

# Digital Literacy in Web-Based Collaborative Inquiry Learning on the Critical and Scientific Thinking Skills of Grade 10 Students

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## Abstract

This study determined the influence of digital literacy and web-based collaborative inquiry learning on the critical and scientific thinking skills of Grade 10 students. It specifically examined students' level of digital literacy, the changes in thinking skills before and after exposure to scaffolding and case-analysis strategies, the relationship between digital literacy and thinking skills, and the differences between the two approaches. A quasi-experimental research design utilizing the non-equivalent pretest–posttest control group design to determine the influence of Digital Literacy and Web-Based Collaborative Inquiry Learning (WCIL) on the Critical and Scientific Thinking Skills of Grade 10 students. Results showed that students demonstrated high to very high digital literacy across all domains. Significant improvements were observed in critical and scientific thinking skills after the intervention, particularly in problem identification, hypothesis formulation, data interpretation, evaluation and reflection, and creative thinking. However, reasoned decision-making under case analysis did not show a significant difference. A limited but significant relationship was found between selected digital literacy skills and thinking skills, particularly in media analysis and access to information. No significant difference was found between the posttest results of scaffolding and case-analysis groups. The study concludes that integrating digital literacy with inquiry-based learning effectively enhances students' higher-order thinking skills.

*Keywords:* Web-Based Collaborative Inquiry Learning (WCIL); Critical and Scientific Thinking; Scaffolding; Case Analysis

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## 1. Introduction

The rapid advancement of technology continues to reshape education worldwide, fundamentally transforming how students learn, particularly in science education. Contemporary learners are expected not only to acquire disciplinary content knowledge but also to develop the capacity to think critically, reason scientifically, and apply their understanding to complex, real-world problems. In response to these evolving demands, educational systems globally have shifted their emphasis toward cultivating higher-order thinking skills alongside digital competence as essential outcomes of 21st-century learning.

In the Philippine context, the Department of Education (DepEd) has articulated this vision through the MATATAG Curriculum (2023), which emphasizes that science instruction must actively cultivate scientific literacy, reasoning, and critical thinking through inquiry-based and technology-integrated pedagogical approaches. Within the Philippine setting, the Department of Education (DepEd) has advocated this vision within the MATATAG Curriculum (2023) that promotes teaching of science by intentionally fostering scientific literacy, reasoning, critical thinking and problem solving through inquiry-based and technology-enriched pedagogical strategies.

This curriculum aligns with the national objective of preparing Filipino learners in the 21st century critical thinking, collaboration, creativity and communication, essential competencies for achieving success in an ever further digitalized global society. Digital literacy is now a core competency, providing opportunity for learning and learning in every discipline in this digital age. Digital literacy includes learners' capacity to access, critically assess, ethically work with, and purposefully produce information through digital technologies in responsible and contextually appropriate ways.

The research evidence from the field points to digital literacy as a facilitator of academic success, a source of problem-solving, and a skill for higher order thinking. Zhao et al. (2022) found that technologically literate learners have significantly better analytical and evaluative skills by interacting with scientific information that is mediated by technology. Likewise, Jamaludin and Hung (2021) reported that digital literacy significantly increases pupils' ability to interpret difficult data and rely on evidence-based decisions within the context of online science inquiry. Luna and Punzalan (2023) noted in Philippine educational settings that meaningful incorporation of digital platforms in science classrooms fosters learner autonomy, co-constructs knowledge and deepens concepts which are critical ingredients in the formation of critical scientific thinking. These results highlight the potential of digital literacy as a transformative tool when applied strategically within the science pedagogical strategy.

Large-scale international studies provide compelling evidence about the importance of digital literacy, and its impact on student academic success. Comprehensive analyses of PISA 2018 and 2022 findings reveal that students' confidence with and intentions of using information and communication technology (ICT), including for structured learning tasks, are strongly related to achievement in scientific literacy. But these studies also highlight an important caveat that general, unstructured or recreational use of ICT does not automatically equate to enhanced academic outcome. Good learning outcomes are rather, best seen when digital resources are purposefully integrated into well-thought-out pedagogical methods that actively encourage inquiry, collaboration, critical evaluation, critique, and metacognitive reflection. Notwithstanding such understandings and the widely acknowledged importance of digital proficiency, Filipino students are generally weaker than students in the international setting in their performance in terms of scientific reasoning and literacy, as indicated by the recent PISA findings (OECD, 2023).

This persistent gap reveals an unmet need for innovative, evidence-based teaching strategies integrating digital literacy development with science instruction, that is, one that addresses science instruction rather than simply deploying technology as an add-on or delivery mechanism. Web-based collaborative inquiry learning represents one of the most promising avenues towards addressing this challenge, as it combines inquiry-based pedagogy with digital collaboration through collaborative tools and platforms. For instance, this method allows learners to approach real-world scientific problems, examine various data sources, engage in open-ended information sharing and critical evaluation with peers, and build knowledge around online experiences in collaboration. Web inquiry-focused environments are particularly well suited for inquiry based learning processes based on the very foundation of active learning, in fact, and are quite well-aligned with constructivist learning beliefs, in which deep learning is co-constructed through interaction, guided investigation, and reflection (through sustained interaction and thought-taking, rather than absorbing learning information passively).

Research demonstrates that technology - enhanced inquiry spaces with this approach are most effective when pedagogy is matched and students have sufficient core digital skills to be able to navigate, assess and produce within these spaces. The efficacy of web-based inquiry learning, for more than a question of technology, turns on students' use of digital tools in such a strategic, critical way that the inquiry is the product of scientific reasoning. Web-based collaborative inquiry learning is not without a number of popular pedagogically sound strategies: in these methods, scaffolding and case analysis take place. Scaffolding involves providing structured, adaptive support through prompts, frameworks, modeling and formative

feedback that gradually guide students from basic understanding of ideas in class to ever more sophisticated reasoning and independent inquiry (Hmelo-Silver et al., 2021). This strategy is in support of students in forming testable hypotheses, designing investigations, analyzing empirical evidence, appraising how good the evidence is and constructing coherent scientific explanations. Scaffolding is especially beneficial for enhancing metacognitive awareness and self-regulation of inquiry processes. Conversely, case analysis allows students to explore authentic real-world or socio-scientific examples — scenarios that demand critical assessment, argumentation grounded in evidence, analysis through multiple lenses, and reasonableness (Fauzi et al., 2021). Case-based learning places scientific findings and concepts in meaningful contexts and promotes applying disciplinary knowledge to complex problems familiar to scientists and informed citizens alike. Both strategies demonstrate DepEd's focus on integrated, inquiry-based science learning and proactively invite students to fill in the gap between the learning experience taught in a classroom and authentic science practice.

Critical and scientific thinking skills such as identifying and creating problems, hypothesis and testing, systematic interpretation of data, critical appraisal of evidence and claims, logical decision making, and flexibility cognitively are essential for the building of scientifically literate citizens, with skills to operate effectively in an escalating and fragmented system of information. These interrelated skills as defined by Krell (2022) are central in the critical assessment of information claims and constructing coherent, evidence-based explanations based on disciplinary practices. Zhou et al. (2023) also reported that digitally mediated inquiry tasks can significantly develop scientific reasoning by facilitating learners to iteratively prove out ideas, review findings with peers, and systematically revise explanations through peer dialogue and feedback. Other local empirical research also finds that it is inquiry-based and technology-supported teaching methods that substantially better scientific higher-order thinking and reasoning skills in Filipino students (Rogayan and Albino, 2021). These converging findings indicate that the strategic inclusion of digital literacy development initiatives in systematic inquiry methodology could provide hope for improving science learning in the Philippine classroom. With these theoretical underpinnings and empirical implications, this study attempts to examine the effect of digital literacy and web-based collaborative inquiry learning in terms of scaffolding and case analysis strategies on Grade 10 critical thinking and scientific thinking skills. The study addresses the following: (1) assesses the connection between students' levels of digital literacy with their scientific reasoning and analysis skills; (2) assesses whether there is a strong positive association between students' critical and scientific thinking skills before and after using the two inquiry approaches, while (3) compare the relative impact of scaffolding and case analysis on students' critical and scientific reasoning in higher order thinking.

Integrating structured web-based inquiry approaches with digital literacy development, this research is both an extension and an intervention within the long-term aspirations of the MATATAG Curriculum that centers around preparing scientifically literate, critically thinking, and digitally competent learners who are upskilled for the requirements of modern-day citizenship and future professions. The results of this study likely are valuable and substantiated for science educators, school administrators, curriculum leaders, and policy makers in planning and designing effective technology supported instructional methods that truly foster higher order thinking skills and support the nation vision of quality, inclusive, relevant and future-ready education for all Filipino learners.

## **2. Objectives of the Study**

This study aimed to determine the influence of digital literacy in web-based collaborative inquiry learning on the critical and scientific thinking skills of Grade 10 students. Specifically, it examined the students' level of digital literacy in terms of access and evaluation of information, utilization and management of information, media analysis, creation of media products, effective application of technology, and interaction through technologies. It also determined the level of critical and scientific thinking skills before

and after exposure to web-based collaborative inquiry learning strategies, particularly scaffolding and case analysis, in terms of problem identification, hypothesis formulation, data interpretation, reasoned decision-making, evaluation and reflection, and creative and flexible thinking. Furthermore, the study investigated the relationship between digital literacy and critical and scientific thinking skills, as well as the significant differences in students' critical and scientific thinking skills before and after the implementation of the two web-based collaborative inquiry learning strategies.

### **3. Methodology**

This study used a quasi-experimental pretest–post-test research design to determine the influence of digital literacy and Web-Based Collaborative Inquiry Learning (WCIL) on the critical and scientific thinking skills of Grade 10 students at Dapdap Integrated School during the School Year 2025–2026. Two intact Grade 10 classes participated in the study: one group was exposed to a scaffolding-based WCIL strategy, while the other used a case analysis-based WCIL strategy. Both groups studied the same Grade 10 Science Quarter 4 lessons and were handled by the same teacher to ensure consistency in instruction. Since random assignment was not possible, cluster sampling was used. A total of 74 students participated, with 38 students in the scaffolding group and 36 students in the case analysis group. Ethical considerations such as informed consent, confidentiality, and voluntary participation were strictly observed.

The study utilized three main research instruments: a Digital Literacy Survey Questionnaire adapted from Baterna et al. (2020), a researcher-made Critical and Scientific Thinking Skills Test based on the framework of Krell (2022), and lesson implementation plans for the two WCIL strategies. The digital literacy questionnaire measured students' skills in accessing, evaluating, managing, and creating information using technology, while the thinking skills test assessed problem identification, hypothesis formulation, data interpretation, decision-making, evaluation, and creative thinking. All instruments underwent validation and reliability testing before implementation.

