2021). For instance, Anderman and Sinatra (2021) highlight several challenges in science education, including students' cognitive limitations, lack of engagement, insufficient teacher preparation of effective instructions and strategies, and the pressure from standardized testing.

Similarly, the Philippines faced these challenges and shows a significant gap in comparison to its neighboring countries, in terms of integrating science education (Rogayan & Dollete, 2019). Chi (2024) quoted in Philippine star global "the Philippine students continue to rank among the lowest globally in science and other selected subjects, according to the Programme for International Student Assessment (PISA) 2022 results released in December 2023". Furthermore, the country's overall performance showed no significant improvement compared to its initial participation in 2018. Bernardo

(2019) noted that that more work needs to be done to reform science education.

Meanwhile, In the TIMSS 2019 cycle, Filipino students achieved an average scale score of 249, the lowest among the 58 participating countries, with the overall average score being approximately 491. Only 19% of Filipino students scored at or above the Low benchmark, indicating that the vast majority have a limited understanding of scientific concepts and a shallow grasp of foundational science literacy (Mullis et al., 2020).

Despite the continuous efforts of the Department of Education (2020) in implementing programs such as the Science Education Institute (SEI) and the National Science and Technology Fair, which promote scientific research, innovation, and experimentation among students, there remains a significant gap in effectively achieving these goals. However, Saro et. al., (2023) noted that the adoption of alternative instructional methods and approaches may significantly improve students' understanding and engagement with science, addressing the existing gaps and fostering better scientific literacy. Such methods could be reliable tools to bridge the existing gaps and enhance the quality of science education.

For instance, one fitted instructional method for the science subject are the Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL), which both fall under the umbrella of Research-Based Instruction (RBI). RBI is an instructional method rooted in reliable research and evidence, advocating for evidence-driven decision-making and continuous improvement (solutiontree, 2021). PBL, a student-centered approach, engages learners in solving real-world problems, fostering critical thinking and collaboration (Cornell University, 2023).

Similarly, IBL centers around inquiry, exploration, and hands-on activities, encouraging students to ask questions and actively shape their learning (Scholl, 2023). As facilitators in PBL and IBL, teachers guide students through the learning process. The interdisciplinary nature of PBL problems and the emphasis on questioning and exploration in IBL align with the principles of RBI, promoting a tailored and continuously improving instructional approach based on empirical findings (Neda & Dragana, 2022).

The researcher, recognizing the challenges in teaching science and finding solution have concluded in utilizing alternative instructional methods like Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL), rooted in Research-Based Instruction (RBI), to create an effective approach to enhancing students' understanding and engagement in science, helping to bridge these gaps and improve overall scientific literacy using this study.

MATERIALS AND METHODS

In this study, a quantitative research approach utilizing a quasi-experimental design was strategically selected to assess the effectiveness of research-based instruction on the academic performance, active learning engagement, and scientific literacy of Grade 9 students. The goal of using this quasi-experimental design was to compare the outcomes of students before and after the utilization of research-based instructional methods—specifically, how students' learning outcomes changed after being exposed to methods such as problem-based learning and inquiry-based learning, compared to traditional instruction.

Second, the design also compared the effectiveness of various research-based instructional methods, such as problem-based learning and inquiry-based learning, in fostering active learning engagement and scientific literacy among students. Furthermore, this design choice provided a structured framework for analyzing measurable changes in the targeted competencies (Thomas, 2020), enabling the researcher to assess the impact of specific instructional strategies.

In this study, two research instruments were designed to accomplish the study's objective of determining the influence of research-based instruction on active learning engagement and scientific literacy among Grade 9 students. Each instrument was crafted to address specific research questions.

The first instrument consisted of seven (7) agreeable statements in each indicator to assess the influence of research-based instruction on students' active learning engagement. It was a criteria-based assessment form constructed based on Mandernach's (2018) Assessment of Student Engagement in Higher Education: A Synthesis of Literature and Assessment Tools. This tool was completed by the teacher in charge during classroom observation. The form evaluated three main aspects of student engagement: interest, interaction, and active cognitive processes. Teachers rated this engagement on a Likert scale from very high extent (5) to very low extent (1).

