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Integration of Technological Pedagogy in Radiologic Technology Education: Impact on Student Learning Skills Development

Amelita C. Garcia[1*], Edgardo Rivera Jr. [1], Miko Andrei C. Dimaano [1], Kristine Ezra B. De Guzman [1], Ma. Angelica N. Daaca [1]
[1] *University of Perpetual Help System DALTA Calamba*
[*] *amelita.garcia@perpetualdalta.edu.ph, Edgardorivera722@gmail.com, mikodimaano506@gmail.com, tintin.brenden@gmail.com, mariaangelica.daa@gmail.com*

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ABSTRACT

The rapid evolution of medical imaging requires a paradigm shift in healthcare education through the purposeful integration of technological pedagogy. This study evaluated the impact of technology-enhanced instruction on the development of essential learning skills among Radiologic Technology students at the University of Perpetual Help System DALTA Calamba. Utilizing a quantitative descriptive-evaluative research design, data were gathered from a total population of students exposed to digital learning management systems, virtual simulation tools, and collaborative online platforms. The structural framework of the assessment focused on four core student development domains: clinical skill competence, digital literacy, self-directed learning initiatives, and collaborative communication and teamwork. The descriptive findings revealed highly positive student perceptions, demonstrating that the systematic adoption of digital imaging tools and technological pedagogical content knowledge (TPACK) significantly strengthens practical competence and reduces procedural errors during simulation training. Furthermore, the integration of interactive multimedia and online collaborative tools successfully cultivated robust digital literacy, empowered students to take proactive autonomy over their learning goals, and improved coordination during group tasks. While the baseline metrics indicate a high level of student readiness and adaptability, the results underscore the necessity of continuous faculty training to maximize pedagogical efficiency. Ultimately, this research provides a data-driven foundation for curriculum designers to institutionalize technology-enhanced frameworks, ensuring that future radiologic technologists possess the sophisticated technical capabilities, critical reasoning, and collaborative proficiencies required to meet the demands of modern clinical practice.

Keywords: *technological pedagogy, radiologic technology, clinical skills, digital literacy, self-directed learning, student development, educational technology*

INTRODUCTION

The rapid advancement of technology has significantly transformed the landscape of education worldwide. In the field of health sciences, particularly in Radiologic Technology, technology plays a central role not only in clinical practice but also in the teaching and learning process. Radiologic Technology programs require students to master both theoretical knowledge and practical skills, such as operating imaging equipment, interpreting diagnostic images, and applying patient care principles (McGee et al., 2024). With the increasing reliance on digital imaging systems, virtual simulations, and learning management platforms, there is a growing need for educators to integrate technology purposefully into pedagogy to enhance students' learning experiences and skill development (Wade et al., 2024).

The concept of technological pedagogy refers to the deliberate use of digital tools, simulation software, multimedia, and online collaborative platforms to facilitate learning. When implemented effectively, technology-enhanced instruction can foster critical thinking, technical competence, self-directed learning, and collaborative skills (Bhat et al., 2024; Sun et al., 2025). However, research has shown that many programs face challenges in fully integrating technology into pedagogy, resulting in inconsistencies in student learning outcomes and skill acquisition. Studies in related health science fields indicate that while technology can improve learning efficiency and engagement, its benefits are maximized only when pedagogical strategies are aligned with technological tools and learning objectives (McGee et al., 2024; Wade et al., 2024).

In the Philippine context, Radiologic Technology education is experiencing a rapid digital transformation, yet challenges persist. Many higher education institutions still rely on traditional lecture-based instruction, while the integration of simulation software, virtual imaging tools, and collaborative online platforms remains limited or inconsistent (Cadiz et al., 2024). This gap has the potential to impact the development of essential learning skills among students, which are crucial for their readiness to practice in technologically advanced clinical environments. Furthermore, the COVID-19 pandemic has accelerated the need for online and blended learning approaches, highlighting the importance of effective technological pedagogy in health professions education (Abella & Rosa, 2023).

The study is particularly relevant in light of the Sustainable Development Goals (SDGs), specifically Goal 4: Quality Education, which aimed to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (United Nations, 2020). Integrating technological pedagogy in Radiologic Technology education aligns with this goal by improving access to high-quality instructional resources, enhancing students' competencies, and preparing graduates to meet the demands of modern healthcare. By exploring the impact of technological pedagogy on student learning skills, this study contributes to developing evidence-based strategies for improving the quality and effectiveness of higher education in the Philippines.

Theoretical Framework

The theoretical foundation of this study is primarily anchored on the Technological Pedagogical and Content Knowledge (TPACK) framework, which extends the original work by Mishra and Koehler (2006) by articulating the specific knowledge domains educators require to integrate technology effectively into teaching (Jibril & Adedokun-Shittu, 2024). The TPACK framework posits that high-quality instruction requires an integrated understanding of content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), as well as the intersections among these domains. In the context of Radiologic Technology education, CK involves mastery of imaging principles, patient care procedures, and diagnostic interpretation; PK refers to instructional strategies that promote clinical reasoning and cognitive engagement; and TK refers to educators' capabilities in leveraging digital tools, simulation software, virtual imaging technologies, and online platforms to support student learning. The integrated domain of technological pedagogical content knowledge thus informs how technology can be meaningfully woven into instruction to improve educational outcomes (Ait Ali et al., 2023).

Recent research within health professions education affirms the value of TPACK as a guiding lens for technology integration. A literature review on TPACK application in health professions contexts found that while empirical studies remain limited, TPACK is associated with positive outcomes in instructional design, technology integration, and professional development, suggesting its relevance for guiding educational interventions in clinical and technical disciplines (Ait Ali et al., 2023). Additionally, studies in other educational settings highlight the necessity of teacher readiness for technology integration, emphasizing that TPACK competencies are critical to realizing the pedagogical benefits of digital tools and aligned instructional strategies.

In line with TPACK, this study suggests that the integration of technological pedagogy in Radiologic Technology courses serves as the independent variable that influences the development of students' learning skills, which is the dependent variable. Technological pedagogy, in this context, includes the deliberate use of digital learning platform, simulation-based learning, multimedia instructional materials, and online collaborative tools that collectively shape the learning environment and instructional experience. When these strategies are applied thoughtfully and aligned with pedagogical goals, they are expected to enhance students' critical thinking, clinical reasoning, technical competence, digital literacy, self-directed learning, and communication and teamwork skills, competencies that are central to effective radiologic practice and reflective of 21st-century learning outcomes.

Additionally, this study draws on constructivist learning theory, which asserts that learners construct knowledge actively through experience, interaction, and reflection within meaningful contexts (Pratama et al., 2024; Zamrin Md Zin et al., 2024). Constructivist principles support the use of technology in education, as interactive simulations, virtual laboratories, multimedia environments, and collaborative platforms provide experiential learning opportunities that mirror real-world problem solving and clinical decision making. These environments allow students to engage with content, test hypotheses, reflect on outcomes, and work with peers, processes that are foundational to the development of higher-order cognitive and metacognitive skills.

By combining the TPACK framework with constructivist theory, this study establishes a foundation for examining how technology-enhanced pedagogy facilitates active learning, problem-solving, and skill development among Radiologic Technology students. The conceptual link between the independent and dependent variables is therefore that higher perceived exposure to technological pedagogy, through the integration of digital learning tools and pedagogical strategies, is expected to positively influence students' learning skills development. This theoretical alignment provides a rationale for investigating the extent, quality, and impact of technology integration in Radiologic Technology education, thereby offering empirical evidence for improving teaching strategies and learning outcomes in technologically evolving educational environments.

Conceptual Framework

The conceptual framework of this study illustrated the relationship between the independent variable, Perceived Exposure to Technological Pedagogy, and the dependent variable, Student Learning Skills Development, in Radiologic Technology education. The independent variable encompassed five key components: Learning platform (MS Teams), simulation-based learning, multimedia instructional materials, and online collaborative tools. These elements represent the deliberate integration of technology into pedagogy, guided by the TPACK framework, which emphasizes the intersection of technological, pedagogical, and content knowledge, and by constructivist learning theory, which highlights the role of active, experiential, and collaborative learning in skill development.

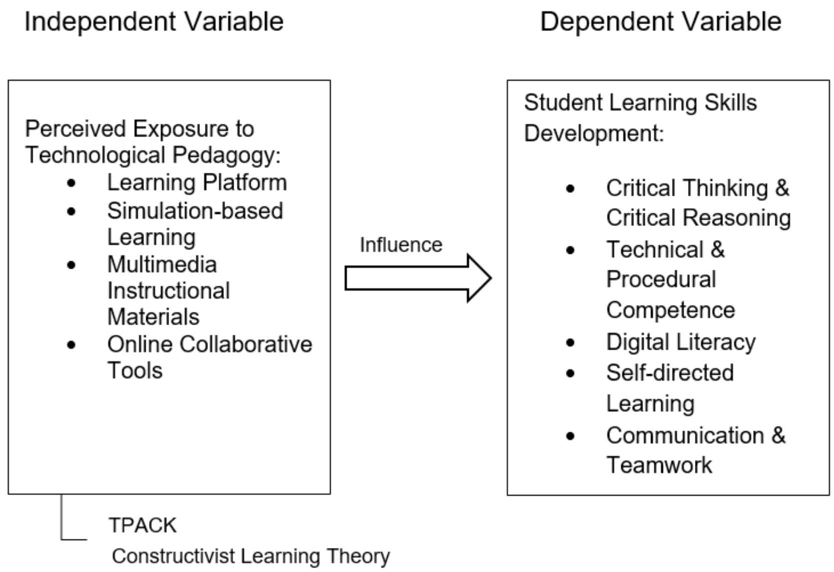

Figure 1. *Conceptual Framework of the Study*

The dependent variable includes students' critical thinking and clinical reasoning, technical and procedural competence, digital literacy, self-directed learning, communication and teamwork, and problem-solving skills. The directional relationship illustrated in the paradigm indicates that higher levels of technological pedagogy integration are expected to positively influence the development of these learning skills. In essence, this framework provides a visual and theoretical representation of how technology-enhanced instruction, when applied purposefully and pedagogically, can enhance the knowledge, competencies, and overall learning outcomes of Radiologic Technology students.