Data gathering was conducted in three phases: pre-implementation, implementation, and post-implementation. During the pre-implementation phase, students answered the digital literacy survey and took a pretest on critical and scientific thinking skills. In the implementation phase, the two WCIL strategies were carried out for two weeks using collaborative online activities through Google Docs and mobile devices. The scaffolding group received guided support and feedback from the teacher, while the case analysis group explored and solved real-world scientific problems collaboratively. After the intervention, students took a post-test to measure improvement in their critical and scientific thinking skills.

To analyze the data, the researcher used weighted mean and standard deviation to determine students' digital literacy and thinking skill levels. Pearson Product-Moment Correlation was applied to identify the relationship between digital literacy and critical and scientific thinking skills. Paired sample t-tests were used to determine significant differences between pretest and post-test scores within each group, while independent samples t-tests were used to compare the post-test performance of the two groups and determine which WCIL strategy was more effective.

### **4. Results and Discussion**

This presents, analyzes, and interprets the data gathered that showed the influence of digital literacy and web-based collaborative inquiry learning on the critical and scientific thinking skills of Grade 10 students.

Table 1. Level of Digital Literacy as to Access and Evaluation of Information

Indicators	Scaffolding			Case-Analysis		
	Mean	SD	VI	Mean	SD	VI
1. Access scientific information efficiently using appropriate and credible sources.	3.33	0.63	HDL	3.16	0.59	HDL
2. Critically evaluate the accuracy and reliability of scientific information.	3.36	0.54	HDL	3.16	0.59	HDL
3. Identify and use trusted and credible science websites and databases.	3.44	0.56	HDL	3.39	0.55	HDL
4. Recognize online risks and threats and protect personal devices	3.36	0.64	HDL	3.13	0.66	HDL
5. Share verified science-related news and resources responsibly.	3.50	0.56	VHDL	3.24	0.54	HDL
<b>Overall</b>	<b>3.40</b>	<b>0.37</b>	<b>HDL</b>	<b>3.22</b>	<b>0.39</b>	<b>HDL</b>

**Legend:** 3.50-4.00 Very High Digital Literacy (VHDL); 2.50-3.49 High Digital Literacy (HDL); 1.50-2.49 Low Digital Literacy (LDL); 1.00-1.49 Very Low Digital Literacy (VLDL)

Table 1 presents the level of students' Digital Literacy in terms of access and evaluation of information prior to the implementation of scaffolding and case-analysis approaches. The results show that students demonstrated High Digital Literacy (HDL) overall, as reflected in the mean scores of 3.40 (SD = 0.37) for scaffolding and 3.22 (SD = 0.39) for case-analysis, with both falling within the HDL range.

The results indicate that students already have the cognitive capacity to search for, select and evaluate digital resources in terms of their reliability, accuracy, relevance, and credibility for academic purposes and research purposes. Students effectively accessed scientific information from sources that were suitable and reliable, recognized trusted science websites and databases, evaluated the accuracy of scientific information, identified the risks and threats in online resources and responsibly shared verified science information. The average mean score on sharing verified science-related news or resources is greater, which means students were more likely to display responsible digital habits while managing science information. But the lower average scores in assessing reliability and assessing online risks also signal that students still have to be continually encouraged to evaluate digital information critically, and to practice safety in online platforms.

This was attributed to students' immersion into digital environments and e-learning where they often research, retrieve and engage scientific information. As noted by Sari et al. (2023), the inclusion of digital equipment (e.g., e-modules and simulations) facilitates the practice of identifying and analyzing information from disparate web-based sources for students. But also (as Son and Ha, 2024) the exposure towards digital information itself is incomplete unless the students were guided in evaluating credibility and trust of the scientific content. Fajardo (2023) also stressed the importance of information literacy competences, especially in source evaluation and content analysis, for learners to discriminate between trustworthy content, misinformation, and problematic content online.

These findings emphasize the importance of strengthening students' ability not only to access scientific information but also to critically evaluate the credibility, accuracy, relevance, and reliability of digital content. In science education, the ability to assess information accurately and responsibly is essential for informed decision-making, scientific understanding, and responsible participation in digital environments. This supports the need for educational practices that promote critical engagement with online information and responsible digital citizenship within inquiry-based and technology-supported learning environments (Mulyani et al., 2023).

Table 2. Level of Digital Literacy as to Utilization and Management of Information

Indicators	Scaffolding			Case-Analysis		
	Mean	SD	VI	Mean	SD	VI
1. Use scientific information accurately and creatively to address current issues and problems.	3.58	0.55	VHDL	3.39	0.68	HDL
2. Organize and manage scientific information from different sources.	3.25	0.69	HDL	3.32	0.70	HDL
3. Follow ethical and legal guidelines when accessing and using information.	3.50	0.56	VHDL	3.34	0.71	HDL
4. Store and retrieve scientific files and data efficiently.	3.39	0.49	HDL	3.21	0.62	HDL
5. Share useful scientific information with proper acknowledgment of sources.	3.44	0.56	HDL	3.26	0.64	HDL
<b>Overall</b>	<b>3.43</b>	<b>0.34</b>	<b>HDL</b>	<b>3.31</b>	<b>0.49</b>	<b>HDL</b>

**Legend:** 3.50-4.00 Very High Digital Literacy (VHDL); 2.50-3.49 High Digital Literacy (HDL); 1.50-2.49 Low Digital Literacy (LDL); 1.00-1.49 Very Low Digital Literacy (VLDL)

Table 2 presents the level of students' Digital Literacy in terms of utilization and management of scientific information prior to the implementation of scaffolding and case-analysis approaches. The results reveal an overall High Digital Literacy (HDL) for both groups, with mean scores of 3.43 (SD = 0.34) for scaffolding and 3.31 (SD = 0.49). Data evidence further shows that two indicators using scientific information accurately and creatively (M = 3.58) and following ethical and legal guidelines (M = 3.50) reached Very High Digital Literacy (VHDL) under scaffolding, while all other indicators remained within the HDL range in both groups.

This indicates that students already have the ability to appropriately and efficiently organize, store, retrieve, evaluate and utilize digital information in an academic situation. Students were competent in the accurate and creative usage of scientific information, ethical and legal guidelines in the handling of scientific information, and digital content management for academic purposes. Based on this result, students are already familiar with the responsible use of digital scientific information and its proper use in learning tasks. Yet, the lower scores of organizations and retrieval of information hint that some students struggle with ordering and managing digital data in a systematic and efficient way, especially if the data were very large or previous information was to be found. This means that instruction in the sciences must not only be about reaching information but also about students acquiring information systematically and responsibly organized, retrieved, appraised, and used. Enhancing these tools plays a crucial role in enabling students better to handle scientific information, to complete academic work effectively, and to participate responsibly in digital learning contexts.

These findings emphasize the need to embed practices that promote information management, ethical use of digital content and responsible use of scientific information into both inquiry-based and technology-supported science teaching. This is due to the students' frequent experience with digital technologies and online learning spaces in which they are routinely searching, accessing, using, and sharing scientific information. Students acquire skills to manage information in multiple formats through digital tools, mobile devices, and online resources. But regular exposure in and of itself does not guarantee effective arrangement and management of information. According to Maya and Suseno (2022) and Prachagool et al. (2022), structured instructional strategies are necessary to enhance learners' ability to systematically organize, retrieve, and utilize digital information efficiently. Moreover, Georgopoulou et al. (2025) highlighted that though students know about ethical rules and review standards, they need support to apply them regularly within increasing sophistication of academia and digital environments.

Table 3. Level of Digital Literacy as to Media Analysis

Indicators	Scaffolding			Case-Analysis		
	Mean	SD	VI	Mean	SD	VI
1. Understand how and why media messages about science are created.	3.50	0.56	VHDL	3.47	0.56	HDL
2. Recognize that people may interpret scientific media messages differently.	3.36	0.64	HDL	3.50	0.60	VHDL
3. Identify values, viewpoints, or biases included or excluded in media content.	3.47	0.56	HDL	3.32	0.57	HDL
4. Explain how media influences beliefs and behaviors about science and technology.	3.42	0.65	HDL	3.47	0.65	HDL
5. Apply ethical and legal principles when analyzing or sharing media content.	3.39	0.55	HDL	3.37	0.67	HDL
Overall	<b>3.43</b>	<b>0.36</b>	<b>HDL</b>	<b>3.43</b>	<b>0.41</b>	<b>HDL</b>

**Legend:** 3.50-4.00 Very High Digital Literacy (VHDL); 2.50-3.49 High Digital Literacy (HDL); 1.50-2.49 Low Digital Literacy (LDL); 1.00-1.49 Very Low Digital Literacy (VLDDL)

Table 3 shows students' level of Digital Literacy for media analysis prior to the implementation of scaffolding and case-analysis approaches, indicating that all students scored a high HDL with the same average score at 3.43 (SD = 0.36; 0.41). With consistently high mean scores on all indicators. The results indicate that Grade 10 learners already had the ability to critically examine, interpret, compare, and evaluate scientific messages, visual representations, and information presented through digital and multimedia formats, such as YouTube science demonstrations, animated simulations, digital graphs, infographic presentations, websites, online articles, and multimedia slides. This indicates that students were capable of determining the accuracy, reliability, relevance, and evidence-based meaning of scientific information presented through various digital media platforms. With consistently high mean scores across all indicators, learners were able to interpret how scientific media messages are constructed, recognize and compare competing content, identify biases, understand media influence, and apply ethical principles when evaluating scientific information.

Comparable findings showed the students' experiences in exploring digital contexts, leading to a more successful interaction with and interpretation of mediated information (Park et al., 2020; Tinmaz et al., 2022). Nonetheless, although students appear competently engaged with media, such higher order skills, including the ability to assess credibility, synthesize contradicting information and apply ethical reasoning in everyday contexts, seem to have less developed (Loos et al., 2018; Mrah, 2022). Here is a contrast between elementary digital competence and higher-value media literacy, which demands explicit and persistent instructional support (Jocius, 2013; Martens and Hobbs, 2015).

These results emphasize the need for an enhancement of scientific media literacy in education, especially in relation to the role of misinformation and biased content in digital spaces. Instruction of students' critical assessment of scientific media, its effects on belief or behavior, is essential for informed judgment and conscientious citizenship (Howell and Brossard, 2021; Osborne and Pimentel, 2023). Research finds further proof that explicit instruction in media analysis and critical evaluation improves students' ability to appraise credibility and apply fact-check strategies (Brodsky et al., 2021). In today's digital environment, students are frequently exposed to misleading scientific information through social media and other online platforms, making it important for schools to strengthen their ability to evaluate information critically. Developing scientific media literacy also helps learners become more responsible users of digital information by teaching them how to identify reliable sources, examine evidence, and avoid being influenced by biased or false claims. Through continuous exposure to inquiry-based and media analysis activities, students can develop stronger critical thinking and scientific reasoning skills that are necessary for making informed decisions in everyday life.