A 45-item objective-type pre-assessment was designed and constructed based on the Grade 9 Science Module and administered to the respondents to assess the Least Learned Competencies (LLCs) of these students based on the Most Essential Learning Competencies (MELCs) in the Science Module.

From this, a 45-item objective assessment was constructed—also adapted from the Grade 9 Science Module: Factors Affecting Climate—and was administered as both a formative and post-assessment focusing on the learning competency: "Explain how different factors affect the climate of an area" (S9ES-IIIe-30). This assessment was made to evaluate the impact of research-based instruction on scientific literacy. The instrument examined critical thinking, creativity, and collaboration. An objective-type questionnaire was used to measure the scientific literacy of students because it provided quantifiable and reliable data that ensured consistency, fairness, and ease of analysis when assessing students' understanding of scientific concepts and skills.

For validity, the instruments were submitted to professional experts including one (1) School Principal, one (1) Head Teacher, two (2) Master Teachers, two (2) Teacher III, and one (1) Teacher II. For reliability, a pilot test involving 30 non-participant respondents was conducted, using test questions comprising topics from the third quarter of Grade 9, factors that affect climate and the effects of changing climate and how to adapt accordingly. The pilot test results were subjected to Cronbach's alpha analysis to ensure consistency. For data authenticity, the questionnaire was distributed using a secure link that only the researcher and individuals in the study could access.

RESULTS AND DISCUSSION

Table 1

Students' Level of Engagement Before and After the Implementation of Research-Based Instruction, as to Interest

Indicators	Problem-Based Learning (PBL) Group				Inquiry-Based Learning (IBL) Group			
	Before		After		Before		After	
	M	SD	M	SD	M	SD	M	SD
1. The student displays a strong effort to meet the instructor's expectations by working harder on tasks and assignments.	2.03	0.54	3.59	0.80	2.31	0.64	3.53	0.80
2. The student shows interest and motivation to better understand someone else's perspective during group activities.	2.19	0.82	3.44	0.84	2.41	0.76	3.50	0.67

3. The student regularly invests additional time in reviewing notes, studying, and preparing for assessments.	2.16	0.57	3.25	0.72	2.47	0.51	3.28	0.68
4. The student consistently comes to class well-prepared with completed assignments and materials.	2.31	0.74	3.25	0.80	2.16	0.77	3.16	0.77
5. The student discusses course material with classmates outside regular class hours.	2.19	0.59	3.19	0.74	2.22	0.66	2.88	0.71
6. The student displays a positive attitude and confidence while participating in classroom activities or answering questions.	1.84	0.63	3.41	0.61	2.31	0.59	3.28	0.63
7. The student willingly takes ownership of learning goals and seeks clarification when needed.	2.28	0.63	3.22	0.75	2.44	0.56	3.28	0.77
Overall	**2.14**	**0.65**	**3.33**	**0.75**	**2.33**	**0.64**	**3.27**	**0.72**

Legend: 4.21-5 "Very High Extent" (VHE); 3.40-4.20 "High Extent" (HE); 2.60-3.39 "Moderate Extent" (ME); 1.80-2.59 "Low Extent" (LE); and 1.0-1.79 "Very Low Extent" (VLE)

Table 1 depicts the students' level of engagement before and after the implementation of research-based instruction as to interest, using both Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) approaches. The data shows students' interest across all indicators following the implementation, as seen in the overall mean scores for both instructional strategies.

These findings suggest that the use of research-based instruction—both problem- and inquiry-based—has a meaningful impact on enhancing students' interest and motivation toward learning science. The results imply that integrating tasks that promote responsibility, goal-orientation, and reflective learning can heighten learners' engagement. However, fostering learning beyond classroom boundaries may need supplementary strategies such as digital collaboration tools or structured peer-learning activities. For instance, Surif et al. (2014) emphasized that PBL enhances students' active participation and motivation by presenting real-world problems, supporting the observed higher mean of the PBL group in terms of task-related effort. Similarly, Akcay (2009) found that PBL encourages collaboration and critical thinking, which may explain the generally high extent of engagement indicators within the PBL group. In contrast, while Inquiry-

Based Learning also promotes curiosity and independent learning (Aditomo et al., 2013), its effect on peer interaction outside the classroom appeared limited in this study, reflecting Monteira and Jiménez-Aleixandre's (2019) observation that IBL requires structured support to extend learning beyond classroom boundaries.