Statement of the Problem

This study sought to investigate the relationship between the integration of technological pedagogy in Radiologic Technology education and the development of students' learning skills. Specifically, it aimed to determine how students perceive their exposure to technological pedagogy and how this perceived exposure affects their acquisition of essential cognitive, technical, and collaborative competencies.

The study was guided by the following specific problems:

1. What is the level of students' perceived exposure to technological pedagogy in Radiologic Technology education in terms of:
   1.1 learning platform;
   1.2 simulation-based learning;
   1.3 multimedia and interactive instructional materials; and
   1.4 online collaborative learning tools?
2. What is the level of students' learning skills development in terms of:
   2.1 critical thinking and clinical reasoning;
   2.2 technical and procedural competence;
   2.3 digital literacy;
   2.4 self-directed learning; and
   2.5 communication and teamwork>

3. Is there a significant relationship between students' perceived exposure to technological pedagogy and their development of learning skills in Radiologic Technology education?
4. To what extent does students' perceived exposure to technological pedagogy predict their learning skills development?

Hypothesis

The following are the hypothesis of the study:

1. There is no significant relationship between students' perceived exposure to technological pedagogy and their development of learning skills in Radiologic Technology education.
2. Students' perceived exposure to technological pedagogy significantly predicts their learning skills development in Radiologic Technology education.

Scope and Delimitations

This study focused on examining the impact of technological pedagogy on the learning skills development of students enrolled in Radiologic Technology programs. Specifically, it investigated students' perceived exposure to various technological pedagogical strategies, including digital learning platform, simulation-based learning, multimedia instructional materials, and online collaborative tools. The dependent variable of the study was the development of students' learning skills, which encompassed critical thinking and clinical reasoning, technical and procedural competence, digital literacy, self-directed learning, communication and teamwork, and problem-solving skills. The research was conducted among 79 students currently enrolled in Radiologic Technology programs in the University of Perpetual Help System DALTA Calamba Campus, representing learners who experienced varying levels of technology integration in their coursework.

The study was delimited in several ways. First, it relied on self-reported perceptions of students regarding their exposure to technological pedagogy, which influenced by individual experiences and subjective interpretation. Second, the study did not measure actual student performance in clinical or laboratory settings but rather focused on perceived skill development. Third, the research was limited to the Radiologic Technology program where the survey was administered, which not fully represent all Radiologic Technology programs in the Philippines. Finally, the study adopted a cross-sectional design, capturing data at a single point in time and therefore not addressing the long-term effects of technological pedagogy on learning outcomes. Despite these delimitations, the study provided valuable insights into how purposeful integration of technology in Radiologic Technology education enhanced students' learning skills, offering guidance for educators, curriculum developers, and policymakers in improving instructional strategies and student outcomes.

Significance of the Study

The findings of this study are expected to have significant implications for multiple stakeholders in Radiologic Technology education.

To the Program Chair of the College of Radiologic Technology. This study provides empirical evidence on the role of technology in enhancing learning outcomes in health professions education, supporting policy development for digital education initiatives, professional development programs, and investments in educational technology infrastructure.

To the Faculty Members. The study will inform educators about the effectiveness of integrating technological pedagogy into their teaching practices. By identifying which technological tools and instructional strategies most strongly influence student learning skills, faculty can design more effective, interactive, and student-centered learning experiences that align with best practices in health professions education.

To the Students. This study will provide insights into how exposure to technological pedagogy, including digital learning management systems, simulation-based learning, virtual imaging software, multimedia instructional materials, and online collaborative tools, can enhance their learning skills.

Understanding these relationships will enable students to recognize the value of technology in developing critical thinking, clinical reasoning, technical competence, digital literacy, self-directed learning, and collaborative skills, which are essential for success in both academic and clinical settings.

To Future Researchers. The study offers a foundation for further research on technological pedagogy in health professions education, including studies that explore the long-term impact of digital and simulation-based interventions on students' clinical performance and employability skills.

Definition of Terms

For clarity and consistency in this study, the following terms are defined as used within the context of this research:

Communication and Teamwork. Skills involving clear expression of ideas and effective collaboration with peers and instructors. Operationally, it is measured through students' reported ability to engage in discussions, teamwork, and collaborative problem-solving in academic and clinical settings.

Critical Thinking and Clinical Reasoning. It is measured through students' perceived improvement in evaluating imaging procedures and interpreting diagnostic results.

Digital Literacy. Operationally, it is assessed through students' reported confidence in navigating software, online resources, and digital tools relevant to Radiologic Technology.

Learning Platform. In this study, it is operationally defined as students' learning platform for lectures, assessments, and interactive exercises.

Multimedia Instructional Materials. It is measured by students' perception of their use and usefulness in understanding radiologic concepts and procedures.

Online Collaborative Tools. It refers to students' perceived participation in online forums, group projects, or collaborative learning tasks.

Self-Directed Learning. Operationally, it is measured by students' perception of their ability to independently plan, monitor, and evaluate their learning progress.

Simulation-Based Learning. Operationally, it is measured by students' perceived engagement with and access to simulations that mimic radiologic procedures or diagnostic imaging tasks.

Student Learning Skills Development. It is measured through students' self-reported development in six areas: critical thinking and clinical reasoning, technical and procedural competence, digital literacy, self-directed learning, communication and teamwork, and problem-solving skills.

Technical and Procedural Competence. Mastery of radiologic procedures and the ability to operate imaging equipment safely and accurately. Operationally, it is measured by students' self-assessment of their proficiency in performing clinical tasks.

Technological Pedagogical Integration. For this study, it specifically includes the use of digital learning management systems, simulation-based learning, virtual imaging software, multimedia instructional materials, and online collaborative learning tools.

Literature Review

Learning Management System

Learning Management Systems (LMS) have become an essential component of modern education as they provide digital platforms that support the delivery and management of instructional content. These systems enable educators to organize course materials, administer assessments, monitor student progress, and facilitate communication between instructors and learners. Through LMS platforms, students can access learning resources, participate in discussions, and submit assignments in an organized online environment. As a result, LMS technologies help improve the efficiency of course management while providing students with flexible access to educational materials and activities (Rosário & Dias, 2022; Alshammari et al., 2024).

In higher education, the integration of LMS platforms also supports more interactive and student-centered learning environments. Features such as discussion forums, online quizzes, collaborative tools, and multimedia resources allow students to actively engage with course content and interact with their peers and instructors. Research indicates that the use of LMS can enhance student engagement, promote independent learning, and support collaborative learning activities, particularly in technology-enhanced learning environments (Kasim & Khalid, 2020; Al-Rahmi et al., 2023).

Furthermore, LMS platforms allow educators to integrate various digital learning materials, including videos, presentations, and interactive modules that can help students better understand complex concepts. These platforms also enable continuous monitoring of student performance through analytics and progress tracking tools. Because of these capabilities, LMS has become a valuable tool for improving teaching effectiveness and enhancing students' learning experiences in higher education institutions (Alshammari et al., 2024; Rosário & Dias, 2022).

Simulation-based learning activities

Recent developments in radiologic technology education have increasingly highlighted simulation-based learning (SBL) as an essential teaching strategy to connect theoretical knowledge with clinical skills. A scoping review by French et al. (2026) found that SBL substantially improves undergraduate radiography students' readiness for clinical placements, allowing them to practice theoretical concepts in a controlled, risk-free environment where errors do not compromise patient safety, while also boosting confidence in clinical and technical skills such as equipment handling and patient positioning (French et al., 2026). Similarly, research indicates that diagnostic radiography programs worldwide have integrated simulation extensively into their curricula. A 2023 international survey by Partner et al. reported that 79 % of educators regularly use SBL activities (including fixed models and immersive environments), with over half increasing simulation use in response to COVID-19 disruptions. This underscores the growing importance of simulation in radiography education.

These results are consistent with previous studies showing that simulation enhances clinical preparedness by providing authentic, collaborative learning experiences that strengthen confidence and professional competence before students enter real clinical settings (Hazell et al., 2020). Taken together, this evidence suggests that simulation-based learning is not simply an auxiliary teaching method but a critical element of contemporary radiologic technology education, supporting safe practice, consolidating theoretical knowledge, and improving student outcomes.

Lastly, a study conducted by Jabaay et al. (2020) investigated the impact of simulation-based learning on pre-clinical medical education. The findings revealed that students who completed an eight-week simulation program showed higher examination scores and improved clinical skills. This indicates that simulation-based learning offers valuable hands-on experiences that can enhance students' academic performance.

Virtual imaging and diagnostic software

Virtual imaging and diagnostic software, including immersive virtual reality (VR) and radiography simulation tools, plays a crucial role in developing practical skills among radiologic technology students in face-to-face education. Studies have shown that first-year students who engaged in immersive 3D VR practice outperformed peers without VR exposure in clinical assessments, demonstrating superior patient positioning, exposure parameter selection, and radiographic image evaluation. This suggests that virtual simulation can effectively translate into clinical competence (O'Connor & Rainford, 2023). A recent pilot study by Ingebrigtsen et al. (2025) explored students' perceptions of VR in a radiographic technique course using Skilitics simulation software. While students recognized VR's value for skill practice, technical setup and guidance challenges were reported, highlighting the importance of thoughtful pedagogical design and faculty support. Overall, evidence indicates that VR enhances confidence, equipment handling, and technical decision-making by providing safe, repeatable opportunities to apply theoretical knowledge in practice (Ingebrigtsen et al., 2025).