Table 4. Level of Digital Literacy as to Creation of Media Products

Indicators	Scaffolding			Case-Analysis		
	Mean	SD	VI	Mean	SD	VI
1. Use appropriate digital tools to create science reports and projects.	3.64	0.54	VHDL	3.34	0.63	HDL
2. Communicate scientific ideas clearly in diverse and multicultural settings.	3.58	0.50	VHDL	3.18	0.51	HDL
3. Create science-related content in various formats (e.g., video, infographic, presentation).	3.44	0.61	HDL	3.26	0.55	HDL
4. Express scientific ideas creatively using digital technologies.	3.56	0.56	VHDL	3.18	0.61	HDL
5. Modify and combine existing digital resources to create original science content while observing ethical standards.	3.39	0.60	HDL	3.05	0.70	HDL
Overall	3.52	0.34	VHDL	3.21	0.37	HDL

Legend: 3.50-4.00 Very High Digital Literacy (VHDL); 2.50-3.49 High Digital Literacy (HDL); 1.50-2.49 Low Digital Literacy (LDL); 1.00-1.49 Very Low Digital Literacy (VLDL)

Table 4 shows the Digital Literacy of the students as far as Creation of Media Products, giving an overall Very High Digital Literacy (VHDL) for scaffolding ( $M = 3.52$ ,  $SD = 0.34$ ) and High Digital Literacy (HDL) for case-analysis ( $M = 3.21$ ,  $SD = 0.37$ ). The results suggest that students have the skills to design, create, and deliver digital material and multimedia outputs that communicate scientific information, concepts, and ideas to a preferred audience. This high results across all the survey also indicates that students have a high degree of ability to use digital tools, explain scientific ideas, develop multimedia content, creatively convey ideas, and ethically modify digital resources. The greater ability credited to students' familiarity with digital tools and platforms, active participation in content creation such as video and presentation, technological integration in classroom activities, and continuous input on digital media have contributed to a strong foundation in digital storytelling and scientific communication amongst students. Students already appear to be good at producing and presenting scientific content in some digital technologies.

However, slightly lower scores on modifying and combining digital resources suggest that higher-order, creative and integrative skills still need further development. This may be because students regularly engage in digital media production, generating and sharing media, thereby developing the skills necessary for digital content creation. Reflexively, as asserted by Hobbs and Jensen (2009) and Reyna and Meier (2020), learners' motivation toward self-expression and engagement in social settings increases how well they can be digital producers. Furthermore, iteration in designing, making and improving digital products can enhance their knowledge of how media is structured, audience communication interaction and ethical considerations in media (Veronika et al., 2023; Mulyani et al., 2023).

These results underscore the need for the creation of media, a central part of the education curriculum in science since students will have to effectively communicate complicated scientific ideas in such a setting. Creating and sharing scientific content facilitates deeper engagement, critical thought, and active engagement in scientific discourse. Research also indicates active media production makes students "prosumers" and this leads to improvements in concepts learning and communicative skills (Rasi and Poikela, 2016; Vodă et al., 2022). In addition, these multimedia products tasks enable creating tasks for science instruction and promoting multimedia applications in science teaching promotes creativity, cooperation, and critical thinking that are important skills for learners to successfully navigate the 21st-century digital realm (Ijiga et al., 2021; Wallace and VanderMolen, 2019). Through multimedia activities, students are given opportunities to express their ideas creatively while working collaboratively with their classmates in completing science-related tasks. These activities also encourage learners to become more engaged and active participants in the learning process because they can use digital tools that are familiar and meaningful to them.

Table 5. Level of Digital Literacy as to Effective Application of Technology

Indicators	Scaffolding			Case-Analysis		
	Mean	SD	VI	Mean	SD	VI
1. Use technology to research, organize, evaluate, and communicate scientific information.	3.58	0.60	VHDL	3.42	0.55	HDL
2. Use digital tools and online platforms responsibly for scientific purposes.	3.72	0.51	VHDL	3.50	0.60	VHDL
3. Follow ethical and legal standards in using digital technologies.	3.42	0.69	HDL	3.32	0.62	HDL
4. Use technology to collaborate and co-create scientific knowledge with others.	3.36	0.54	HDL	3.29	0.65	HDL
5. Promote safe and responsible online behavior and respect cultural diversity.	3.56	0.56	VHDL	3.32	0.57	HDL
Overall	<b>3.53</b>	<b>0.38</b>	<b>VHDL</b>	<b>3.37</b>	<b>0.39</b>	<b>HDL</b>

**Legend:** 3.50-4.00 Very High Digital Literacy (VHDL); 2.50-3.49 High Digital Literacy (HDL); 1.50-2.49 Low Digital Literacy (LDL); 1.00-1.49 Very Low Digital Literacy (VLDL)

Table 5 provides students' Digital Literacy as regards effective application of technology: Overall Very High Digital Literacy (VHDL) for scaffolding ( $M = 3.53$ ,  $SD = 0.38$ ) and High Digital Literacy (HDL) for case-analysis ( $M = 3.37$ ,  $SD = 0.39$ ). Results show that students in Grade 10 are very high achievers and capable of managing the use of digital tools, appropriately and safely, for accessing scientific messages, organizing, evaluating and communicating scientific knowledge. The high proficiency level of the students is probably due to them using the smartphones, computers and internet-based tools for academic activities (researching scientific subjects, preparing digital presentations and presenting the results) and using online learning systems. Moreover (and again), the use of the ICT tools in science classes with the provision of multimedia formats such as visual aids and simulation tools and online collaboration groups seems to have improved their capacity to structure, analyze, and communicate information efficiently. Their engagement with social media and technology chat rooms could have strengthened their knowledge and confidence, leading them towards responsible online behavior, digital collaboration, and content sharing. Further, many students are involved in project-based tasks that involve the use of digital technologies: group activities, investigation, and science-related presentations, which may have enhanced their capability of utilizing technology in solving genuine science problems.

The implication is that students are already presented with strong technological competencies, which may be due to exposure and interaction with digital environments. But despite the high results, some dimensions of deeper critical evaluation and the ethical deployment of technology have not been refined as well. This is likely due to the broad application of technology in education, which often gives students access to a number of digital resources as students often interact using technology, but usually without developing higher-level judgment and ethical reasoning abilities. As noted by Cutumisu et al. (2020) and Soufghalem (2024), the inclusion of ICT into curricula enhances students' ability to consider and utilise digital information effectively. Nonetheless explicit instruction is essential to enhance students' critical and ethical use of technology (Son & Ha, 2024). The results emphasize the significance of digital literacy for assisting learners to face more challenging digital technologies and evaluate scientific information and misinformation (Fausan et al., 2021). The students are at a high level of skill in the use of technology, indicating that there is a tendency in digital literacy to involve critical thinking and to consider ethical uses of technology as well as responsible communication (Hussain & Phulpoto, 2024; Zulkarnain et al., 2024). Additionally, as the digital technologies progress, these skills are becoming more and more crucial in both education and future professions that depend on accurate information handling, solving problems and good ethical behaviour in electronic mediums (Dašić et al., 2024).

Table 6. Level of Digital Literacy as to Interaction through Technologies

Indicators	Scaffolding			Case-Analysis		
	Mean	SD	VI	Mean	SD	VI
1. Communicate using various digital devices and applications.	3.50	0.61	VHDL	3.34	0.75	HDL
2. Understand how digital communication is shared and managed in scientific contexts.	3.36	0.64	HDL	3.32	0.62	HDL
3. Use appropriate digital communication etiquette in academic settings.	3.36	0.68	HDL	3.05	0.46	HDL
4. Adjust communication style based on the target audience.	3.53	0.61	VHDL	3.26	0.45	HDL
5. Apply proper citation practices and integrate new information into existing scientific knowledge.	3.61	0.49	VHDL	3.05	0.73	HDL
Overall	<b>3.47</b>	<b>0.39</b>	<b>HDL</b>	<b>3.21</b>	<b>0.40</b>	<b>HDL</b>

**Legend:** 3.50-4.00 Very High Digital Literacy (VHDL); 2.50-3.49 High Digital Literacy (HDL); 1.50-2.49 Low Digital Literacy (LDL); 1.00-1.49 Very Low Digital Literacy (VLDL)

Table 6 shows Digital Literacy of students regarding interaction through technologies and findings on the overall High Digital Literacy (HDL) for scaffolding ( $M = 3.47$ ,  $SD = 0.39$ ) and High Digital Literacy (HDL) for case-analysis ( $M = 3.21$ ,  $SD = 0.40$ ). As a result, the findings show that students are able to communicate, collaborate, and exchange information and ideas through digital platforms and technological tools in both academic and educational situations. The high level of results could depend on students' day-to-day utilization of apps used for messaging applications like Messenger and email, learning management systems like Google Classroom, and social media platforms that need incessant digital communication and interaction. Moreover, students often work together in groups, online, through collaborative science activities and group work, sharing ideas, exchanging files, and giving feedback through digital tools. For example, their academic activities such as report writing, presentations, and citation skills are common, they may have increased their communication etiquette, adapt the way they use their language and presentation style to audience and context and integration of information, as well as practice the process of integrating information from sources with an application of language. In addition, the integration of ICT in classroom learning including virtual collaboration and online output generation and submission could have also increased their acquaintance with and experience with the use of digital communication in academic settings appropriately and digitally in the way of communication.

The results indicate that students already know enough about digital communication and collaboration from constant encounter with technology mediated interaction. Nevertheless, their ability to adopt the behavior of communicating etiquette at the same time and to comprehend the complete management of digital communication in scientific and academic settings may still need strengthening. It is expected that students use digital media as communication technology quite often to communicate however are not always taught about academic formal communication and appropriate digital discourse behaviors. These findings point to the need for interaction skills being a key component of the development of digital literacy in a connected and information-rich world. So, beyond technical expertise, effective digital communication implies developing critical, social and ethical skills to interpret, share and respond to information (Martínez-Bravo et al., 2020; Farias-Gaytan et al., 2021). This is in line with the importance of learners analyzing messages for their socio-cultural context in use and adapting suitable communication strategies on all platforms (Aguaded et al., 2022; Akram et al., 2023). Moreover, proficiency in interacting with technology must be used in order to overcome challenges (e.g., misinformation) and encourage constructive engagement in scientific debate and collaborative learning contexts (Ruiz, 2024; Fiordelli et al., 2023).