Table 2

Students' Level of Engagement Before and After the Implementation of Research-Based Instruction, as to Interaction

Indicators	PBL				IBL			
	Before		After		Before		After	
	M	SD	M	SD	M	SD	M	SD
1. The student frequently asks questions during class discussions to clarify concepts or deepen understanding.	2.28	0.73	3.19	0.59	2.34	0.65	3.34	0.65
2. The student actively participates in group projects or collaborative activities assigned by the instructor.	2.44	0.67	3.44	0.76	2.31	0.64	3.41	0.84
3. The student willingly volunteers to tutor or assist a classmate who is struggling with course material.	2.28	0.77	3.22	0.55	2.56	0.62	3.25	0.72
4. The student regularly attends school-organized, or community events related to the course material.	2.44	0.67	3.44	0.67	2.31	0.64	3.25	0.57
5. The student is attentive and contributes to classroom activities, such as brainstorming, debates, or group work.	2.44	0.62	3.44	0.76	2.44	0.56	3.44	0.67
6. The student takes the initiative to submit tasks, projects, and assignments on time without teacher reminders.	2.03	0.59	3.44	0.67	2.25	0.51	3.28	0.68
7. The student actively participates in class polls, surveys, or other interactive tools provided by the instructor.	2.28	0.58	3.44	0.56	2.31	0.69	3.28	0.63
Overall	**2.31**	**0.66**	**3.37**	**0.65**	**2.36**	**0.62**	**3.32**	**0.68**

Legend: 4.21-5 "Very High Extent" (VHE); 3.40-4.20 "High Extent" (HE); 2.60-3.39 "Moderate Extent" (ME); 1.80-2.59 "Low Extent" (LE); and 1.0-1.79 "Very Low Extent" (VLE)

Table 2 demonstrates the students' level of engagement before and after the implementation of research-based instruction as to interaction, focusing on both Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL). Results show a marked increase in student interaction following the implementation of these instructional approaches. The overall mean for the PBL group increased from before to after the implementation, while the IBL group improved also. These gains represent a shift from Low Extent to Moderate Extent levels of engagement, indicating that research-based instruction had a positive effect on how students interact within the learning environment.

These findings imply that research-based instruction not only promotes active collaboration and class participation but also encourages students to develop autonomy and accountability in their learning. The consistent improvements across all interaction indicators highlight the value of integrating student-centered strategies in fostering meaningful engagement and communication in the classroom setting. Furthermore, Nyakiti et al. (2022) argued that science curricula should prioritize interaction-rich process skills, and the data here reflect that both methods do support such engagement, albeit more consistently in PBL settings. While both groups achieved moderate to high levels of interaction across various indicators, the slightly stronger performance of the PBL group aligns with the findings of Miles (2022) and Amoah and Phillips (2019), who found that active, structured learning environments contribute more effectively to student engagement in collaborative and task-oriented activities.

Table 3

Students' Level of Engagement Before and After the Implementation of Research-Based Instruction as to Active Cognitive Process

Indicators	PBL				IBL			
	Before		After		Before		After	
	M	SD	M	SD	M	SD	M	SD
1. The student consistently completes coursework that requires higher-order thinking skills, such as analysis and evaluation.	2.50	0.67	3.28	0.58	2.34	0.55	3.25	0.62
2. The student demonstrates the ability to integrate and synthesize ideas when working on an academic project.	2.25	0.57	3.22	0.61	2.25	0.80	3.16	0.68

3. The student dedicates time to coursework that involves applying theoretical knowledge to practical situations.	2.44	0.62	3.16	0.57	2.47	0.67	3.06	0.62
4. The student uses critical thinking strategies when solving an academic problem or answering challenging questions.	2.19	0.78	3.13	0.61	2.31	0.69	3.19	0.69
5. The student reflects on lessons by connecting course concepts to real-life applications.	2.44	0.76	3.13	0.66	2.41	0.67	2.91	0.59
6. The student completes independent tasks that involve synthesizing multiple sources of information.	2.34	0.75	3.13	0.66	2.25	0.72	2.94	0.67
7. The student demonstrates effort in tasks that require problem-solving and deeper cognitive processing.	2.22	0.79	3.16	0.68	2.44	0.56	2.94	0.67
Overall	**2.34**	**0.71**	**3.17**	**0.62**	**2.35**	**0.67**	**3.06**	**0.65**