Additionally, using PACS (Picture Archiving and Communication System) in radiology education allows students to interact directly with full diagnostic image sets, perform basic manipulations such as window adjustments and multiplanar reconstructions, and interpret anatomical relationships. This approach significantly improves short-answer image interpretation scores compared with traditional slide-based methods, while also increasing familiarity with CT principles and confidence in image analysis (Mojtahedzadeh et al., 2024).

Furthermore, a 2024 study on artificial intelligence-assisted diagnostic (AISD) software utilizing volume data reconstruction (VDR) techniques demonstrated that integrating such tools into practical teaching enhances CT and MRI diagnostic performance, academic self-efficacy, and self-directed learning. By converting 2D images into annotated 3D reconstructions, the software improves visualization of complex anatomy, facilitates lesion identification, and strengthens image interpretation skills (Wang et al., 2024).

Overall, these results indicate that software initially created for clinical diagnostics can be repurposed as a valuable educational resource, allowing students to practice diagnostic reasoning, improve image interpretation skills, and participate in self-directed learning more effectively than conventional methods. Incorporating this software into in-person instruction helps connect theoretical knowledge with practical application, preparing students with the necessary skills for clinical competence in contemporary radiologic practice.

Multimedia and interactive instructional materials

According to Haleem et al. (2022), digital technologies have greatly transformed the education system. Technological advancements have made learning more accessible and convenient for students. Rather than depending only on traditional pen-and-paper approaches, learners now utilize various software applications and digital tools to develop presentations and accomplish academic projects. Portable devices such as tablets are lighter and easier to carry compared to multiple notebooks, and using an e-book is more convenient than handling bulky printed textbooks. The use of digitized instructional materials has enabled students to access a variety of digital tools and online resources that support the learning process. These materials can be effectively integrated into education because they help enhance academic performance and improve the quality of instruction delivered by teachers. In addition, incorporating digital learning tools into teaching practices increases student engagement and performance, both of which are essential for achieving successful learning outcomes.

Multimedia instructional materials integrate text, images, audio, animation, and video to create an interactive learning environment. These materials support diverse learning styles and improve comprehension. Multimedia-based instruction allows learners to interact with content through multiple sensory modalities such as text, graphics, images, and video, which significantly enhances students' understanding and engagement in the learning process. The integration of multimedia also increases students' motivation and encourages greater participation in classroom activities (Gallego II, 2024).

Furthermore, a study examining the use of multimedia tools in instruction found that incorporating digital technologies into learning environments improves students' academic performance, communication abilities, and analytical skills. The study emphasized that technology-based instructional materials promote active learning and provide students with more effective opportunities to interact with educational content (Amores, 2025). In medical education, digital tools such as online radiology platforms, imaging databases, and multimedia learning systems enhance both theoretical knowledge and diagnostic skills among medical students. These resources allow students to interactively analyze imaging data, thereby strengthening clinical reasoning and improving diagnostic accuracy (Stirrat et al., 2024).

Similarly, research on medical extended reality (XR) technologies in radiology education highlights the value of immersive multimedia learning environments. A study published in the Journal of the American

College of Radiology (2024) explains that XR technologies—including virtual reality (VR), augmented reality (AR), and mixed reality (MR)—create realistic and interactive training settings that enhance students' spatial understanding of anatomy and their ability to interpret radiologic images. These technologies also support collaborative learning and improve image analysis skills among radiology students.

Moreover, a study published in Learning and Motivation (2024) investigated the use of interactive visual multimedia technology and reported that students who were exposed to multimedia learning interventions demonstrated significant improvements in literacy and comprehension skills compared to those who relied on traditional instructional methods.

Additionally, another study focused on the development of interactive multimedia learning materials in vocational education. The researchers found that multimedia-based instruction significantly improved students' learning outcomes. The implementation of interactive learning media increased students' scores from 42.1% to 84.21%, demonstrating that multimedia learning tools can effectively enhance students' understanding and academic performance (Rizqa et al., 2023).

Online collaborative learning tools

In current traditional face-to-face learning settings, particularly in health-related programs such as Radiologic Technology, online collaborative tools have become increasingly essential in supporting student learning and engagement. Digital platforms, including shared documents, discussion forums, and social media tools, facilitate effective communication and interaction between students and instructors. Even in traditional classroom environments, these tools allow learners to exchange ideas, collaborate on group tasks, and access learning materials efficiently. Research indicates that collaborative technologies enhance students' academic engagement and knowledge sharing in higher education (Ansari et al., 2020). Furthermore, integrating these tools into classroom instruction promotes active learning and strengthens teamwork skills.

In face-to-face courses, online platforms provide students with opportunities to collaborate on assignments, discuss medical concepts, and engage in group projects beyond classroom hours. Such approaches are particularly valuable in professional programs like Radiologic Technology, where students are expected to develop strong communication, teamwork, and problem-solving skills (Dahal, 2022). Supporting this, a study published in BMC Medical Education (2023) found that collaborative digital tools, such as Padlet and other shared learning platforms, enhance student participation and improve understanding of complex healthcare concepts. The study concluded that integrating collaborative technologies into classroom instruction increases student engagement and better prepares learners for clinical practice.

Digital collaborative platforms are increasingly utilized in healthcare education to support learning in both face-to-face and hybrid environments. Platforms like Microsoft Teams enable students and instructors to communicate, share files, and collaborate on academic tasks in real time, facilitating continued discussion, group work, and case analyses outside the classroom. A study examining the usability of Microsoft Teams in nursing and allied health education found that students perceived the platform as useful and easy to navigate for communication, content sharing, and collaborative activities. The results suggested that such digital tools enhance the teaching–learning process and simulate teamwork similar to healthcare clinical settings (Herbert et al., 2022). Similarly, Caleya (2024) reported that Microsoft Teams supports collaborative learning among healthcare students, enabling group work, resource sharing, and active participation in discussions. The study emphasized that collaborative platforms improve student engagement and foster teamwork skills essential for healthcare professions.

In radiology education specifically, virtual collaborative activities have been shown to strengthen students' comprehension of medical imaging concepts. Research published in Nurse Education Today (2021) reported that online radiology sessions incorporating collaborative discussions and group tasks enhanced students' confidence in interpreting chest radiographs, abdominal radiographs, and brain CT scans.

Beyond healthcare, online collaborative tools also contribute to improved learning outcomes, motivation, and engagement in general science education. A quasi-experimental study with middle school students found that collaborative tools significantly enhanced academic achievement while encouraging active participation and teamwork. These platforms allow learners to share ideas, communicate effectively, and collaborate on tasks regardless of physical location (Ateş et al., 2024).

Critical thinking and clinical reasoning

Critical thinking and clinical reasoning are essential competencies in healthcare education because they enable students to analyze clinical situations, interpret medical information, and make appropriate decisions for patient care. These skills involve the ability to evaluate evidence, identify problems, and apply knowledge to real-world healthcare scenarios. In health professions education, developing strong critical thinking and clinical reasoning skills is necessary to ensure accurate diagnosis, effective treatment planning, and safe patient management. Without these cognitive abilities, healthcare professionals may struggle to respond appropriately to complex clinical situations (Firman et al., 2025).

In recent years, educational strategies such as simulation-based learning, case-based learning, and technology-supported instruction have been widely used to improve these competencies among healthcare students. Simulation activities allow students to practice decision-making in realistic clinical environments while receiving feedback and reflection opportunities. Studies have shown that simulation-based learning can enhance students' critical thinking and clinical reasoning skills by allowing them to analyze clinical cases, evaluate patient conditions, and apply theoretical knowledge to practical situations (Firman et al., 2025).

Furthermore, the integration of technology and innovative teaching approaches in healthcare education has been shown to support the development of higher-order thinking skills. Methods such as digital simulations, virtual learning environments, and problem-based learning encourage students to actively participate in the learning process and develop analytical thinking. These strategies not only improve students' understanding of clinical concepts but also strengthen their ability to make sound clinical judgments in professional practice (Firman et al., 2025).

Technical and procedural competence

Technical and procedural competence is a critical component of healthcare education because it ensures that students are able to perform clinical tasks accurately and safely. These competencies involve the ability to apply theoretical knowledge while performing clinical procedures and operating medical equipment in real healthcare settings. In health professions education, developing procedural competence requires structured training, continuous practice, and supervision to ensure that students gain the necessary skills for professional practice. Studies have shown that healthcare students who receive proper clinical training and practice opportunities are more likely to develop higher levels of competence and confidence when performing procedures (Ahmedin et al., 2024). Simulation-based learning has also been widely used in healthcare education to improve students' procedural and technical skills. Through simulation activities, students are able to practice clinical procedures in a controlled environment where they can learn from mistakes without risking patient safety. This method allows learners to strengthen their psychomotor skills, improve their clinical decision-making abilities, and gain confidence in performing professional tasks. Research indicates that simulation training plays an important role in enhancing students' clinical competence and preparing them for real healthcare practice (Zafošnik et al., 2024).

Furthermore, structured clinical training and evaluation methods help educators assess students' procedural performance and ensure that they meet the required competency standards in healthcare practice. By integrating simulation, supervised clinical experiences, and competency-based assessments, educational institutions can effectively support the development of technical and procedural competence among healthcare students. These approaches contribute to better preparation of students for professional responsibilities and improve the overall quality of patient care (Albalawi & Rezq, 2024).

Digital literacy

Digital literacy has emerged as a crucial competency for both teaching and learning within educational contexts. It empowers educators to effectively integrate technology into their curricula while enabling students to acquire essential skills for future professional and academic pursuits. In an era characterized by rapid technological advancement, digital literacy is increasingly recognized as a fundamental skill for both students and educators in higher education. The ongoing digital transformation in education is altering the ways in which knowledge is accessed, processed, and applied. Consequently, digital literacy has evolved from being an optional skill to a critical requirement for academic success and professional development (Aripradono, 2025).