**Table 7.** Level of Critical and Scientific Thinking Skills as to Problem Identification

Level	Case Analysis				Scaffolding				VI
	Pretest		Posttest		Pretest		Posttest		
	f	%	f	%	f	%	f	%	
4	1	2.6	11	28.9	7	19.4	13	36.1	Advanced
3	18	47.4	20	52.7	17	47.2	17	47.2	Proficient
2	16	42.1	7	18.4	11	30.6	5	13.8	Developing
1	3	7.9	-	-	1	2.7	1	2.6	Emerging
<b>TOTAL</b>	<b>38</b>	<b>100.0</b>	<b>38</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	

*Legend: f=frequency; %=percentage score; 6 points Level 4; 4-5 points Level 3; 2-3 points Level 2 and 0 Level 1*

Table 7 The level of the critical and scientific thinking ability of grade 10 students in terms of problem identification, as the first before and after experiencing the two web-based collaborative inquiry learning approaches: case-analysis and scaffolding. In these study, advanced students were able to recognize, define, and state the main problem, issue or question associated with a scientific situation or scenario. Those at the proficient level could accurately identify scientific problems and explain the problem with minimal help, but certain critical aspects of the analysis still needed to be addressed. Developing level students demonstrated limited acquaintance with scientific issues and were able to identify elementary issues, although they frequently required further assistance in linking concepts and accurately applying interpretations. At the same time, the students at the emerging level faced problems for identifying the science problem and needed considerable support in analyzing scientific problems and finding relevant information.

The above identified skills became apparent when working on lesson activities surrounding Boyle's Law and Charles' Law, especially in engagement and exploration phase where students would use PhET simulations, interpret graphs, and face real issue situations with tire pressures, aerosol cans and hot air balloons. These activities allowed students to identify scientific problems, identify the variables affecting gas behavior, interpret pressure-volume and temperature-volume relationships, and explain observed changes from scientific reasoning. In addition to the step-by-step inquiry tasks and structured worksheets, teacher prompts, discussions, and guided responses also allowed students to systematically break down scientific situations and determine the key scientific issue and/or question in each scientific scenario. With data available in this study, we can see how students' performance levels changed in both groups after being exposed to the strategy. The advanced group saw the group of students in this case-analysis increase from 2.6% to 28.9% at the advanced level, while those in the developing level decreased from 42.1% to 18.4%, with no student remaining in the emerging level. The scaffolding group, which experienced an increase in students at advanced level 19.4% to 36.1%, and those at developing level decreased 30.6% to 13.8%). Both groups of students were posttest proficient level and most of the learners exhibited the ability to read, define scientific problems and apply logic with minimal support.

Higher posttest performance was related to various learning experiences characteristic of Grade 10 students: use of online platforms to access science tasks, experience with teacher-driven prompting/step-by-step methods, participation in collaborative discussions, and access to digital tools, such as PhET simulations. Through these opportunities students can analyze situations closely, identify scientific problems, see the interrelations between variables and can find the principal problem in scientific situations that are shown visually.

The higher posttest performance was further explained by the structure of web-based collaborative inquiry learning. Guided prompts, step-by-step tasks, and collaborative investigation enabled students to recognize, define, and analyze scientific problems logically and systematically. Scaffolding simplified complex tasks into manageable steps, while case-analysis exposed students to authentic and contextualized scientific situations requiring interpretation, reasoning, and evidence-based analysis. Studies support that inquiry-based and collaborative learning enhance reasoning, argumentation, and problem-solving skills (Setyorini et al., 2021; Hendratmoko et al., 2023; Ojetunde and Ramnarain, 2023). Problem identification is considered an important component of scientific literacy because it enables learners to recognize and define real-world scientific issues critically and prepare for more complex scientific investigations. Research further shows that technology-enhanced inquiry learning strengthens critical thinking, conceptual understanding, and scientific reasoning among learners (Sui et al., 2022; Mohammed et al., 2020; Topalsan, 2020).

Table 8. Level of Critical and Scientific Thinking Skills as to Hypothesis Formulation

Level	Case Analysis				Scaffolding				VI
	Pretest		Posttest		Pretest		Posttest		
	f	%	f	%	f	%	f	%	
4	1	2.6	10	26.3	1	2.8	2	5.6	Advanced
3	18	47.4	18	47.4	10	27.8	15	41.7	Proficient
2	15	39.5	8	21.1	18	50	12	33.3	Developing
1	5	10.5	2	5.3	7	19.4	7	19.4	Emerging
<b>TOTAL</b>	<b>38</b>	<b>100.0</b>	<b>38</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	

*Legend: f=frequency; %= percentage score; 6 points Level 4; 4-5 points Level 3; 2-3 points Level 2 and 0 Level 1*

Table 8 presents the level of Grade 10 students' critical and scientific thinking skills as to hypothesis formulation before and after exposure to web-based collaborative inquiry learning using case-analysis and scaffolding. In this study, students classified under the advanced level were able to develop clear, logical, and testable predictions based on scientific concepts, observations, and prior knowledge. Students in the proficient level showed they could form appropriate and testable hypotheses with less guidance, although some explanations were not supported with full justification. In the developing level, students initially had a basic understanding of hypothesis formulation and made basic predictions, but typically needed help determining which variables, and what these variables refer to in a scientific perspective. Meanwhile, they struggled to make logical and testable predictions and needed much help to describe relationships between the variables.

The research shows changes in students' performance levels for both groups after they have had the intervention. In the case-analysis group, students in the advanced level went from 2.6% one student to 26.3% 10 students, while those in the developing level went from 39.5% to 21.1%, and those in the emerging level diminished from 10.5% to 5.3%. In the scaffolding group, students of proficient status increased from 27.8% to 41.7%, and those of developing levels dropped from 50% to 33.3%. The majority of students in the two samples were proficient in the posttest, meaning that many users were able to make well defined and testable predictions with a minimum of extra assistance based on scientific ideas, observations, and understanding.

It is clear in the lesson of Boyle's Law and Charles' Law where students were required to predict prior to doing the experiments and simulations. In the PhET simulations, graph interpreting tasks, and the applications to natural sciences scenarios students identified variable behavior about gas and were able to predict the changing behavior of pressure, temperature, and volume to changes. Guided questions, peer interaction and structured worksheets helped students to build and justify hypotheses in an organized manner. Students

formed connections between their prior scientific knowledge, those they observed, and made predictions that they could test during the learning activities through these questioning activities.

The higher posttest performance was connected with the structure of web-based collaborative inquiry learning, which underlined prediction, observation, testing, and explanation. Guided prompts, step-by-step procedures, collaborative investigation, and interactive simulations enabled students to formulate hypotheses logically and scientifically. Scaffolding activities supported students in identifying variables and organizing their predictions clearly, while case-analysis tasks exposed students to contextualized scientific situations requiring them to explain possible outcomes using evidence and prior knowledge. Studies support that guided inquiry strengthens students' ability to define variables and formulate logical predictions (Gunawan et al., 2019; Efstathiou et al., 2018; Novitra et al., 2021). Furthermore, inquiry-based approaches support students' abilities in predicting outcomes, gathering evidence, and constructing explanations (Sari et al., 2024; Yanto et al., 2019). Technology-enhanced inquiry environments also enable learners to visualize scientific relationships and test predictions, strengthening scientific reasoning and critical thinking skills (Hamed and Aljanazrah, 2020).

Table 9. Level of Critical and Scientific Thinking Skills as to Data Interpretation

Level	Case Analysis				Scaffolding				VI
	Pretest		Posttest		Pretest		Posttest		
	f	%	f	%	f	%	f	%	
4	4	10.5	10	26.3	2	5.6	2	5.6	Advanced
3	22	57.9	20	52.6	16	44.4	24	66.7	Proficient
2	8	21.1	8	21.1	13	36.1	10	27.8	Developing
1	4	10.5	-	0.0	5	13.9	2	5.6	Emerging
<b>TOTAL</b>	<b>38</b>	<b>100.0</b>	<b>38</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	

**Legend:** f=frequency; %=percentage score; 6 points Level 4; 4-5 points Level 3; 2-3 points Level 2 and 0 Level 1

Table 9 presents the level of Grade 10 students' critical and scientific thinking skills as to data interpretation before and after exposure to web-based collaborative inquiry learning using case-analysis and scaffolding. In this study, students classified under the advanced level were able to analyze, organize, and interpret scientific data independently and draw accurate conclusions using evidence and logical reasoning. At the proficient level, students could identify patterns, describe relationships, and interpret data correctly with minimal guidance, although the responses slightly lacked depth and complete analysis. Those at the developing level understood some data interpretation and recognized basic concepts and relationships; however, they often required support to arrange and synthesize information to reach evidence-based conclusions. On the other hand, emerging students struggled to analyze data properly and needed a great deal of assistance to interpret results and link evidence to scientific explanations.

Data evidence reveals differences in the performance levels of students between groups following exposure to the intervention. In the case-analysis group, advanced students improved from 10.5% to 26.3% and emerging students decreased from 10.5% to 0%, indicating that no student remained in the lowest level after completing the posttest. In the scaffolding condition, proficient students increased from 44.4% to 66.7%, developing students decreased from 36.1% to 27.8%, and emerging students decreased from 13.9% to 5.6%. The majority of students in both groups fell within the proficient and advanced levels for the posttest, thus reflecting learners' abilities to analyze, organize, and connect scientific data through evidence and deductive reasoning.

These skills were evident during the Boyle's Law and Charles' Law lesson as students analyzed graphs,

simulation outputs, experimental observations, and tables of findings. Students also understood variation in variables, looked for patterns and trends in data, analyzed results, and interpreted relationships between data and scientific concepts as they explored the PhET simulations, digital graphs, pressure-volume relationships, and temperature-volume investigations. Facilitation of collaborative discussions, structured worksheet assignments, guiding questions, and inquiry tasks supported the students in structuring information systematically and employing evidence to describe scientific observations and claims.

The higher posttest performance was associated with the structure of web-based collaborative inquiry learning, which emphasized investigation, analysis, interpretation, and evidence-based reasoning. Guided inquiry tasks, collaborative discussions, digital tools, and interactive simulations enabled students to examine data carefully, organize information logically, and construct conclusions based on evidence. Scaffolding activities provided step-by-step support in analyzing graphs and interpreting relationships, while case-analysis activities exposed students to contextualized scientific situations requiring interpretation of results and evidence-based explanations. Literature supports that inquiry-based learning strengthens data interpretation skills by promoting analysis, inference, and evaluation (Wale and Bishaw, 2020; Sutiani et al., 2021). Furthermore, simulations and scaffolding tools support learners in interpreting complex information and strengthening critical thinking skills (Aji et al., 2024). Research also shows that structured inquiry and technology integration strengthen students' ability to analyze, interpret, and synthesize scientific information effectively (Al-Kreimeen, 2024).