Legend: 4.21-5 "Very High Extent" (VHE); 3.40-4.20 "High Extent" (HE); 2.60-3.39 "Moderate Extent" (ME); 1.80-2.59 "Low Extent" (LE); and 1.0-1.79 "Very Low Extent" (VLE)

Table 3 provides the students' level of engagement before and after the implementation of research-based instruction as to active cognitive process, using both Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL) approaches. The data reveal a noticeable increase in students' engagement with tasks requiring higher-order thinking after the implementation of these instructional strategies. For the PBL group, the overall mean elevates, while the IBL group showed an increase. These shifts reflect a transition from Low Extent to Moderate Extent in terms of students' active cognitive engagement, underscoring the positive influence of research-based instruction.

The implications of these findings suggest that research-based instruction successfully stimulated cognitive engagement by encouraging students to process, apply, and evaluate information rather than simply recall it. The consistent increase across all indicators demonstrates that when students are provided with meaningful, intellectually demanding activities—hallmarks of PBL and IBL—they are more likely to invest cognitive effort, think critically, and connect learning to broader contexts. This supports the development of essential 21st-century skills such as problem-solving, analysis, and

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independent thinking, which are vital for academic and lifelong success. These findings reinforce the importance of scaffolding cognitive engagement strategies, particularly in student-led learning environments, to support deeper and more consistent intellectual involvement. However, studies by Wakhidah et al. (2022) and Monteira and Jiménez-Aleixandre (2019) suggest that without sufficient scaffolding, IBL may fall short in guiding students to independently synthesize information or apply concepts to real-world contexts—evident in the lower mean scores in those domains for the IBL group. These contrasting findings indicate that while both instructional models can stimulate active cognitive engagement, PBL may provide more consistent structure for developing complex thinking skills, a view echoed by Gallagher and Gallagher (2013) in their support for guided cognitive apprenticeship models within problem-based contexts.

Table 4

Pre-Performance Assessment on Scientific Literacy of Respondents Exposed to Research-Based Instructions

SCORES	Critical Thinking				Creativity				Collaboration			
	PBL		IBL		PBL		IBL		PBL		IBL	
	f	%	f	%	f	%	f	%	f	%	f	%
13 – 15	-	0	1	3	-	-	-	-	-	-	-	-
10 – 12	11	34	7	22	1	3	4	13	-	-	2	6
7 – 9	15	47	11	34	11	34	7	22	10	31	5	16
4 – 6	5	16	12	38	20	63	16	50	18	56	22	69
1 – 3	1	3	1	3	-	-	5	16	4	13	3	9
Total	**32**	**100**	**32**	**100**	**32**	**100**	**32**	**100**	**32**	**100**	**32**	**100**

Legend: 13 – 15 "Excellent"; 10 – 12 "Very Good"; 7 – 9 "Good"; 4 – 6 "Fair"; 1 – 3 "Poor

Table 4 presents the pre-performance assessment scores of Grade 9 students in the domains of critical thinking, creativity, and collaboration, comparing two groups exposed to Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL). The data reflects students' baseline competencies before the implementation of research-based instruction.

The overall Fair to Good pre-assessment results underscore the need for instructional approaches that actively build higher-order cognitive and collaborative skills. The findings justify the adoption of research-based strategies like PBL and IBL, which are designed to move students from procedural understanding to deeper conceptual grasp and independent inquiry. These methods offer the potential to transform students from passive receivers of knowledge into active participants in the construction of scientific understanding. Moreover, the pretest serves as a diagnostic tool, highlighting areas where support is most needed—particularly in fostering creative problem-solving and authentic collaboration. These findings provide a meaningful baseline from which to assess the growth and development of students' scientific literacy throughout the intervention.