In allied health programs, digital literacy is particularly important, even in traditional face-to-face learning environments, as contemporary health professions increasingly rely on technology for both educational and clinical purposes. Aydınlar et al. (2024) conducted a comprehensive study on health-science undergraduates, revealing that students' digital literacy levels varied across domains such as software and multimedia use, network communication, and ethical and security practices. The study also found that most students recognized digital literacy as essential for their academic learning and future clinical practice, leading the authors to recommend curricular improvements to strengthen competencies that support both academic engagement and clinical preparedness. Although the study did not specifically focus on Radiologic Technology students, its findings are highly relevant, given that allied health students—including those in imaging sciences—routinely utilize digital tools such as picture archiving and communication systems (PACS), electronic health records, and simulation software in classroom and clinical settings.

Further research on digital competence in healthcare education underscores the necessity for systematic assessment and integration of digital literacy into health curricula. For instance, Wang et al. (2025) developed the Digital Literacy Across Disciplines (DLAD) scale for medical education, highlighting discipline-specific variations in digital competencies and emphasizing the importance of structured digital literacy training in health professions education. This framework is particularly applicable to Radiologic Technology programs, which integrate both technical and clinical instruction. Additionally, narrative and scoping reviews on digital literacy in health professional education indicate that digital skills—including critical evaluation of information, ethical use of technology, and effective collaboration through digital platforms—are essential for preparing students to operate in technology-intensive healthcare environments. These skills also enhance learning outcomes in both face-to-face and blended educational models (Mainz et al., 2024).

Collectively, these studies suggest that in contemporary face-to-face education within allied health disciplines, developing robust digital literacy is indispensable for Radiologic Technology students. It enables them to achieve professional competence, adapt to evolving clinical technologies, and integrate digital tools into both academic and clinical practice. Supporting this, Yuan N. et al. (2025) demonstrated that digital literacy positively influences college students' learning outcomes by improving perceptions of digital learning, fostering self-efficacy with digital tools, and enhancing engagement in technology-mediated educational environments. These findings highlight the value of institutional initiatives aimed at strengthening digital competencies to improve academic achievement.

Self-directed learning

Self-directed learning (SDL) is an instructional approach in which learners take an active role in managing their own learning processes. This model allows individuals to study at their own pace while following learning objectives or content that may be guided by instructors. SDL emphasizes learner autonomy, self-management, and personal responsibility in the learning process. Through this approach, learners are encouraged to identify their learning needs, establish goals, locate appropriate resources, and evaluate their own progress. SDL is particularly effective in adult education because adult learners often possess higher levels of motivation and accountability in pursuing their learning goals. Due to these benefits, SDL has been widely adopted in different fields, including business training and medical education, to promote lifelong learning skills. However, although SDL encourages independence, it may present challenges for students who are not fully prepared or who are accustomed to traditional teacher-centered learning methods. For SDL to be implemented effectively, educators must provide supportive learning environments, appropriate guidance, and gradual exposure to self-directed practices. In addition, various assessment tools have been developed to measure learners' readiness and perceptions regarding their self-directed learning abilities. Overall, SDL helps develop critical thinking and self-awareness, enabling learners to take greater control of their educational development (Smith & Tricia, 2021).

Self-directed learning also empowers students by encouraging them to take responsibility for their own educational experiences. Learners who actively participate in planning and organizing their learning activities tend to demonstrate higher motivation and stronger problem-solving skills. In this sense, SDL transforms students from passive recipients of knowledge into active participants in the learning process. This concept became increasingly significant during the transition to online education (Hernandez, 2020). Another study highlighted that digital learning environments require students to independently manage their time, monitor their learning progress, and actively engage with instructional materials. As a result, the shift to online learning has strengthened the development of learner autonomy and responsibility, which are essential components of SDL (Setiawan & Artini, 2021).

Several studies have also examined the relationship between self-directed learning and academic performance. Findings indicate that students who possess strong self-directed learning skills tend to achieve better academic outcomes because they are able to organize effective study strategies and maintain consistent motivation. Furthermore, psychological factors such as optimism and overall well-being can enhance the effectiveness of SDL and contribute to improved learning outcomes (Li et al., 2022). In addition, Gerard et al. (2022) investigated the role of self-directed learning in supporting inquiry-based and science learning, particularly in flexible and remote learning environments. Their study revealed that when students are provided with opportunities to explore resources and investigate concepts independently, they develop deeper understanding and greater engagement in the learning process. These results highlight the important role of SDL in promoting active learning and critical thinking.

Moreover, research has emphasized the relevance of self-directed learning in modern digital and professional learning contexts, including online courses and Massive Open Online Courses (MOOCs). Factors such as motivation, self-management, and the development of continuous learning habits significantly influence the success of self-directed learning. These findings suggest that SDL is not only essential in formal education but also plays a vital role in lifelong learning and professional development (Ferdianto & Anindita, 2023).

Communication and teamwork

Effective communication is a critical aspect of healthcare, particularly as radiographers often serve as the first point of contact for patients. The results of a study showed that many students strongly support the integration of communication training into radiography education, and students with higher academic performance placed greater emphasis on communication skills. The study also concluded that structured communication courses should be incorporated into radiography programs to enhance patient interaction and teamwork in clinical settings (Rawashdeh et al., 2025). In another study, researchers used a 360-degree evaluation to assess communication skills and professionalism among radiologic technologists in a hospital radiology department. The findings indicated that effective communication between technologists, patients, and other healthcare professionals is essential for accurate procedures and high-quality patient care. The evaluation tool produced reliable results, suggesting that communication and teamwork competencies should be consistently assessed during radiologic technology training programs (Raza et al., 2024).

O'Connor et al. (2024) explored radiography students' experiences with teamwork in both university settings and clinical placements. The study identified several barriers to effective teamwork, including challenges in integrating into clinical teams and the gap between theoretical knowledge and practical clinical experience. Despite these obstacles, the research highlighted that teamwork skills are crucial for safe and efficient radiology services, as imaging procedures require coordination among radiographers, physicians, and other healthcare professionals.

In addition, a scoping review examining communication education in radiology training programs revealed that communication training enhances interactions with patients and improves collaboration with healthcare teams. However, the review also pointed out the lack of structured communication curricula in many radiology programs worldwide. The authors recommended developing comprehensive communication training modules and assessment tools to strengthen teamwork and improve clinical outcomes (Zhang et al., 2024).

Furthermore, a study on peer-assisted learning among radiography students found that collaborative learning activities foster communication, discussion, and teamwork among students. Through peer interaction, students gain confidence in clinical decision-making and develop interpersonal skills, which are essential for effective participation in multidisciplinary healthcare teams (Elshami et al., 2020).

The Journal of Education and Health Promotion (2025) reported that practical training in teamwork and communication is included in approximately 60–70% of health professional education programs. The study emphasized that communication with colleagues and patients significantly affects teamwork effectiveness and healthcare outcomes. Developing these competencies during undergraduate education prepares students for collaborative clinical environments.

METHODS

Research Design

This study employed a quantitative, descriptive-correlational research design to investigate the impact of technological pedagogy on the learning skills development of Radiologic Technology students. The descriptive aspect of the study allowed the researcher to determine the level of students' perceived exposure to technological pedagogy and the extent of their learning skills development, providing a clear picture of the current status of technology integration in the instructional process. The correlational aspect, on the other hand, enabled the researcher to examine the relationship between students' perceived exposure to technological pedagogy and their learning skills development, as well as to determine the predictive influence of technological pedagogy on the enhancement of these skills.

By utilizing a quantitative approach, this study ensured that data could be collected in a structured and measurable manner through standardized survey instruments. The design was appropriate for the study because it allowed for statistical analysis of relationships and trends among variables, providing empirical evidence on how the purposeful integration of technology in Radiologic Technology education contributes to student outcomes. Furthermore, the research design facilitated the examination of multiple dimensions of technological pedagogy such as digital learning management systems, simulation-based learning, virtual imaging software, multimedia instructional materials, and online collaborative tools and their specific impact on various aspects of learning skills development, including critical thinking, technical competence, digital literacy, self-directed learning, communication, and problem-solving abilities.

Population and Sampling

The study employed a total enumeration approach, wherein all students from the second, third, and fourth-year levels were invited to participate. However, despite this intention, not all students were able or willing to respond to the questionnaire, in consideration of their voluntary participation and ethical rights.

This approach was selected to ensure that the data gathered would be as representative as possible of the target population, thereby enhancing the reliability and validity of the findings. First-year students were excluded from the study due to their limited exposure to technological pedagogy in Radiologic Technology courses, as well as their minimal engagement in hands-on clinical or simulation-based learning experiences.

Respondents of the Study

The respondents of this study were the 79 students currently enrolled in selected Radiologic Technology programs in the Philippines during the academic year 2025–2026. These students were chosen because they are directly exposed to technological pedagogy within their coursework and are actively engaged in learning both theoretical and practical skills necessary for their future roles as radiologic technologists. The study specifically targeted students from second, third, and fourth-year levels, as they have sufficient exposure to both clinical and technology-enhanced learning experiences, unlike first-year students who may have limited hands-on exposure to radiologic procedures and simulation-based learning**.**

Instrument of the Study

The primary instrument used in this study was a researcher-developed questionnaire designed to measure students' perceived exposure to technological pedagogy and their learning skills development in Radiologic Technology education. The questionnaire was structured into two main parts. The first part gathered demographic information of the respondents, including year level, age, and gender. The second part consisted of two major sections corresponding to the independent and dependent variables. The first section assessed students' perceived exposure to technological pedagogy, with items measuring the use of digital learning platform, simulation-based learning, multimedia instructional materials, and online collaborative learning tools. The second section measured students' learning skills development, including critical thinking and clinical reasoning, technical and procedural competence, digital literacy, self-directed learning, and communication and teamwork.

Both sections utilized a 5-point Likert scale, allowing respondents to indicate the frequency of exposure or extent of skill development.