Table 10. Level of Critical and Scientific Thinking Skills as to Reasoned Decision-Making

Level	Case Analysis				Scaffolding				VI
	Pretest		Posttest		Pretest		Posttest		
	f	%	f	%	f	%	f	%	
4	15	39.5	22	57.9	15	41.7	27	75	Advanced
3	4	10.5	1	2.6	5	13.9	2	5.6	Proficient
2	11	28.9	8	21.1	8	22.2	3	8.3	Developing
1	8	21.1	7	18.4	8	22.3	4	11.1	Emerging
<b>TOTAL</b>	<b>38</b>	<b>100.0</b>	<b>38</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	

Legend: f=frequency; %= percentage score; 4 points Level 4; 3 points Level 3; 2 points Level 2 and 0 Level 1

Table 10 presents the level of Grade 10 students' critical and scientific thinking skills as to reasoned decision-making before and after exposure to the instructional strategies of scaffolding and case analysis within a web-based collaborative learning environment. In this study, students classified under the advanced level were able to make logical and informed conclusions based on scientific evidence, critical analysis, and sound reasoning. They were capable of analyzing scientific situations accurately, evaluating evidence, comparing explanations or solutions, and defending decisions using scientific concepts and observations. Proficient students were able to make better decisions around answers and answer them based on evidence, but many explanations did not provide sufficient analysis or justification. Although developing-level students demonstrated limited understanding and were able to draw basic inferences, they struggled to make consistent links between evidence and scientific reasoning. On the other hand, students in the emerging level struggled to assess evidence and choose scientifically valid conclusions and needed quite a bit of help understanding the context in which they find themselves and defending their answers.

These skills were shown in the various learning activities in the Boyle's Law and Charles' Law lessons. For the Boyle's Law lesson, students did a marshmallow/syringe activity, observing changes in pressure in the marshmallow filling a syringe. Students reviewed what occurred when the plunger was being pushed or pulled, recognized relationships between pressure and volume, interpreted the observations, and selected an

explanation that explained best the phenomenon from the evidence gathered during the activity. Questions (guided like “Why did the marshmallow grow in size?” and “What occurred in response to the increase in pressure?”) inspired students to support their conclusions with scientific reasoning. In the Charles’ Law class, students examined why a hot air balloon expanded and rose with rising temperature. They considered the relationships between temperature and volume using videos, simulated and real-life scenarios with a hot air balloon and how heated air balloons move and why they feel the way they do. Through collaborative discussions and evidence-based questioning, students compared explanations, defended their answers and selected the most scientifically accurate conclusion. In a scaffolding approach, teacher-guided prompts such as “What evidence supports your answer?”, “What variable changed?”, and “How can you put the result in terms of scientific thinking?” allowed students to form their thinking in order.

Based on the data it shows that students’ performance levels in both groups changed after receiving the intervention. On the case-analysis group, advanced levels’ students increased from 39.5% to 57.9%, developing levels decreased from 28.9% to 21.1% and emerging level students decreased from 21.1% to 18.4%. The score of the scaffold students in the advanced level was 41.7%, compared to 22.2% in the developing level, which was reduced to 8.3%, and 22.3% to 11.1% in the emerging level. Both groups’ posttest results also classified most students between proficient and advanced skills so many learners were already able to reach logical and evidence-based conclusions using scientific reasoning with minimal guidance.

Students’ greater performance after the posttest was attributed to the types of scaffolding and case analysis strategies, which involved higher order thinking, evidence-based reasoning, and active analysis by critical actors of scientific situations. Scaffold was used to aid learners by dividing complex tasks into easy-to-follow stages and then structuring them systematically through the reasoning process, while case analysis required participants to explore evidence- and logically- grounded, genuine or real-world scientific scenarios and make decisions. There is literature that argues that guided questioning and real-world problem-solving strategies strengthens decision-making and critical thinking skills (Saekawati and Nasrudin, 2021; Wahyudi et al., 2023; Isdianti et al., 2021).

Table 11. Level of Critical and Scientific Thinking Skills as to Evaluation and Reflection

Level	Case Analysis				Scaffolding				VI
	Pretest		Posttest		Pretest		Posttest		
	f	%	f	%	f	%	f	%	
4	2	5.3	10	26.3	6	16.7	16	44.4	Advanced
3	8	21.1	12	31.6	7	19.4	8	22.2	Proficient
2	9	23.7	12	31.6	9	25.0	7	19.4	Developing
1	19	50	4	10.5	14	38.9	5	13.9	Emerging
<b>TOTAL</b>	<b>38</b>	<b>100.0</b>	<b>38</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	

Legend: f=frequency; %=percentage score; 4 points Level 4; 3 points Level 3; 2 points Level 2 and 0 Level 1

Table 11 illustrates Grade 10 students’ critical and scientific thinking skill levels during evaluation and reflection prior to and following practice with scaffolding and case analysis strategies. In the study, advanced level students have the ability to assess experimental procedures, identify strengths and limitations, and reflect on outcomes in order to improve understanding and future practices. Proficient students were able to critically appraise procedures and findings and to describe pros and cons with little prompting, so some reflections were shallow and superficial. At the developing level, however, students evidenced only partial understandings and reported identifying simple strengths, weaknesses, or mistakes, but required considerable help connecting observations to scientific explanations and reflections. Conversely, emerging level students encountered challenges with accurately assessing evidence, processes, and outcomes, and needed extensive support to make sense of scientific endeavors and interpretations.

The data evidence indicating that both student performance levels were affected by the strategy of both groups. For advanced students from the case-analysis group, it increased from 5.3% to 26.3%, and emerging students dropped from 50% to 10.5%. In the scaffolding condition, students in the advanced level increased from 16.7% to 44.4%, with students in the emerging level decreasing from 38.9% to 13.9%. The proficient level for both groups also increased, suggesting more students were able to appraise scientific procedures already, determine capabilities and limitations and analyze scientific outcomes with evidence and conclusion.

During the Boyle's Law and Charles' Law lesson activities, these skills in practice exceeded through as students analyzed their predictions and compared their experimental observations to the simulation results, evaluating if the evidence they gathered supported what the scientific explanations in the lesson had explained. Students watched pressure-volume and temperature-volume graphs during the PhET simulation activities and observed discrepancies between predictions and experiment output, explaining possible intentions of these inconsistencies. Based on both evidence analysis and graphed interpretation activities, students assessed the data collected with respect to Boyle's Law and Charles' Law and reflected on the influence variables have on findings of data in the graphs. Further, students responded to levels of secondary-level reflective questions such as, "How does the evidence support or contradict your explanation?", "What alternative explanation are you able to make based on the data?", "What would shift if one variable were to be adjusted?", "What issues impacted the validity of your findings?", and "How could the process be enhanced in order to provide more precise scientific evidence?" Group conversations, reflection sheets and teacher directed explanation contributed further to assist students in evaluating scientific process, recognizing limitations, and evidence to reflect for knowledge and reasoning.

The higher posttest performance was associated with the nature of scaffolding and case-analysis strategies, which emphasized evidence evaluation, reflection, and critical examination of scientific procedures and conclusions. Guided prompts, reflection questions, collaborative discussions, and inquiry-based tasks supported students in examining evidence carefully, identifying strengths and limitations, and refining their scientific explanations. Scaffolding activities organized reflection tasks into manageable steps, while case-analysis activities required students to analyze authentic scientific situations and evaluate conclusions based on evidence and reasoning. Inquiry-based and project-based learning approaches strengthen evaluation and reflection skills by encouraging metacognitive thinking and critical analysis (Indriyana and Susilowati, 2020). Research further shows that integrating digital literacy and inquiry-based strategies strengthens students' ability to analyze, evaluate, and reflect on information effectively (Chang et al., 2023). These approaches also allow students to become more independent learners by giving them opportunities to explore ideas, ask questions, and make meaningful connections between scientific concepts and real-life situations.

Table 12. Level of Critical and Scientific Thinking Skills as to Creative and Flexible Thinking

Level	Case Analysis				Scaffolding				VI
	Pretest		Posttest		Pretest		Posttest		
	f	%	f	%	f	%	f	%	
4	5	13.2	13	34.2	10	27.8	15	41.7	Advanced
3	13	34.2	12	31.6	5	13.9	14	38.9	Proficient
2	7	18.4	5	13.2	8	22.2	4	11.1	Developing
1	13	34.2	8	21.1	13	36.1	3	8.3	Emerging
<b>TOTAL</b>	<b>38</b>	<b>100.0</b>	<b>38</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	<b>36</b>	<b>100.0</b>	

Legend: f=frequency; %= percentage score; 4 points Level 4; 3 points Level 3; 2 points Level 2 and 0 Level 1

Table 12 presents the level of Grade 10 students' critical and scientific thinking skills as to creative and flexible thinking before and after exposure to the instructional strategies of scaffolding and case analysis.

Students in the advanced level in this study demonstrated capacity apply knowledge and skills in new or unfamiliar situations and to generate innovative, adaptable, and original ideas in solving problems. Students in the proficient tier exhibited the capability to generate reasonable and adjustable solutions with little direct assistance, although some concepts appeared to lack originality or deeper analysis. Students in the developing level had a basic comprehension and were able to suggest simple solutions but often encountered problems in terms of changing ideas or applying them to new situations. In contrast, students who sat at the emerging level struggled to build other forms of explanation or create flexible solutions and needed significant support for creative application of scientific concepts.

Evidence indicates differences in the performance levels of students after exposure of both groups to the intervention. Within the case-analysis group, students in the advanced level saw an increase from 13.2% to 34.2%, and students in the emerging level a decline from 34.2% to 21.1%. In the scaffolding group the advanced level increased from 27.8% to 41.7%, the proficient level increased from 13.9% to 38.9%, and the emerging level decreased from 36.1% to 8.3%. Upon completing the posttest, most students in both groups were classified as proficient and advanced levels, suggesting that many learners were already capable of using concepts from science in new contexts, coming up with flexible solutions and producing new ideas with limited assistance within the classroom.