Table 5

Post-Performance Assessment on Scientific Literacy of Respondents Exposed to Research-Based Instructions

SCORES	Critical Thinking				Creativity				Collaboration			
	PBL		IBL		PBL		IBL		PBL		IBL	
	f	%	f	%	f	%	f	%	f	%	f	%
13 – 15	5	16	3	9	5	16	2	6	7	22	-	-
10 – 12	8	25	9	28	10	31	9	28	5	16	9	28
7 – 9	8	25	15	47	5	16	12	38	8	25	18	56
4 – 6	10	31	5	16	7	22	7	22	7	22	4	13
1 – 3	1	3	-	-	5	16	2	6	5	16	1	3
Total	**32**	**100**	**32**	**100**	**32**	**100**	**32**	**100**	**32**	**100**	**32**	**100**

Legend: 13 – 15 "Excellent"; 10 – 12 "Very Good"; 7 – 9 "Good"; 4 – 6 "Fair"; 1 – 3 "Poor

Table 5 presents the scientific literacy performance of students exposed to research-based instruction, highlighting what learners are capable of demonstrating in critical thinking, creativity, and collaboration. The data suggest that students are able to engage in logical reasoning, make informed judgments, and support arguments with evidence. In terms of creativity, they are capable of generating original ideas, offering alternative solutions, and expressing scientific concepts in innovative ways. Their collaboration skills are evident in their ability to participate actively in group tasks, share responsibilities, and contribute constructively to collective problem-solving. Overall, the data indicate that students exposed to both instructional strategies exhibited varying levels of competence across all three domains, with strengths in analytical thinking, creative application, and peer interaction.

In sum, the progression from pre-assessment (defining) to post-assessment (analyzing, creating, collaborating) reflects meaningful development of scientific literacy. PBL's real-world problem framing and collaborative learning structures directly contributed to gains in critical thinking, creativity, and collaboration. Meanwhile, IBL's focus on student-driven inquiry and hypothesis testing fostered deeper analytical and creative skills, along with improved peer interactions. These instructional designs effectively moved students from passive knowledge recall to active, higher-order scientific engagement.

Table 6

Scores Performance of the Respondents on Formative Assessment

Scores	Formative 2		Scores	Formative 1		Formative 3		VI
	f	%		f	%	f	%	
13-15	12	37.5	9-10	24	75	15	46.9	Excellent
10-12	12	37.5	7-8	4	12.5	14	43.8	Very Good
7-9	5	15.6	5-6	2	6.25	3	9.4	Good
4-6	3	9.4	3-4	2	6.25	-	-	Fair
1-3	-	-	1-2	-	-	-	-	Poor
Total	32	100	Total	32	100	32	100	

Table 6 reflects what students were able to demonstrate in their formative assessments after engaging with research-based instruction. The results suggest that students were generally capable of applying concepts with a high degree of accuracy, showing consistency in their understanding across multiple assessments. Many exhibited strong analytical and problem-solving skills, with a significant number consistently producing high-quality responses. Their performance indicates a solid grasp of subject matter, the ability to transfer knowledge to new situations, and sustained engagement with learning tasks. These outcomes point to learners who are not only retaining information but also processing and applying it effectively across different formative tasks.

The implications of these findings are significant. The data support the idea that formative assessments paired with research-based instruction foster continuous academic growth. The improvements across assessments suggest that students were not only retaining knowledge but also improving in skills such as critical thinking, analysis, and application over time. These results validate the importance of integrating regular formative assessments with innovative teaching strategies to monitor student progress, identify learning gaps early, and inform instructional adjustments. Moreover, the steady increase in high-performing students underscores the value of sustained, student-centered instruction in promoting academic excellence and reinforcing deep learning outcomes.

Table 7

Test of Difference between the Pretest and Posttest Scores Performance of Scientific Literacy of the Respondents Exposed to Problem-Based Learning (PBL)

Scientific Literacy	Paired Differences				t	df	Sig. (2-tailed)
	Pretest		Posttest				
	M	SD	M	SD			
Critical Thinking	8.44	2.55	8.75	3.48	-0.410	31	0.685

Creativity	6.38	1.68	8.16	3.86	-2.471	31	0.019
Collaboration	5.69	1.57	8.09	3.99	-3.181	31	0.003

Legend: p>.05- Not Significant; p<.05- Significant

Table 7 presents the paired sample t-test results comparing pretest and posttest scores of scientific literacy among students exposed to Problem-Based Learning (PBL) across three domains: critical thinking, creativity, and collaboration.