Scale	Verbal Interpretation
5	Always / Strongly Agree
4	Often / Agree
3	Sometimes / Uncertain
2	Rarely / Disagree
1	Never / Strongly Disagree

This format was chosen for its simplicity and effectiveness in capturing subjective perceptions while enabling quantifiable analysis. The structured questionnaire allowed for systematic data collection across all targeted respondents, providing a clear and standardized way to examine the relationship between technological pedagogy and student learning outcomes.

Validation of the Instrument

To ensure the reliability and validity of the questionnaire, a two-step validation process was conducted. First, the instrument underwent content validation by a panel of experts in Radiologic Technology education and educational research. The experts evaluated the questionnaire items for clarity, relevance, and alignment with the study's objectives, suggesting minor revisions to improve readability and accuracy.

Second, a pilot test was conducted with a small group of Radiologic Technology students who were not included in the final study. The purpose of the pilot test was to determine the instrument's reliability and internal consistency. Reliability was assessed using Cronbach's alpha, with a computed value of 0.92

which was considered acceptable. The results indicated that the questionnaire items were consistent and effectively measured both students' perceived exposure to technological pedagogy and their learning skills development. These validation procedures ensured that the instrument was both credible and dependable, providing trustworthy data for statistical analysis in the study.

Data Gathering Procedures

The data for this study were collected following a systematic and structured procedure to ensure accuracy, reliability, and ethical compliance. First, permission to conduct the study was obtained from the program chairman and the office of the school director. The objectives, significance, and scope of the study were clearly explained to ensure transparency and to secure support from the institution.

Next, the respondents were formally invited to participate, and the purpose of the study was thoroughly communicated to them. The participants were assured of confidentiality and anonymity, and their consent was obtained prior to administering the questionnaire. They were informed that participation was entirely voluntary and that they could withdraw at any time without any penalty.

The questionnaire was then distributed to all second-year, third-year, and fourth-year students through a combination of online and face-to-face administration, depending on accessibility and convenience. Respondents were given clear instructions on how to complete the survey and were encouraged to answer honestly based on their experiences and perceptions. A period of one to two weeks was allotted for completing the questionnaire to allow respondents ample time to provide thoughtful responses. After collection, the responses were checked for completeness and consistency. Any incomplete or improperly filled questionnaires were excluded from the final dataset to maintain data quality. The gathered data were then coded and prepared for statistical analysis to examine the levels of students' perceived exposure to technological pedagogy, their learning skills development, and the relationships and predictive effects between these variables.

The data gathering procedure was carefully designed to uphold ethical standards, ensure accuracy of responses, and facilitate the collection of reliable data necessary for answering the research questions and testing the hypothesis of the study.

Statistical Treatment of the Study

The data collected in this study ere analyzed using quantitative statistical methods appropriate for descriptive-correlational research. To determine the level of students' perceived exposure to technological pedagogy and their learning skills development, means was employed. Mean scores were interpreted based on a 5-point Likert scale, where higher scores indicated greater perceived exposure to technological pedagogy or higher levels of learning skills development.

To examine the relationship between students' perceived exposure to technological pedagogy and their learning skills development, the Pearson Product-Moment Correlation Coefficient (r) was used. This statistical test allowed the researcher to determine the strength and direction of the linear relationship between the independent variable and the dependent variable.

Furthermore, to assess the predictive influence of technological pedagogy on students' learning skills development, simple linear regression analysis was conducted. This analysis determined whether perceived exposure to technological pedagogy significantly predicts learning skills development and quantified the extent of its influence on the dependent variable.

All statistical analyses were performed using IBM SPSS Statistics software, and the level of significance was set at 0.05. The chosen statistical treatments ensured that the study's results were accurate, reliable, and aligned with the research objectives and hypothesis, allowing for meaningful interpretation and evidence-based conclusions regarding the impact of technological pedagogy on students' learning skills in Radiologic Technology education.

Ethical Considerations

This study adhered to ethical standards to ensure the protection, rights, and welfare of all participants. Prior to data collection, permission to conduct the research was obtained from the administration and program coordinators of the selected Radiologic Technology programs. The respondents were fully informed about the purpose, objectives, and significance of the study, and their voluntary participation was emphasized. Informed consent was secured from all participants, assuring them that they could withdraw from the study at any time without any academic or personal repercussions.

To protect confidentiality and anonymity, respondents were assigned codes instead of using their names, and all data were handled in a secure manner. The information collected was used exclusively for research purposes, and results were presented in aggregated form to prevent identification of individual respondents. The study also adhered to ethical guidelines for research involving human subjects, ensuring that no harm, discomfort, or risk was imposed on the participants during the survey process.

These ethical measures ensured that the research was conducted responsibly, respecting the dignity, privacy, and rights of all student participants while allowing for the collection of accurate and reliable data for examining the impact of technological pedagogy on learning skills development in Radiologic Technology education.

RESULTS AND DISCUSSION

Level of Students' Perceived Exposure to Technological Pedagogy in Radiologic Technology Education

Tables 1 – 5 displays the level of students' perceived exposure to technological pedagogy in radiologic technology education in terms of learning platform, simulation-based learning, multimedia instructional materials, and online collaborative tools.

Table 1. *Level of students' perceived exposure to technological pedagogy in Radiologic Technology education – Learning Platform*

Indicators	Mean	Interpretation
1. I access lecture materials and resources through MS Teams regularly.	4.24	High level
2. I submit assignments and complete online assessments via our learning platform	4.35	High level
3. I participate in online quizzes and polls on our learning platform.	4.28	High level
4. Our present learning platform is the tool that help me track my learning progress and grades.	4.15	High level
5. I interact with instructors and peers through our learning platform forums and discussion boards.	4.15	High level
Composite Mean	4.24	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

The results in Table 1 reveal that the overall level of students' perceived exposure to technological pedagogy through the learning platform is high, as indicated by the composite mean of 4.24. This suggests that students are consistently engaged with the platform in various aspects of their learning.

The indicator *"I submit assignments and complete online assessments via our learning platform"* obtained the highest mean of 4.35, interpreted as a high level of exposure. This finding indicates that students are highly engaged in using Microsoft Teams for submitting academic requirements and completing assessments, making it the most utilized function of the platform. This suggests that assessment-related activities are strongly integrated into the students' learning experience and are consistently practiced in their courses. This result is supported by existing literature on Learning Management Systems (LMS), which emphasizes that one of the primary functions of digital learning platforms is the administration and management of assessments. According to Rosário and Dias (2022) and Alshammari et al. (2024), LMS platforms streamline the submission of assignments and facilitate online assessments, improving efficiency, accessibility, and organization in course management. These systems allow instructors to provide timely feedback and enable students to complete tasks in a structured and flexible environment. Furthermore, the high engagement in assessment-related activities reflects the effectiveness of LMS tools in promoting accountability and continuous evaluation of student learning. The high mean for this indicator implies that the learning platform is successfully utilized for academic compliance and performance evaluation. However, it also suggests that students may associate the platform primarily with submission and assessment tasks rather than as a holistic learning environment.

On the other hand, the lowest mean of 4.15, although still interpreted as high level, was observed in the indicators *"Our present learning platform helps me track my learning progress and grades"* and *"I interact with instructors and peers through our learning platform forums and discussion boards."* This indicates that while students do use the platform for monitoring progress and communication, these aspects are relatively less emphasized compared to assessment-related functions. This finding is consistent with literature suggesting that while LMS platforms are designed to support communication and progress tracking, these features are often underutilized by students. Kasim and Khalid (2020) and Al-Rahmi et al. (2023) highlight that discussion forums, collaborative tools, and progress monitoring systems are essential for promoting interactive and student-centered learning. However, the effectiveness of these features depends on how frequently they are integrated into instructional practices. Additionally, Rosário and Dias (2022) noted that although LMS platforms provide analytics and tracking tools, students may not fully engage with these unless guided by instructors. The relatively lower mean suggests a need to strengthen the use of the platform for interaction and self-monitoring of learning. This implies that instructors may need to design more collaborative and interactive activities, such as discussion-based tasks and peer engagement, to maximize these features. Moreover, encouraging students to actively monitor their progress can foster greater self-regulated learning, which is essential in higher education.

Table 2. *Level of students' perceived exposure to technological pedagogy in Radiologic Technology education – Simulation-Based Learning*

Indicators	Mean	Interpretation
1. I engage in simulated radiologic procedures to practice clinical skills.	3.85	High level
2. Simulation exercises help me understand patient care protocols.	4.20	High level
3. I can safely practice imaging procedures in simulations before real clinical exposure.	4.01	High level
4. Simulations allow me to experiment with techniques and learn from mistakes	4.15	High level
5. I feel more confident in performing tasks after simulation-based learning.	4.04	High level
Composite Mean	4.05	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

Table 2 illustrates the level of of students' perceived exposure to technological pedagogy in Radiologic Technology education in terms of simulation-based learning. The indicator *"Simulation exercises help me understand patient care protocols"* obtained the highest mean of 4.20, interpreted as a high level of exposure. This finding indicates that simulation-based learning is most effective in enhancing students' understanding of proper patient care procedures, which are critical in Radiologic Technology practice. It suggests that students are able to connect theoretical knowledge with clinical application through structured simulation activities.

This result is supported by literature emphasizing the role of simulation-based learning (SBL) in bridging theory and practice. According to French et al. (2026), SBL allows students to apply theoretical concepts in a controlled and risk-free environment, significantly improving their readiness for clinical placements and their understanding of patient care protocols. Similarly, Hazell et al. (2020) highlighted that simulation provides authentic learning experiences that strengthen students' clinical competence and professional confidence. Moreover, Jabaay et al. (2020) found that students exposed to simulation-based learning demonstrated improved clinical skills and academic performance, further supporting its effectiveness in enhancing comprehension of essential healthcare procedures. The high mean implies that simulation-based learning is particularly effective in reinforcing patient care knowledge, which is fundamental in Radiologic Technology education. This suggests that institutions should continue strengthening simulation activities focused on patient handling, safety protocols, and clinical decision-making.