These were demonstrated in the practice exercises with Boyle's Law and Charles' Law, where students interacted and solved real-life problems based on gas behavior and produced multiple possible solutions based on scientific concepts. For the Boyle's Law lesson, students explored situations in which bicycle tires were overinflated, air was compressed for use in syringes and containers were sealed under pressure. Using Boyle's Law, the students explored the problem in order to identify possible causes, to anticipate what will happen if pressure changes, and to suggest safe and realistic solutions. In the Charles' Law lesson, students analyzed cases of hot air balloons, heated aerosol cans and balloons subject to different temperatures. Students examined how changes in temperature impacted gas volume and described how to prevent accidents and how to explain results with scientific reasoning. Open-ended problem-solving questions like "What alternative solution can you propose?", "How can the problem be solved differently?", "What would happen if the conditions changed?", and "How might gas laws be used in another real-life scenario?" prompted students to suggest multiple explanations and solutions. Working collaboratively, working from inquiry worksheets, evidence-based reasoning tasks and so on further assisted students in modifying concepts, thinking of other possible solutions, and creatively utilizing scientific principles in addressing real-life problems.

The higher posttest performance was associated with the nature of scaffolding and case-analysis strategies, which emphasized exploration, reasoning, adaptability, and evidence-based problem-solving. Guided prompts, collaborative discussions, inquiry-based tasks, and technology-supported activities encouraged students to examine different possibilities, evaluate options, and apply scientific concepts flexibly in various situations. Scaffolding activities organized complex tasks into manageable steps that supported flexible reasoning, while case-analysis activities exposed students to authentic scientific problems requiring adaptable and original solutions. Inquiry-based and blended learning approaches strengthen creative and critical thinking through active engagement, exploration, and problem-solving (Putri et al., 2023). Guided and technology-supported learning environments also support learners in refining reasoning processes and applying ideas flexibly (Adeyele, 2024).

Research further underlines that integrating critical and scientific thinking, digital literacy, and inquiry-based learning prepares students to evaluate information, generate ideas, and make informed decisions in real-world situations (Bissonnette et al., 2021). Through these approaches, students are encouraged to actively explore problems, analyze evidence, and communicate their ideas rather than simply memorizing scientific facts. This allows learners to become more engaged in the learning process and helps them develop the confidence to apply their knowledge in practical situations both inside and outside the classroom. In today's digital world, where students are regularly exposed to substantial amounts of information, the ability to think critically and evaluate the reliability of sources has become increasingly important.

Likewise, critical thinking remains key to scientific literacy because it enables learners to apply scientific knowledge effectively in solving real-world problems (Xu et al., 2023). Students who possess strong critical thinking skills are better able to interpret data, identify possible solutions, make evidence-based decisions, and reflect on the consequences of their actions. These skills are especially valuable in addressing everyday issues related to health, environment, technology, and society. By improving critical and scientific thinking alongside digital literacy, science education can help learners become more informed, responsible, and active participants in an increasingly complex and technology-driven world.

Table 13. Test of Relationship Between the Digital Literacy and Critical and Scientific Thinking Exposed to Scaffolding

Digital Literacy	Critical and Scientific Thinking Skills					
	Problem Identification	Hypothesis Formulation	Data Interpretation	Reasoned Decision-Making	Evaluation and Reflection	Creative and Flexible Thinking
Access and Evaluation of Information	0.247	0.013	0.287	0.115	0.275	0.112
Utilization and Management of Information	0.060	0.307	0.310	0.162	0.298	0.142
Media Analysis	0.326	0.263	.551**	0.295	.479**	0.209
Creation of Media Products	0.041	-0.052	0.281	-0.022	-0.076	-0.141
Effective Application of Technology	0.098	0.242	0.286	-0.088	0.127	0.030
Interaction Through Technology	0.287	0.187	0.238	0.084	0.184	0.256

\*\*Correlation is significant at 0.01 level

\*Correlation is significant at 0.05 level

Table 13 presents the relationship between digital literacy and critical and scientific thinking skills of Grade 10 students under the scaffolding group. Data evidence shows that media analysis is related to data interpretation ( $r = 0.551$ ,  $p < 0.01$ ) and evaluation and reflection ( $r = 0.479$ ,  $p < 0.01$ ). Other domains of digital literacy, such as access and evaluation of information, utilization and management of information, creation of media products, effective application of technology, and interaction through technology, show low to moderate relationships with the different dimensions of critical and scientific thinking skills.

Despite this, media analysis still showed relationships with data interpretation and evaluation and reflection. This indicates that among the domains of digital literacy, media analysis demonstrated enough variation to reveal its connection with specific critical and scientific thinking skills. The results show that students' relatively strong performance in media analysis is associated with the scaffolded learning activities implemented during the lessons on Boyle's Law and Charles's Law. During the lesson, students viewed YouTube science videos for gas laws, animated simulations of gas particle motions, digital graphs for pressure-volume and temperature-volume relations, infographics on gas behaviour, and multimedia on real-life gas laws. Students also examined media footage of shrinking plastic bottles and aerosol cans in response to heat, inflatable boats, as well as heated basketballs used in video, digital imagery, and scenario-based slides. Teacher-guided prompts and structured prompt questions were used when students examined these scientific media sources. Students identified patterns that were apparent in graphs and simulations, identified

changes in variables shown in videos and infographics, compared data from various media sources and assessed whether or not the scientific explanations offered in the media were backed up with evidence collected in the classroom through activities and observations.

The findings were interpreted in relation to the students' generally high to very high levels of digital literacy per domain. Because most students indicated that they already had relatively high competencies relative to information access, usage of digital tools, technology interaction, and media analysis, the range of results in digital literacy was therefore less broad. This limited inter-individual variability led to a lack of relations in several domains of digital literacy and critical and scientific thinking. When students get similarly high scores, the relationships seem weak as students score in a relatively small range.

The relationship between media analysis and both data interpretation and evaluation and reflection is associated with the scaffolded tasks used during the lessons. Students analyzed scientific media such as YouTube science demonstrations, animated simulations, digital graphs, infographic presentations, and multimedia slides before interpreting data and forming conclusions. Through teacher-guided questioning and step-by-step analysis, students practiced identifying patterns, interpreting graphical information, comparing evidence from media and classroom observations, and evaluating whether the explanations presented were scientifically accurate. These scaffolded activities significantly improved students' ability to interpret scientific information in a more organized and systematic way while also enhancing their capacity to reflect on the validity and reliability of evidence-based explanations. Media literacy enhances students' ability to evaluate information and strengthens critical thinking skills necessary for scientific inquiry (Izzah et al., 2022). Similarly, the ability to interpret and assess digital scientific information is essential for developing scientific literacy in modern learning environments (Toharudin et al., 2023). Furthermore, pedagogical approaches that combine digital literacy and guided learning improve students' ability to navigate complex information and engage in evidence-based reasoning (Mills et al., 2022). Research shows that digital literacy is strongly linked to critical and scientific thinking skills and plays a vital role in preparing students to engage responsibly with scientific and technological information (Rahayu et al., 2022; Oliva et al., 2024). In today's digital era, students are regularly exposed to large amounts of information from various online platforms, making it important for them to develop the ability to evaluate the accuracy, reliability, and credibility of scientific content. Digital literacy helps learners analyze information critically, identify reliable sources, and make evidence-based judgments when solving problems or making decisions. It also supports the development of scientific thinking by encouraging students to interpret data, examine evidence, and reflect on the validity of information presented in digital environments.

Table 14. Test of Relationship Between the Digital Literacy and Critical and Scientific Thinking Exposed to Case Analysis  
 Case-Analysis

Digital Literacy	Critical and Scientific Thinking Skills					
	Problem Identification	Hypothesis Formulation	Data Interpretation	Reasoned Decision-Making	Evaluation and Reflection	Creative and Flexible Thinking
Access and Evaluation of Information	.329*	0.235	0.229	0.259	0.200	0.110
Utilization and Management of Information	0.139	-0.038	0.084	0.099	0.158	0.264
Media Analysis	-0.085	0.004	0.004	0.205	0.094	0.044
Creation of Media Products	0.017	-0.126	0.087	0.044	0.243	-0.033
Effective Application of Technology	0.004	-0.020	0.038	0.180	0.069	0.029
Interaction Through Technology	0.004	-0.020	0.038	0.180	0.069	0.029

\*\*Correlation is significant at 0.01 level

\*Correlation is significant at 0.05 level

Table 14 presents the relationship between digital literacy and critical and scientific thinking skills of Grade 10 students under the case-analysis group. Data evidence shows that access and evaluation of information is significantly correlated with problem identification ( $r = 0.329$ ,  $p < 0.05$ ), indicating a significant relationship. Other domains of digital literacy such as utilization and management of information, media analysis, creation of media products, effective application of technology, and interaction through technology show weak and non-significant correlations with the different components of critical and scientific thinking skills.

The significant relationship between access and evaluation of information and problem identification is associated with the specific case-analysis activities implemented during the lessons on Boyle's Law and Charles's Law. During the "Exploding Balloon Mystery" activity, students examined the situation where a balloon inside a sealed syringe became smaller when compressed and expanded when the plunger was pulled. Learners analyzed the guide questions, identified relevant scientific information, and determined the scientific problem by examining how pressure affects gas volume. In the "Plastic Bottle Shrinking" case scenario, students analyzed a video and multimedia presentation showing a plastic bottle becoming crushed after being left overnight in a colder environment. Students evaluated the information presented in the scientific media, identified relevant evidence, and determined the scientific problem related to temperature and gas volume changes. Real-life examples like inflatable boats, aerosol cans, basketballs exposed to heat, and bottled drinks left inside vehicles were also shared with videos, digital slides, and scenario-based questions. Students had to analyze information they saw in videos, simulations, graphs, and multimedia sources to determine whether the information was scientifically accurate and relevant before identifying the central scientific issue in each situation.

The relation indicates that students who have a better ability to access and evaluate scientific information are better at recognizing and identifying scientific problems. For the case-analysis exercises, students first reviewed specific evidence from scientific media sources, then asked the questions “Why did the bottle shrink when the temperature got colder?” and “What happens to gas particles when pressure increases?”, students practiced finding the relevant information, checking what scientific explanation is valid, and distinguishing important evidence from irrelevant information. These activities reinforced problem identification because students were taught how to judge the reliability and applicability of information, as well as identify what scientific problem they have in each case, respectively. This conclusion is consistent with studies stressing that knowing when and how to critically access and evaluate information is a central building block in identifying scientific problems and participating in inquiry processes (Fausan et al., 2021).