For educators, this underscores the importance of integrating structured reflection and explicit critical thinking scaffolds in PBL to amplify gains in this domain. Future implementations might include targeted activities like argument mapping, Socratic questioning, and self-assessment to better nurture critical thinking development alongside creativity and collaboration.

These observations align with prior research. Erturk and Kaptan (2022) and Rauf et al. (2020) emphasize that PBL's collaborative nature strongly enhances communication and teamwork. Gholam (2019) and Suyatmo et al. (2023) found that PBL's problem-solving contexts stimulate creativity by encouraging divergent thinking and innovation. Conversely, Maknun (2020) and Öztürk et al. (2022) note that critical thinking gains through PBL often require longer exposure and explicit scaffolding, explaining why critical thinking improvement was less pronounced in this study.

Table 8

Test of Difference between the Pretest and Posttest Scores Performance of Scientific Literacy of the Respondents Exposed to Inquiry-Based Learning (IBL)

Scientific Literacy	Paired Differences				t	df	Sig. (2-tailed)
	Pretest		Posttest				
	M	SD	M	SD			
Critical Thinking	7.78	2.72	9.09	2.29	-2.246	31	0.032
Creativity	6.00	2.48	8.16	2.87	-3.267	31	0.003
Collaboration	5.56	1.83	8.19	2.15	-4.981	31	0.000

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Legend: p>.05- Not Significant; p<.05- Significant

Table 8 displays the paired sample t-test results comparing pretest and posttest scores of scientific literacies for Grade 9 students exposed to Inquiry-Based Learning (IBL), assessed across critical thinking, creativity, and collaboration domains.

These results echo findings by Adnan et al. (2021) and Kılıç et al. (2022), who documented positive effects of IBL on critical thinking through active engagement in scientific inquiry. Gholam (2019) and Liu et al. (2022) similarly highlighted IBL's capacity to foster creativity and problem-solving skills. The robust increase in collaboration aligns with Erturk and Kaptan (2022) and Nyakiti et al. (2022), who identified teamwork as a key outcome of inquiry-based strategies.

While Rivera (2020) cautions that IBL effectiveness depends on teacher readiness and resources, the present study's positive results underscore that when properly implemented, IBL can significantly elevate students' scientific literacy across multiple domains.

Table 9

Test of Difference on the Active Learning Engagement of the Respondents Exposed to Problem Based Learning (PBL)

Level of Engagement	Paired Difference				t	df	Sig. (2 tailed)
	Before		After				
	M	SD	M	SD			
Interest	2.14	0.16	3.34	0.64	10.144	31	.000
Interaction	2.31	0.26	3.37	0.56	11.005	31	.000
Active Cognitive Processes	2.34	0.31	3.17	0.57	7.168	31	.000

Legend: p>.05- Not Significant; p<.05- Significant

Table 9 illustrates the test of significant difference in the posttest performance of Grade 9 students in the Problem-Based Learning (PBL) group, focusing on three dimensions of active learning engagement such as interest, interaction, and active cognitive processes. A paired samples t-test was used to determine whether the differences between pretest and posttest scores were statistically significant, using an alpha level of .05.

The result implies that students in the PBL group are capable of demonstrating increased interest in learning tasks, engaging more meaningfully with peers and instructors, and applying active cognitive strategies such as analyzing, evaluating, and synthesizing information. Their ability to interact and participate suggests improved communication and collaboration skills, while their cognitive engagement reflects a readiness to think critically and independently when solving problems or exploring new ideas.