However, the indicator *"I engage in simulated radiologic procedures to practice clinical skills"* obtained the lowest mean of 3.85, although still interpreted as a high level. This suggests that while students are exposed to simulation activities, their actual engagement in performing simulated procedures is relatively lower compared to other aspects such as understanding protocols and gaining confidence. This finding aligns with studies indicating that although simulation is widely recognized as an effective teaching strategy, the level of hands-on engagement may vary depending on access to resources, time allocation, and instructional design. Partner et al. (2023) reported that while a majority of radiography programs utilize simulation, the extent of student participation can differ based on available facilities and integration into the curriculum. Additionally, French et al. (2026) emphasized that optimal benefits of SBL are achieved when students are actively involved in repeated and immersive practice, suggesting that limited engagement may reduce its full impact. The relatively lower mean indicates a need to increase opportunities for active participation in simulated procedures. This implies that the institution may enhance the frequency, duration, or accessibility of simulation sessions to ensure that all students can fully practice clinical skills.

Table 3. *Level of students' perceived exposure to technological pedagogy in Radiologic Technology education – Multimedia Instructional Materials*

Indicators	Mean	Interpretation
1. I watch videos or animations to understand radiologic procedures.	4.06	High level
2. Interactive presentations help me grasp complex imaging concepts.	4.32	High level
3. Multimedia resources make learning more engaging.	4.37	High level
4. Audio-visual materials aid in retaining theoretical knowledge.	4.25	High level
5. I use multimedia tools to review lessons independently.	4.24	High level
Composite Mean	4.25	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

This table presents findings related to level of students' perceived exposure to technological pedagogy in Radiologic Technology education in terms of multi-media instructional materials. The indicator *"Multimedia resources make learning more engaging"* obtained the highest mean of 4.37, interpreted as a high level of exposure. This finding indicates that students perceive multimedia instructional materials as highly effective in increasing their engagement in learning Radiologic Technology concepts. It suggests that the integration of various digital elements such as videos, animations, and interactive content significantly enhances students' interest and participation in the learning process. This result is strongly supported by existing literature, which emphasizes the role of multimedia in creating engaging and interactive learning environments. According to Haleem et al. (2022), digital technologies have transformed education by making learning more accessible, interactive, and student-centered, thereby improving both engagement and academic performance. Similarly, Gallego II (2024) explained that multimedia instructional materials, which combine text, images, audio, and video, cater to different learning styles and increase student motivation and participation. Furthermore, Amores (2025) highlighted that technology-based instructional tools promote active learning and enhance students' ability to interact with educational content effectively. In the context of radiologic and medical education, Stirrat et al. (2024) also emphasized that multimedia tools such as imaging platforms and digital resources improve students' understanding and diagnostic skills, making learning more meaningful and engaging. The high mean implies that multimedia instructional materials play a crucial role in sustaining student engagement and motivation in learning. This suggests that educators should continue integrating diverse multimedia resources into instruction to maintain student interest and promote active participation.

Nevertheless, the indicator *"I watch videos or animations to understand radiologic procedures"* obtained the lowest mean of 4.06, although still interpreted as a high level. This suggests that while students do utilize videos and animations, their use is relatively less frequent or less emphasized compared to other multimedia components such as interactive presentations and overall engagement. This finding aligns with literature indicating that while multimedia materials are widely beneficial, the extent of their use may vary depending on instructional design and accessibility. Haleem et al. (2022) noted that although digital tools provide convenient access to learning resources, their effectiveness depends on how they are integrated into teaching practices. Additionally, Rizqa et al. (2023) emphasized that structured and interactive multimedia implementation significantly improves learning outcomes, suggesting that passive use of videos alone may not be as impactful as more interactive multimedia approaches. Moreover, studies on extended reality (XR) technologies in radiology education highlight that more immersive and interactive tools tend to produce stronger learning outcomes compared to traditional video-based materials, as they enhance spatial understanding and clinical reasoning skills (Journal of the American College of Radiology, 2024). The relatively lower mean implies a need to further enhance the use of video- and animation-based learning resources by making them more interactive and integrated into course activities. Educators may incorporate guided video analysis, embedded questions, or simulation-linked multimedia to maximize their effectiveness.

Table 4. *Level of students' perceived exposure to technological pedagogy in Radiologic Technology education – Online Collaborative Tools*

Indicators	Mean	Interpretation
1. I collaborate with peers using online platforms for group projects.	4.10	High level
2. I participate in online discussions or forums to exchange ideas.	3.96	High level
3. Online tools help me coordinate tasks effectively with group members.	4.20	High level
4. I use digital platforms to provide and receive feedback from peers.	4.11	High level
5. Collaborative tools improve my communication and teamwork skills.	4.15	High level
Composite Mean	4.11	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

Table 4 discusses the students' level of perceived exposure to technological pedagogy in Radiologic Technology education in term sof collaborative tools. It is observed that the indicator *"Online tools help me coordinate tasks effectively with group members"* obtained the highest mean of 4.20, interpreted as a high level of exposure. This finding indicates that students strongly perceive online collaborative tools as effective in organizing and managing group tasks. It suggests that digital platforms play a significant role in facilitating coordination, task delegation, and communication among students, particularly in group-based academic activities. This result is supported by literature emphasizing the importance of online collaborative tools in enhancing teamwork and productivity in educational settings. Studies have shown that digital platforms enable efficient communication, task management, and real-time collaboration, allowing students to work together despite time and location constraints. These tools promote structured collaboration by providing shared workspaces, file-sharing capabilities, and communication channels, which improve group coordination and overall task performance. Additionally, research highlights that technology-supported collaboration fosters essential 21st-century skills such as teamwork, communication, and problem-solving, which are crucial in health-related fields like Radiologic Technology. The high mean implies that online collaborative tools are effectively supporting group coordination and teamwork among students. This suggests that educators should continue integrating collaborative digital platforms into instructional activities, particularly for group projects and task-based learning.

In contrast, the indicator *"I participate in online discussions or forums to exchange ideas"* obtained the lowest mean of 3.96, although still interpreted as a high level. This suggests that while students do engage in online discussions, their participation in forums or idea-sharing platforms is relatively less frequent compared to other collaborative activities such as task coordination and feedback exchange. This finding is consistent with literature indicating that while online collaborative tools provide opportunities for interaction, active participation in discussions depends largely on instructional design and facilitation. Studies suggest that students are more likely to engage in task-oriented collaboration (e.g., completing group work) than in open-ended discussions unless guided by structured activities. Furthermore, research on technology-enhanced learning environments highlights that discussion forums require clear prompts, active moderation, and integration into assessment to encourage meaningful participation and knowledge exchange. The relatively lower mean indicates a need to strengthen students' engagement in online discussions and idea exchange. This implies that instructors may incorporate more structured discussion activities, such as graded forums, guided questions, or peer-led discussions, to encourage active participation.

Table 5. *Summary of the level of students' perceived exposure to technological pedagogy in Radiologic Technology education*

Indicators	Mean	Interpretation
Learning Platform	4.24	High level
Simulation-based learning activities	4.05	High level
Multimedia and interactive instructional materials	4.25	High level
Online collaborative learning tools	4.11	High level
Composite Mean	4.07	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

Table 5 presents the overall summary of students' perceived exposure to technological pedagogy in Radiologic Technology education. The table shows that students reported a high level of exposure across all examined technological pedagogies. Specifically, the highest mean was observed in multimedia and interactive instructional materials (4.25), indicating that students most frequently engage with videos, animations, and interactive content to support their learning. This is closely followed by the learning platform (4.24), showing that students regularly use the learning management system to access course materials, submit assignments, and track progress. Online collaborative learning tools received a mean of 4.11, reflecting consistent use of digital platforms to collaborate, communicate, and exchange feedback with peers. Meanwhile, simulation-based learning activities had a slightly lower mean of 4.05, still at a high level, suggesting that students actively engage in simulations to practice radiologic procedures in controlled, risk-free environments.

The composite mean of 4.07 confirms that, overall, students perceive their exposure to technological pedagogies in Radiologic Technology education as high. This indicates that the integration of multiple digital tools and instructional methods is consistently present in the curriculum, providing students with diverse opportunities to enhance their learning experiences, develop practical skills, and engage interactively with course content.

Level of Student Learning Skills Development

Table 6. *Level of students' learning skills development - Critical Thinking and Clinical Reasoning*

Indicators	Mean	Interpretation
1. I can analyze clinical scenarios more effectively after technology-enhanced instruction.	4.04	High level
2. I make more informed decisions when interpreting imaging results.	4.00	High level
3. Technology-based learning helps me evaluate patient conditions accurately.	4.00	High level
4. I can identify errors or inconsistencies in procedures more effectively.	3.92	High level
5. Technology integration promotes reflective thinking on my clinical performance.	4.03	High level
Composite Mean	4.00	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

Table 6 shows the level of students' learning skills development in terms of critical thinking and clinical reasoning. The overall composite mean of 4.00, interpreted as a high level, indicates that students perceive their critical thinking and clinical reasoning skills as well-developed through technology-enhanced instruction. This suggests that the integration of technological tools and methods in Radiologic Technology education contributes significantly to students' ability to analyze clinical scenarios, make informed decisions, and evaluate patient conditions effectively. This aligns with literature emphasizing the importance of critical thinking and clinical reasoning in healthcare education. Firman et al. (2025) note that these cognitive competencies are essential for accurate diagnosis, effective treatment planning, and safe patient management. Technology-enhanced instruction, including simulations, virtual learning, and interactive case-based activities, provides students with opportunities to practice decision-making, analyze clinical information, and reflect on performance in a structured and risk-free environment, thereby reinforcing these essential skills.