On the contrary, other aspects of digital literacy usage and management of information, media analysis, media products creation, and effective technology usage and interaction through technology do not correlate significantly and at a very small scale with hypothesis formation, data interpretation, reasoned decision making, evaluation and reflection, creative and flexible thinking. Thus, while students developed the skills to organize information, engage with digital tools, communicate via technology, and produce digital products, such learning did not significantly correlate with higher-order scientific thought processes in the case-in-depth activities. Studies indicate that students are inclined to engage with the superficial features of online resources and not the legitimacy and scientific veracity of content, contributing to the under-utilization of digital skills for deeper scientific thought and analysis (Kohnen et al., 2020). In addition to exposure to misinformation and untrustworthy web content, students’ ability to use digital information effectively in solving scientific reasoning problems cannot always be adequately improved without proper guidance and instruction (Pimentel, 2024). Many learners may know how to access online information and use digital tools, but they often struggle to evaluate the credibility of sources, distinguish factual information from misleading claims, and apply what they have learned to scientific problem-solving situations. As a result, students may rely on inaccurate information or develop misunderstandings that can affect their reasoning and decision-making skills. This emphasizes the increasing challenge faced by educators in helping students navigate the vast amount of information available in digital spaces.

This confirms the idea that digital literacy has a broader scope that goes beyond technical proficiency and basic technology use. According to Son and Ha (2024), digital literacy also includes higher-level cognitive skills that enable learners to critically analyze, interpret, and apply information effectively in scientific contexts. Students need to develop the ability to question information, examine evidence carefully, compare different viewpoints, and make logical conclusions based on reliable data. These skills are essential in science education because they help learners become more critical, reflective, and responsible users of information. By strengthening digital literacy together with critical and scientific thinking, students can become better prepared to solve real-world problems and make informed decisions in an increasingly digital and information-rich society.

**Table 15.** Performance on Critical and Scientific Thinking Skills Exposed to Scaffolding

Critical and Scientific Thinking Skills	Scaffolding Web-Based Collaborative Inquiry Learning							
	Mean	SD	Std. Error Mean	95% Confidence Intervals of the Difference		t	df	Sig (2-tailed)
				Lower	Upper			
Problem Identification	0.94	1.19	0.20	0.54	1.35	4.75	35	0.000
Hypothesis Formulation	1.81	1.53	0.25	1.29	2.32	7.09	35	0.000
Data Interpretation	1.53	1.44	0.24	1.04	2.02	6.35	35	0.000
Reasoned Decision-Making	0.72	0.91	0.15	0.41	1.03	4.74	35	0.000
Evaluation and Reflection	1.03	1.18	0.20	0.63	1.43	5.21	35	0.000
Creative and Flexible Thinking	1.03	1.28	0.21	0.60	1.46	4.83	35	0.000

Table 15 test showed differences between the pretest and posttest scores of Grade 10 students using the scaffolding web-based collaborative inquiry learning approach on critical and scientific thinking skills. The mean scores represent the average difference between students' pretest and posttest scores on the six dimensions in the study; the standard deviation values explain the consistency of students' responses. Hypothesis formulation was found to have the highest mean difference across the six dimensions ( $M = 1.81$ ,  $SD = 1.53$ ) followed by data interpretation ( $M = 1.53$ ,  $SD = 1.44$ ), meaning students are quite able to provide logical predictions and interpret scientific evidence after being involved in the scaffolded activities. Evaluation and reflection and creative and flexible thinking achieved a mean difference of 1.03 ( $SD = 1.18$  and  $1.28$ , respectively), while problem identification recorded a mean difference of 0.94 ( $SD = 1.19$ ). Reasoned decision-making scored the lowest ( $M = 0.72$ ) and the lowest ( $SD = 0.91$ ) as well, indicating that students respond more consistently when making decisions using evidence. Moderate standard deviation for all measures implies that, whereas differences persisted among students, they showed similar trends in performing in the posttest.

The computed t-values and significance (2-tailed) values indicate whether differences between the pretest and posttest scores were statistically meaningful. All dimensions obtained significance values of 0.000, which are lower than the 0.05 level of significance, indicating differences between the pretest and posttest performances under the scaffolding approach. The highest t-value was observed in hypothesis formulation ( $t = 7.09$ ), followed by data interpretation ( $t = 6.35$ ), showing strong differences between students' pretest and posttest scores in these dimensions. Evaluation and reflection ( $t = 5.21$ ), creative and flexible thinking ( $t = 4.83$ ), problem identification ( $t = 4.75$ ), and reasoned decision-making ( $t = 4.74$ ) also showed differences between pretest and posttest performances. The degrees of freedom ( $df = 35$ ) indicate that the statistical analysis involved 36 students under the scaffolding group. These findings indicate that the scaffolding web-based collaborative inquiry learning approach was associated with higher posttest performance across all dimensions of critical and scientific thinking skills.

When students were instructed to analyze the response of a balloon placed inside a syringe during the "Exploding Balloon Mystery" activity in Boyle's Law the higher score on the posttest for problem

identification became apparent. By the teacher's prompting questions such as "Why does the balloon change size when pressure changes?" and "What happens to gas particles when pressure increases?", students defined a scientific problem that concerns the inverse relationship between pressure and volume. Likewise, through the Charles's Law "Igniting Curiosity" activity, students looked at a hot air balloon animation and used guided questioning to determine how temperature affected gas volume. The higher posttest scores for hypothesis formulation appeared in the "Expanding Possibilities" tasks both in the Boyle's Law/classroom lecture and in Charles's Law. Before carrying out the balloon investigations, students anticipated what would happen to volume of gas when pressure or temperature variations occurred. Scaffolded prompts including, "What do you think will happen when the plunger is pushed?" and "How will heating affect the size of the balloon?" directed students in predicting logically and based upon evidence in a video, simulation, and classroom demonstration.

Results revealed higher posttest scores in interpreting data in experimental, as well as analytical tasks where students were required to document observations, draw data tables, and interpret graphs that reveal relationships between pressure-volume and temperature-volume. Boyle's Law was taught to reflect changes in balloon size inside the syringe as pressure was increased and decreased, while Charles's Law asked students to estimate balloon circumference at different temperatures and interpret the results. Teacher-directed questions like "What trend do you observe?" and "How does changing pressure or temperature affect gas volume?" asked students to develop scientific evidence analytically and systematically using tables, simulations, and graphical representations. These higher posttest scores in the reasoned decision-making component were demonstrated during "Real-World Relay" HOTS activities during which students were able to analyze actual situations involving aerosol cans, inflatable boats, bottled drinks left in vehicles, and heated basketballs. When under varying temperature and pressure, the students explained why these objects expand or contract, and explained safety precautions that depended on Boyle's Law and Charles's Law concepts. Scaffolded questions like, "What evidence supports your explanation?" and "Which gas law best describes the situation?" helped students arrive at scientifically sound inferences supported by evidence from activities, discussion. The higher posttest evaluation and reflection scores were attributed to "Think Boyle!" and "Think Charles!" exit card reflection and multimedia analysis. Students analyzed scientific claims, discussed misunderstandings, and evaluated whether explanations in videos, animations, graphs, and multimedia matched experimental data. The reflection questions encouraged the students to look at the correctness and soundness of scientific explanations and relate gas laws to their own experiences.

Results showed higher scores for creative and flexible thinking in posttest scores when students applied Boyle's Law and Charles's Law to new and real-world problem-solving and application activities. Learners discussed the way pressure and temperature changes have an effect on real life, including in syringes and balloons, aerosol cans and heated containers. Students also posed other solutions and explanations for gas-related scenarios presented in collaborative tasks and inquiry activities. These tasks challenged students to formulate scientific ideas using different modalities, justify, and apply evidence-based reasoning to problem solving in science.

These outcomes means that the students significantly improved were consistent with literature suggesting that, through structured reasoning and active engagement, inquiry-based and problem-based learning reinforce critical thinking skills (Sujanem and Suwindra, 2023). Scaffolded activities, like the "Exploding Balloon Mystery," "Expanding Possibilities," "Think Boyle!," "Think Charles!," and "Real-World Relay" activities, gave students guidance to review situations, determine evidence, rationalize explanations and utilize gas law theories in the real world. With guided questioning, controlled experiments, multimedia presentation and real-life problem scenarios involving the scientific explanations, students explored relationships between pressure, temperature, and gas volume. In addition, the significantly increased posttest scores by all the dimensions confirm Irwanto (2023)'s observations and demonstrate that well-implemented instructional strategies, particularly with respect to guidance, collaboration, and solving problems through the real world, would help the students in their higher-order thinking skills and cognitive process.

**Table 16.** Performance on Critical and Scientific Thinking Skills Exposed to Case Analysis

Case Analysis Web-Based Collaborative Inquiry Learning

Critical and Scientific Thinking Skills	Mean	SD	Std. Error Mean	95% Confidence Intervals of the Difference		t	df	Sig (2-tailed)
				Lower	Upper			
Problem Identification	1.16	1.15	0.19	0.78	1.54	6.20	37	0.000
Hypothesis Formulation	1.16	1.44	0.23	0.68	1.63	4.95	37	0.000
Data Interpretation	1.50	1.45	0.23	1.02	1.98	6.39	37	0.000
Reasoned Decision-Making	0.34	1.68	0.27	-0.21	0.89	1.25	37	0.220
Evaluation and Reflection	1.13	1.55	0.25	0.62	1.64	4.51	37	0.000
Creative and Flexible Thinking	0.58	1.33	0.22	0.14	1.02	2.69	37	0.010

Table 16 presents the test of difference between the pretest and posttest scores of Grade 10 students under the case-analysis web-based collaborative inquiry learning approach in terms of critical and scientific thinking skills. The mean scores indicate the average difference between students' pretest and posttest performances across the six dimensions, while the standard deviation values describe the consistency of students' responses. Among the dimensions, data interpretation obtained the highest mean difference ( $M = 1.50$ ,  $SD = 1.45$ ), indicating that students were capable of interpreting scientific evidence, identifying relationships between variables, and analyzing graphical and simulation data after exposure to the case-analysis activities. Problem identification obtained a mean difference of 1.16 ( $SD = 1.15$ ), while hypothesis formulation obtained a mean difference of 1.16 ( $SD = 1.44$ ), showing that students were able to recognize scientific problems and construct logical predictions using scientific concepts and observations. Evaluation and reflection obtained a mean difference of 1.13 ( $SD = 1.55$ ), indicating that students were capable of evaluating scientific explanations and reflecting on evidence-based conclusions. Creative and flexible thinking obtained a mean difference of 0.58 ( $SD = 1.33$ ), while reasoned decision-making obtained the lowest mean difference ( $M = 0.34$ ) and the highest standard deviation ( $SD = 1.68$ ), indicating wider variation in students' responses in making evidence-based decisions and justifying conclusions scientifically. Overall, the moderate standard deviation values indicate that although differences existed among learners, students generally demonstrated comparable performance patterns in the posttest.