In line with the current study's findings, Khasanah et al. (2022) and Sihombing et al. (2022) highlight the development of critical thinking and self-confidence through PBL, reinforcing the observed improvement in active cognitive processes. Furthermore, Caramay and Ortega-Dela Cruz (2023) reported that PBL leads to significant learning gains, particularly in science education, and this was mirrored by the substantial increase in cognitive engagement measured in this study. The findings of this study contrast with some studies, such as those by Beichner et al. (2022), who report challenges in implementing PBL due to time and resource constraints, suggesting that while the approach is effective, its successful adoption requires careful consideration of these barriers.

Table 10

Test of Difference on Active Learning Engagement of Respondents Exposed to Inquiry Based Learning (IBL)

Level of Engagement	Paired Difference				t	df	Sig. (2 tailed)
	Before		After				
	M	SD	M	SD			
Interest	2.14	0.16	3.28	0.6	10.689	31	.000
Interaction	2.36	0.23	3.32	0.57	7.889	31	.000
Active Cognitive Processes	2.35	0.27	3.06	0.56	6.727	31	.000

Legend: p>.05- Not Significant; p<.05- Significant

Table 10 presents the results of a paired samples t-test that assessed the effectiveness of Inquiry-Based Learning (IBL) on the posttest performance of Grade 9 students across three dimensions of active learning engagement such as interest, interaction, and active cognitive processes. The test examined whether there were statistically significant differences between the students' pretest and posttest scores, using an alpha level of .05.

The significant improvements in the pretest and posttest scores of the Inquiry-Based Learning (IBL) group can be attributed to the student-centered, exploratory nature of IBL that actively engages learners in constructing their own knowledge through questioning, investigation, and reflection. The substantial gains in interest suggest that IBL successfully ignited students' curiosity and motivation by encouraging them to take an active role in their learning process, transforming science lessons into meaningful discovery experiences rather than passive information reception. The enhanced interaction scores reflect how IBL fosters collaborative learning environments where students share ideas, challenge assumptions, and co-construct knowledge through dialogue with peers and teachers. This social engagement is crucial for deepening understanding and building communication skills. Furthermore, the notable increase in active cognitive processes indicates that IBL stimulates higher-order thinking by requiring students to analyze data, formulate hypotheses, and draw evidence-based conclusions throughout inquiry cycles. Through IBL, students were not simply learning definitions or memorizing facts, instead they were challenged to engage deeply with scientific content by actively exploring key questions. Personal observations during the intervention revealed students' growing confidence in asking questions, designing experiments, and synthesizing findings, which likely contributed to these cognitive gains.

According to Adnan et al. (2021) and Gholam (2019), inquiry-based approaches significantly enhance students' interest and critical thinking abilities, aligning with the observed increase in interest and active cognitive processes in this study. Kılıç et al. (2022) and Maknun (2020) also highlight that IBL fosters better conceptual understanding and critical thinking, which corresponds with the improvements in cognitive engagement measured in the posttest results. Moreover, Santos and Boyon (2020) found that inquiry-based learning can effectively boost students' knowledge and engagement, mirroring the significant increases in both interest and interaction in the current study. Similarly, the findings of Liu et al. (2022) and Ichsan et al. (2023) suggest that IBL encourages active participation and collaborative learning, which is evident in the significant rise in interaction among students in this study. Furthermore, Suyatmo et al. (2023) and Kesici (2022) noted that IBL, especially when integrated with technology, fosters deeper cognitive engagement, creativity, and independent learning, supporting the significant changes observed in the active cognitive processes dimension.

Table 11

Test of Difference on the Posttest Scores Performance in Scientific Literacy of Two Groups of Respondents

		M	SD	t	df	Sig. (2-tailed)
Critical Thinking	PBL	8.75	3.48	-0.466	53.599	0.643
	IBL	9.09	2.29			
Creativity	PBL	8.16	3.86	0.000	57.290	1.000
	IBL	8.16	2.87			
Collaboration	PBL	8.09	3.99	-0.117	47.584	0.907
	IBL	8.19	2.15			

Legend: p>.05- Not Significant; p<.05- Significant

Table 11 discusses the outcomes of the study, emphasizing the impact of research-based instruction on the two learning groups. This section reflects on how these approaches contributed to the development of key 21st-century competencies such as critical thinking, creativity and collaboration. Based on the test of difference in the performance on the post-assessment between the PBL and IBL groups, the results revealed no significant differences in the students' critical thinking, creativity, and collaboration skills according to the research-based instruction they received. This implies that both instructional approaches provided similar opportunities for learners to demonstrate the targeted competencies in scientific literacy. Whether engaged through PBL or IBL, students were able to articulate ideas, engage in creative thinking, and collaborate effectively during the assessment tasks. Since the differences were statistically insignificant, the hypothesis stating that there is no significant difference in the performance between the two groups is sustained. This suggests that either approach can be considered equally viable for enhancing performance in key scientific literacy domains.