The highest mean of 4.04 was obtained by the indicator: *"I can analyze clinical scenarios more effectively after technology-enhanced instruction."* This suggests that students perceive the strongest impact of technology integration on their ability to critically analyze clinical situations. This finding is supported by studies indicating that simulation-based and technology-supported learning enhances students' analytical and decision-making skills. Firman et al. (2025) highlight that simulation activities allow students to engage in realistic clinical scenarios, evaluate patient conditions, and apply theoretical knowledge practically, which strengthens their clinical reasoning abilities. Similarly, virtual learning environments and problem-based learning approaches encourage students to actively engage with complex cases, promoting higher-order thinking and reflective analysis. The highest mean indicates that technology-enhanced instruction is particularly effective in fostering analytical thinking and scenario-based problem solving.

The lowest mean of 3.92 was observed in the indicator: *"I can identify errors or inconsistencies in procedures more effectively."* Although still interpreted as high level, this suggests that students feel slightly less confident in detecting procedural errors compared to other critical thinking tasks. Literature indicates that identifying errors and inconsistencies requires repeated practice and exposure to varied clinical scenarios. Firman et al. (2025) emphasize that while simulations and technology-supported learning improve overall clinical reasoning, the ability to detect mistakes depends on structured feedback, guided reflection, and iterative practice. Without sufficient opportunities to analyze mistakes in controlled settings, students' confidence in error detection may be lower compared to other reasoning skills. The relatively lower mean highlights a need to strengthen students' exposure to activities that focus on error recognition and quality control in clinical procedures.

On the other hand, table 7 shows the level of students' learning skills development in terms of technical and procedural competence. The overall composite mean of 3.84, interpreted as high level, indicates that students perceive their technical and procedural competence as well-developed through technology-enhanced learning activities. This suggests that the integration of technological tools, simulations, and structured practice in Radiologic Technology education supports the development of practical skills, confidence, and accuracy in performing clinical procedures.

Table 7. *Level of students' learning skills development - Technical and Procedural Competence*

Indicators	Mean	Interpretation
1. My skills in handling radiologic equipment have improved through technology-enhanced activities.	3.95	High level
2. I can perform imaging procedures with greater accuracy.	3.77	High level
3. Technology-based practice has strengthened my clinical skills.	3.82	High level
4. I feel confident in applying procedural techniques independently.	3.71	High level
5. Technology-supported learning has reduced errors in performing tasks.	3.92	High level
Composite Mean	3.84	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

This finding is consistent with literature emphasizing the importance of technical and procedural competence in healthcare education. Ahmedin et al. (2024) highlight that structured training, continuous practice, and supervised clinical experiences are essential for developing students' ability to safely and accurately perform clinical tasks.

Moreover, the highest mean of 3.95 was observed in the indicator: *"My skills in handling radiologic equipment have improved through technology-enhanced activities."* This indicates that students perceive the most significant benefit of technology integration in terms of practical skills related to equipment handling. This result aligns with studies emphasizing that hands-on practice with clinical equipment, combined with technology-supported learning, improves students' technical abilities and operational confidence. Zafošnik et al. (2024) note that simulation-based and technology-enhanced activities allow learners to familiarize themselves with medical devices in a risk-free environment, reinforcing correct handling techniques and procedural accuracy. Ahmedin et al. (2024) further explain that repeated exposure to equipment and procedural practice strengthens psychomotor skills and reduces errors during real clinical applications. The highest mean suggests that technology-enhanced instruction is particularly effective in developing equipment handling skills, which are fundamental to safe and accurate radiologic practice.

However, the lowest mean of 3.71 was recorded in the indicator: *"I feel confident in applying procedural techniques independently."* Although still interpreted as high level, this indicates that students feel slightly less confident performing procedures independently compared to other technical skills. This aligns with literature emphasizing that independent procedural confidence develops gradually and requires consistent practice, feedback, and assessment. Simulation-based learning allows students to practice safely, but independent competence often depends on sufficient exposure to varied scenarios and supervision (Zafošnik et al., 2024; Albalawi & Rezq, 2024). Limited practice opportunities, time constraints, or access to advanced equipment may affect students' confidence in performing tasks without guidance. The relatively lower mean highlights the need to increase opportunities for independent procedural practice.

Structured simulation exercises, supervised clinical sessions, and progressive autonomy in performing tasks can help students build confidence and ensure readiness for real-world clinical responsibilities.

Table 8. *Level of students' learning skills development - Digital Literacy*

Indicators	Mean	Interpretation
1. I can effectively use software, apps, and digital resources for learning.	4.19	High level
2. Technology integration has enhanced my ability to navigate digital tools for academic purposes.	4.20	High level
3. I can adapt to new technological tools more quickly.	4.25	High level
4. I feel confident using digital tools to solve learning-related problems.	4.18	High level
5. I can integrate digital resources into my independent study effectively.	4.14	High level
Composite Mean	4.19	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

Table 8 highlights the level of students' learning skills development in terms of digital literacy. It is noted that the overall composite mean of 4.19, interpreted as a high level, indicates that students perceive their digital literacy skills as well-developed through technology-enhanced instruction. This suggests that Radiologic Technology students are generally confident in using digital tools, applications, and resources to support both academic and clinical learning. This aligns with literature emphasizing the critical role of digital literacy in higher education. Aripradono (2025) explains that digital literacy is a fundamental skill for academic success and professional development, enabling students to effectively access, process, and apply information using digital technologies. In allied health education, digital literacy is particularly important, as students routinely use technologies in classroom and clinical settings (Aydınlar et al., 2024). Strong digital literacy ensures that students can navigate these tools confidently, integrate resources into independent learning, and adapt to evolving technological demands in healthcare practice.

Furthermore, the highest mean of 4.25 was observed in the indicator: *"I can adapt to new technological tools more quickly."* This indicates that students perceive themselves as highly capable of learning and adjusting to emerging digital tools. This finding is supported by research highlighting that adaptive digital literacy is a critical component of 21st-century learning. Wang et al. (2025) emphasized that discipline-specific digital competencies, including adaptability to new software and digital environments, are essential for students in health professions. Similarly, Mainz et al. (2024) argued that the ability to quickly learn and apply new technological tools enhances student engagement, self-efficacy, and preparedness for both academic and clinical challenges. For Radiologic Technology students, rapid adaptation is especially important as clinical technologies, imaging software, and simulation tools are constantly evolving. The highest mean implies that students are confident in their ability to learn and use new digital tools, which is critical for continuous learning and professional growth.

Conversely, the lowest mean of 4.14 was found in the indicator: *"I can integrate digital resources into my independent study effectively."* Although still interpreted as high level, this suggests that students feel slightly less confident in independently applying digital tools to organize and enhance their learning outside structured instruction. This aligns with literature noting that while students may be proficient with digital tools, independent application requires guidance, structured tasks, and opportunities to develop self-directed learning strategies (Yuan N. et al., 2025). Aydınlar et al. (2024) highlighted that independent integration of digital resources can vary among students and recommended curricular support to strengthen competencies for self-directed digital learning. In Radiologic Technology education, students must not only operate digital tools but also apply them independently for tasks such as reviewing imaging cases, analyzing simulations, or conducting research.

Table 9. *Level of students' learning skills development - Self-Directed Learning*

Indicators	Mean	Interpretation
1. I take initiative in planning and managing my learning.	4.01	High level
2. I can set learning goals and monitor my progress independently.	4.11	High level
3. Technology-enhanced learning encourages me to seek additional resources.	4.08	High level
4. I can evaluate my own understanding and performance effectively.	4.09	High level
5. I am motivated to learn independently using digital tools.	4.11	High level
Composite Mean	4.08	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

` The table illustrates the level of students' learning skills in terms of self-directed learning. It can seen from the table that the composite mean is 4.08 which interpreted as high level. It indicates that students perceive their self-directed learning (SDL) skills as well-developed through technology-enhanced instruction. This suggests that students are actively managing their learning, setting goals, seeking additional resources, and evaluating their own progress with considerable independence. This finding is supported by literature emphasizing that SDL promotes learner autonomy, responsibility, and active engagement in the learning process. Smith & Tricia (2021) describe SDL as an instructional approach that empowers learners to take control of their education, plan their study, and monitor progress independently. In healthcare and allied health education, SDL encourages students to develop critical thinking, self-awareness, and problem-solving skills, all of which are essential for professional competence (Hernandez, 2020; Setiawan & Artini, 2021).

The result show that there are two indicators with the highest mean, "*I can set learning goals and monitor my progress independently*." And *"I am motivated to learn independently using digital tools.*", bothe with a mean of 4.11 and interpreted as high level. These findings indicate that students perceive themselves as particularly strong in goal-setting, progress monitoring, and motivation for independent learning, which are essential aspects of SDL. Literature supports this by highlighting that goal-setting and self-monitoring are central to effective self-directed learning. Li et al. (2022) note that students who can independently plan, track, and evaluate their learning tend to achieve higher academic outcomes due to increased motivation and structured study strategies. Additionally, Gerard et al. (2022) emphasize that SDL promotes active inquiry and deeper engagement with learning materials, particularly when learners are provided with opportunities to explore resources independently. The use of technology enhances these processes by enabling students to access diverse learning tools and monitor progress digitally, which strengthens motivation and self-efficacy (Ferdianto & Anindita, 2023).

The lowest mean of 4.01 was recorded in the indicator: "*I take initiative in planning and managing my learning*." Although still interpreted as high level, this suggests that students are slightly less confident in proactively initiating learning activities compared to other SDL skills. This is consistent with literature indicating that while technology can enhance independent learning, some students may require additional guidance or scaffolding to develop the habit of taking initiative. Hernandez (2020) and Setiawan & Artini (2021) explain that students transitioning from teacher-centered instruction may initially struggle with self-management and proactive learning behaviors. Therefore, structured support, gradual exposure to independent tasks, and clear expectations are critical for fostering initiative in SDL.