The computed t-values, degrees of freedom, and significance (2-tailed) values indicate whether differences between the pretest and posttest scores were statistically meaningful. Problem identification ( $t = 6.20$ ,  $df = 37$ ,  $p = 0.000$ ), hypothesis formulation ( $t = 4.95$ ,  $df = 37$ ,  $p = 0.000$ ), data interpretation ( $t = 6.39$ ,  $df = 37$ ,  $p = 0.000$ ), evaluation and reflection ( $t = 4.51$ ,  $df = 37$ ,  $p = 0.000$ ), and creative and flexible thinking ( $t = 2.69$ ,  $df = 37$ ,  $p = 0.010$ ) all obtained significance values lower than the 0.05 level of significance, indicating differences between the pretest and posttest performances in these dimensions under the case-analysis approach. Among the dimensions, data interpretation obtained the highest t-value, showing the strongest difference between pretest and posttest performance. However, reasoned decision-making ( $t = 1.25$ ,  $df = 37$ ,  $p = 0.220$ ) obtained a significance value higher than 0.05, indicating that no difference was observed between the pretest and posttest performances in this dimension. The degrees of freedom ( $df = 37$ ) indicate that the statistical analysis involved 38 students under the case-analysis group. These findings indicate that the case-analysis web-based collaborative inquiry learning approach was associated with higher posttest performance in most dimensions of critical and scientific thinking skills except reasoned decision-making.

The higher posttest scores in problem identification were evident during the Decode the Mole! activity where students analyzed images, videos, and multimedia presentations showing gas particles under different pressure and temperature conditions. Students examined the movement and arrangement of particles and identified the scientific problem related to changes in pressure, temperature, and gas volume. Guide questions such as “What changes do you observe in the particles?” and “What scientific concept explains this situation?” directed students to identify the issue being investigated before discussing the formal gas law concepts.

The higher posttest scores in hypothesis formulation were observed during the Fill It Right: Pressure–Volume Challenge and prediction activities where students completed missing scientific concepts and predicted how gases would behave in different situations. Learners proposed explanations regarding what would happen to gas particles when pressure increased or when temperature decreased. Through videos, infographic presentations, and simulation outputs, students generated predictions and possible explanations before verifying them during classroom discussions and inquiry activities.

The higher posttest scores in data interpretation were demonstrated during the Interactive Insight and simulation analysis activities where students examined digital graphs, videos, and animations explaining Boyle’s Law and Charles’s Law. Students discussed the pressure–volume and temperature–volume relations, based on graphical presentations and simulation outputs. Learners discussed the results of the data in tables and multimedia resources presented to them and found the relationships between the variables. Questions such as “What relationship exists between the variables?” and “How does the graph support the explanation?” instructed students to make scientific interpretations systematically.

The reasoned decision-making results indicated no differences from pretest to posttest performance. That means that students identified gas law concepts and studied scientific situations but struggled to consistently evaluate evidence and defend their conclusions with deeper scientific reasoning. While performing the application activities on aerosol cans, bottled drinks, heated objects, and gas expansion scenarios, some students paid more attention to the observable effects, while others did not elaborate and justify their understanding and conclusions by scientific principles as well as evidence.

This suggests reasoned decision-making involves increased opportunities for evaluation and argumentation as well as evidence-based justification during more sustained decision-making processes. Higher posttest scores in evaluation and reflection were indicated within the Knowledge Check and Exit Card Reflection activities when students evaluated scientific explanations and reflected on misconceptions from the lessons. Students assessed whether statements and explanations presented in videos, graphs, simulations, and classroom discussions correctly explained Boyle’s Law and Charles’s Law. Reflection prompts encouraged learners to examine the accuracy of scientific information and connect gas law concepts to real-life situations involving gases.

The higher posttest scores in creative and flexible thinking were evident during the Application Challenge and enrichment activities where students explained practical situations involving baking bread, inflated sports equipment, shrinking containers, and pressure changes in everyday life. Learners generated multiple explanations for gas behavior and applied Boyle’s Law and Charles’s Law concepts to unfamiliar situations using evidence gathered from videos, simulations, and classroom discussions. These activities encouraged students to think flexibly and apply scientific concepts creatively in solving real-world scientific problems.

These findings mean that students significantly improved which was align with literature indicating that inquiry-based and problem-based learning strengthen critical thinking through active analysis, real-world problem-solving, and engagement with authentic situations. The case-analysis activities such as Decode the Mole!, Fill It Right: Pressure–Volume Challenge, Interactive Insight, Knowledge Check, and Application Challenge provided students with opportunities to analyze scientific situations, interpret evidence, formulate explanations, and connect gas law concepts to practical experiences. Through multimedia presentations, simulations, videos, and collaborative discussions, students actively examined scientific information and applied concepts to authentic situations. These learning activities allowed students to become more engaged

in the lesson because they were able to visualize scientific concepts, interact with digital content, and exchange ideas with their classmates. Instead of passively receiving information, learners were encouraged to analyze evidence, ask questions, solve problems, and connect scientific concepts to real-life experiences. This type of learning environment helped students develop deeper understanding and improved their confidence in expressing ideas and making evidence-based conclusions.

Moreover, the higher posttest scores in most dimensions support the findings of Irwanto (2023), emphasizing that instructional interventions integrating real-life problem-solving, collaboration, and guided analysis support students' higher-order thinking skills and cognitive processes (Sujanem and Suwindra, 2023). When students are given opportunities to work collaboratively and engage in meaningful inquiry activities, they become more capable of interpreting information, evaluating evidence, and making reasoned decisions. Guided analysis and scaffolded learning experiences also help learners process complex scientific ideas in a more organized and manageable way.

Table 17. Test of Difference Between the Post Assessment in Critical and Scientific Thinking Skills Exposed to Scaffolding and Scaffolding Case Analysis

	t-test for Equality of Means					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Problem Identification	-0.134	72	0.894	-0.03801	0.28410	-0.60436	0.52834
Hypothesis Formulation	-0.660	72	0.511	-0.21199	0.32104	-0.85197	0.42799
Data Interpretation	-1.116	72	0.268	-0.33480	0.29998	-0.93280	0.26321
Reasoned Decision-making	-1.480	72	0.143	-0.44152	0.29831	-1.03620	0.15316
Evaluation and Reflection	-0.544	72	0.588	-0.15058	0.27699	-0.70276	0.40159
Creative and Flexible Thinking	-1.118	72	0.267	-0.33772	0.30215	-0.94004	0.26460

Table 17 presents the test of difference in the posttest scores between the case-analysis and scaffolding approaches in terms of students' critical and scientific thinking skills. Data evidence shows that all components yielded non-significant results, including problem identification, hypothesis formulation, data interpretation, reasoned decision-making, evaluation and reflection, and creative and flexible thinking. Additionally, the confidence intervals for all variables include zero, indicating that no difference was observed between the two groups' posttest performances.

The absence of differences between the posttest performances explained by the similar learning experiences provided by both scaffolding and case-analysis approaches within the web-based collaborative inquiry learning (WCIL) environment. In both groups, students engaged in inquiry-centered activities that required them to analyze scientific problems, interpret evidence, discuss ideas collaboratively, and construct

explanations using scientific reasoning. Both approaches exposed students to the same science concepts on Boyle's Law and Charles's Law and involved similar digital and inquiry-based learning experiences such as analyzing videos, infographic presentations, simulations, digital graphs, and multimedia scientific explanations.

In the scaffolding group, students participated in graph interpretation tasks, simulation analysis, guided inquiry worksheets, multimedia reflection activities, and teacher-guided questioning where they examined pressure-volume and temperature-volume relationships systematically. In the case-analysis group, students engaged in scenario-based activities involving aerosol cans, tire pressure changes, heated containers, shrinking bottles, and gas expansion situations where they analyzed scientific evidence and proposed explanations using Boyle's Law and Charles's Law concepts. While the instructional approaches varied in format, both groups performed inquiries, interpretations, evidence-based reasoning, collaboration, and reflective analysis.

Following this, similar posttest performance was correlated to the common structural elements of the WCIL used across groups. Students from both streams engaged in collaborative sessions, multimedia analyses, simulating experiments, interpreting different charts and graphs, inquiry worksheets and infographic-making tasks; and evidence-based inquiries. During the lesson tasks, students were required to synthesize infographics about Boyle's Law and Charles's Law, which is visible in appendix B page 187. Student made infographic task that was to organize science information, and summarize gas law concepts, interpret visual and electronic media, and communicate scientific explanations creatively using digital aids. In addition, both groups employed same digital learning resources, including PhET simulations, videos, infographic presentations, and online scientific media, enabling them to view the behavior of gas particles and to explore the correlations between pressure, temperature, and volume. With a combination of inquiry-based and technology-supported experiences, both inquiry activities stimulated participation in learning and participation, shared reasoning, active participation and collaborative reasoning, and analysis of scientific evidence were included, even across multiple approaches of instruction.

On the other hand, teachers guided them both groups received instruction with teacher facilitation, peer interactions, collaborative work, guided inquiry-based learning, guided and inquiry-based processes for investigation, supported that students developed peer inquiry-strategized structures and structured classroom conversation to help students to organize their thoughts and interpretation of scientific data and evidence, interpreting scientific information and explaining science information, and creating logical, structured discourse structures. Both groups of students were consistently given direct experiences with evidence-based questions and activities where students in both the groups of two groups experienced question and answers combined with evidence-based questioning, peer learning, cooperative inquiry, and practical science applications from students' everyday life applications to enhance the scientific theory and practice. Since the WCIL environment features active participation, scientific inquiry, multimedia analysis, collaborative reasoning that promote higher-order reasoning ability among students, the WCIL environment generated similar posttest performance as those in the conventional study methods. Moreover, the findings indicate that inquiry-based and technology-supported learning experiences improved the students' critical and scientific thinking skills than the scaffolding or case-analysis strategies alone. These results support studies showing that collaborative inquiry activities involving reasoning, evidence analysis, and problem-solving help improve higher-order thinking skills (Hugerat and Kortam, 2014; Wahyuni et al., 2019).

## **5. Conclusion and Recommendation**

The study found that digital literacy did not have a strong overall relationship with the critical and scientific thinking skills of Grade 10 students, although some areas showed connections. Both scaffolding-based and case analysis-based web-based collaborative inquiry learning helped improve students' critical and scientific thinking skills, but neither approach was found to be more effective than the other. Based on the findings,

schools and teachers are encouraged to continue using digital tools and web-based collaborative inquiry activities in science classes to enhance students' reasoning, analysis, collaboration, and problem-solving skills. Future studies may also explore these strategies in other subjects, grade levels, and learning settings.

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