Both strategies placed a strong emphasis on peer interaction and group problem-solving when it came to collaboration. Students collaborated in groups, exchanged ideas, and helped one another learn, whether through cooperative project work in PBL or collaborative research in IBL. The same results here demonstrate how well both approaches work to create cooperative learning settings where students actively participate in group projects and gain knowledge through social interaction. All things considered, these results demonstrate that PBL and IBL are both successful teaching strategies for raising scientific literacy in science classes in middle schools. A strong framework for assisting students in acquiring not only knowledge but also the abilities required to think critically, work cooperatively, and creatively express ideas in the context of scientific research is provided by their shared emphasis on student autonomy, real-world applicability, and active inquiry.

For instance, Chengay (2023) found no significant difference in student performance between IBL and traditional methods, suggesting comparable effectiveness of different instructional approaches. Similarly, Saldo and Walag (2020) observed no notable differences in communication and collaboration skills between PBL and other student-centered methods, indicating that both PBL and IBL can provide similar opportunities for skill development. Kılıç et al. (2022), Maknun (2020), and Santos and Boyon (2020) also highlighted the positive impact of IBL on critical thinking and knowledge acquisition, aligning with findings that PBL fosters similar competencies (Tu, 2022).

Conversely, some studies suggest that PBL may have advantages; Halimah et al. (2023) emphasized the significant impact of PBL on conceptual understanding and critical thinking, while Hou and An (2023) reported that PBL students often outperform those in traditional classes. Aguila and Ricafort (2023) and Farooqi (2020) highlighted the strong benefits of IBL in science and mathematics achievement, respectively. Variability in PBL effectiveness depending on teacher implementation was also noted (Caramay & Ortega-Dela Cruz, 2023).

CONCLUSIONS

Based on the findings, the researcher has drawn the following conclusions:

The implementation of research-based instruction, specifically through Problem-Based Learning (PBL) and Inquiry-Based Learning (IBL), enhanced the active learning engagement of Grade 9 students. This improvement was evident in the increased levels of student interest, interaction, and active cognitive processes, indicating that both instructional approaches effectively engaged students in the learning process. Both PBL and IBL methods are effective in improving students' scientific literacy; however, the approaches tend to emphasize different domains of learning. While PBL showed stronger gains in creativity and collaboration, IBL demonstrated a more pronounced impact on critical thinking. This suggests that each instructional strategy complements different facets of scientific literacy and could be integrated strategically for comprehensive development. Since both PBL and IBL improved students' scientific literacy across most indicators, the exception being the lack of significant improvement in critical thinking for the PBL group, these results highlight the particular strength of IBL in fostering higher-order cognitive skills. The especially strong positive impact of IBL across all domains implies that inquiry-based approaches may better support critical thinking development alongside creativity and collaboration. The result shows that there is a significant difference found in the pre and post assessment on the active learning engagement of

Grade 9 students for both of the PBL and IBL group as to their interest, interaction and active cognitive process. Thus, the null hypothesis is not sustained. The study concludes that there is a significant difference in the pre- and post-assessment performance of the two groups of students in their scientific literacy except for the PBL group in terms of critical thinking. Thus, the null hypothesis is partially not sustained. Furthermore, there is a significant difference in the post-assessment performance of the two groups regarding their scientific literacy. Therefore, the null hypothesis tested in the study is not supported. The results revealed no significant differences in the students' critical thinking, creativity, and collaboration skills to the post-assessment of the students regardless of the research-based instruction they received. This implies that both instructional approaches provided similar development for learners to demonstrate the targeted competencies in scientific literacy.

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DECLARATION OF CONFLICT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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