Table 10. Level of students' learning skills development - Communication and Teamwork

Indicators	Mean	Interpretation
1. Technology-supported group activities improve my teamwork skills.	4.19	High level
2. I communicate effectively with peers and instructors through online tools.	4.15	High level
3. I can contribute ideas and collaborate efficiently in online group tasks.	4.14	High level

4. I can resolve conflicts and coordinate tasks better through collaborative platforms.	4.04	High level
5. Technology integration enhances my overall communication skills in academic settings.	4.15	High level
Composite Mean	4.13	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

Table 10 presents the level of students' learning skill development in terms of communication and teamwork. It is observed the composite mean is 4.13 and interpreted as high level. It indicates that students perceive their communication and teamwork skills as well-developed through technology-enhanced learning. This suggests that Radiologic Technology students are effectively using digital tools to communicate, collaborate, and coordinate with peers and instructors, which is essential for academic and clinical success. These results align with studies highlighting the critical role of communication and teamwork in healthcare education. Rawashdeh et al. (2025) emphasize that structured communication training in radiography programs improves patient interaction and promotes effective teamwork in clinical settings.

The highest mean of 4.19 was observed in the indicator: *"Technology-supported group activities improve my teamwork skills."* This suggests that students perceive the strongest benefit of technology integration in the development of teamwork abilities. Literature supports this finding by showing that collaborative digital learning environments foster interaction, discussion, and problem-solving among students. Elshami et al. (2020) report that peer-assisted learning and technology-supported group tasks increase confidence in decision-making, promote interpersonal skills, and enhance collaborative abilities essential for healthcare teams. Additionally, Zhang et al. (2024) emphasize that structured teamwork activities, especially when supported by online tools, improve coordination and communication among students, thereby reinforcing practical competencies required in clinical settings. The highest mean implies that technology-enhanced group activities are particularly effective in developing teamwork skills.

However, the lowest mean of 4.04 was recorded in the indicator: *"I can resolve conflicts and coordinate tasks better through collaborative platforms."* Although still interpreted as high level, this suggests that students feel slightly less confident in using technology specifically for conflict resolution and task coordination. This is consistent with literature noting that while collaborative tools improve general communication, students may need additional guidance to effectively manage conflicts and coordinate complex tasks. O'Connor et al. (2024) identified that barriers to teamwork include integrating into clinical teams and bridging the gap between theoretical and practical experiences. Technology alone may not fully address these challenges; structured training in conflict resolution, role assignment, and task management is also necessary.

Table 11. *Summary of the level students' learning skills development*

Indicators	Mean	Interpretation
Critical Thinking and Clinical Reasoning	4.00	High level
Technical and Procedural Competence	3.84	High level
Digital Literacy	4.19	High level
Self-Directed Learning	4.08	High level
Communication and Teamwork	4.13	High level
Composite Mean	4.05	High level

Legend:5.00 – 4.50, Very highly level; 4.49 – 3.50, High level; 3.49 - 2.50, Moderate level; 2.49 – 1.50, Low level; 1.49 – 1.00, very low level

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Table 11 displays the summary of the level of students learning skills development. The overall composite mean of 4.05, interpreted as high level, indicates that students perceive their learning skills development in Radiologic Technology education as generally well-developed. This suggests that technology-enhanced learning across multiple domains such as critical thinking, technical competence, digital literacy, self-directed learning, and communication and teamwork, has positively contributed to students' overall academic and professional preparedness. In healthcare education, integrating technology-enhanced instruction, simulation, and collaborative digital tools strengthens higher-order thinking, practical competence, and digital readiness. Firman et al. (2025) emphasize that simulation and technology-supported instruction enhance critical thinking and clinical reasoning, while Ahmedin et al. (2024) and Zafošnik et al. (2024) note that technical and procedural competence improves with structured practice and simulation.

The highest mean of 4.19 was observed in Digital Literacy. This indicates that students perceive themselves as most proficient in navigating, adapting to, and applying digital tools and resources for learning. This is consistent with literature showing that digital literacy is increasingly essential in higher education and allied health fields. Aydınlar et al. (2024) emphasized that digital competencies, including the use of software, online resources, and simulation platforms, are critical for academic success and professional readiness. The highest mean highlights the importance of continuing to integrate and update technology-based learning resources.

The lowest mean of 3.84 was recorded in Technical and Procedural Competence, indicating that while students' practical skills are still at a high level, they are relatively lower compared to other domains. This aligns with studies suggesting that developing procedural competence requires consistent practice, supervision, and structured learning opportunities. Simulation-based activities are helpful, but students may need additional hands-on experiences or progressive exposure to complex procedures to gain confidence and mastery (Ahmedin et al., 2024).

Significant Relationship Between Students' Perceived Exposure To Technological Pedagogy and Their Development Of Learning Skills In Radiologic Technology Education

Table 12. *Significant relationship between students' perceived exposure to technological pedagogy and their development of learning skills in Radiologic Technology education*

Variable		Technical and Procedural Competence	Digital Literacy	Self-Directed Learning	Communication and Teamwork	Critical Thinking and Clinical Reasoning
Learning Platform	Pearson Correlation	0.440**	0.486**	0.499**	0.527**	0.516**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
	N	79	79	79	79	79
Virtual imaging and diagnostic software	Pearson Correlation	0.482**	0.475**	0.572**	0.517**	0.524**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
	N	79	79	79	79	79
Multimedia and interactive instructional materials	Pearson Correlation	0.563**	0.678**	0.660**	0.691**	0.644**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
	N	79	79	79	79	79
	Pearson Correlation	0.558**	0.619**	0.672**	0.676**	0.672**

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Online collaborative learning tools	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000
	N	79	79	79	79	79

**. Correlation is significant at the 0.01 level (2-tailed).

Table 12 illustrates the significant relationships between students' perceived exposure to technological pedagogy and the development of their learning skills in Radiologic Technology education. The findings reveal that all technological pedagogy variables such aslLearning platform, simulation-based learning, multimedia and interactive instructional materials, and online collaborative learning tools, demonstrate positive and statistically significant correlations with the five dimensions of learning skills: technical and procedural competence, digital literacy, self-directed learning, communication and teamwork, and critical thinking and clinical reasoning. All correlations are significant at the 0.01 level ($p = 0.000$), indicating robust evidence that technological pedagogical exposure is associated with enhanced learning skill development among the 79 student respondents.

The Learning Platform (MS Teams) shows moderate positive correlations with all learning skill variables, with correlation coefficients ranging from $r = 0.440$ to $r = 0.527$, the strongest being with communication and teamwork ($r = 0.527$), followed by critical thinking and clinical reasoning ($r = 0.516$). This suggests that learning platforms facilitate access to course materials, assignment submission, and peer-instructor interaction, which supports both collaborative and cognitive learning outcomes. Research by Rosário & Dias (2022) and Al-Rahmi et al. (2023) affirms that LMS platforms improve student engagement, support active participation, and enhance organizational and communication skills, thereby fostering effective learning.

Simulation-based learning activities also exhibit moderate positive correlations with all learning skills (ranging from $r = 0.524$ to $r = 0.579$), with the highest correlation observed in critical thinking and clinical reasoning ($r = 0.579$). This underscores the critical role of simulation in strengthening students' analytical and decision-making skills. Simulation allows learners to practice clinical procedures in a safe, controlled environment, enhancing procedural competence and confidence before real clinical exposure (French et al., 2026; Hazell et al., 2020).

Among all technological pedagogy variables, multimedia and interactive instructional materials show the strongest relationships, with correlations ranging from $r = 0.563$ to $r = 0.691$. The highest correlation is with communication and teamwork ($r = 0.691$), followed by digital literacy ($r = 0.678$) and self-directed learning ($r = 0.660$). These results highlight that multimedia resources, including videos, animations, and interactive presentations, create engaging learning experiences that enhance comprehension, facilitate collaboration, and develop digital proficiency (Haleem et al., 2022; Gallego II, 2024; Amores, 2025).

Similarly, online collaborative learning tools exhibit strong positive correlations across all learning skill variables, with coefficients ranging from $r = 0.558$ to $r = 0.676$, the highest being in communication and teamwork ($r = 0.676$), self-directed learning ($r = 0.672$), and critical thinking and clinical reasoning ($r = 0.672$). This finding aligns with research emphasizing that collaborative digital platforms foster peer interaction, cooperative problem-solving, and active engagement, which are essential for developing interpersonal and cognitive skills in healthcare education (Elshami et al., 2020; Rawashdeh et al., 2025; Zhang et al., 2024).

The consistent positive correlations across all technological pedagogy variables indicate that greater exposure to technology-enhanced instructional strategies is associated with higher levels of learning skills development among Radiologic Technology students. Integrating learning platforms, simulation exercises, multimedia resources, and collaborative tools into the curriculum not only strengthens technical and procedural competence but also enhances digital literacy, self-directed learning, teamwork, and critical thinking.

Effect of Students' Perceived Exposure to Technological Pedagogy on Learning Skills Development

Table 13. *Predictive Effect of Students' Perceived Exposure to Technological Pedagogy on Learning Skills Development*

Variable	Critical Thinking & Clinical Reasoning (β)	Technical & Procedural Competence (β)	Digital Literacy (β)	Self-Directed Learning (β)	Communication & Teamwork (β)
Learning Management System	0.011	0.032	0.009	0.039	0.036
Simulation-Based Learning Activities	0.137	0.032	0.071	0.025	0.025
Multimedia & Interactive Instructional Materials	0.232	0.236	0.440	0.340	0.393
Online Collaborative Learning Tools	0.304	0.185	0.187	0.292	0.275
Model Summary					
Learning Skill Variable		R	R^2	F-value	P-value
Critical Thinking & Clinical Reasoning		0.724	0524	16.073	0.000
Technical & Procedural Competence		0.636	0.404	9.894	0.000
Digital Literacy		0.707	0.500	14.616	0.000
Self-Directed Learning		0.737	0.544	17.394	0.000
Communication & Teamwork		0.741	0.549	17.805	0.000

**Note: β = standardized regression coefficient; p < 0.05*

Table 13 presents the predictive effect of students' perceived exposure to technological pedagogy on the development of learning skills in Radiologic Technology education. The regression analysis indicates that all models are statistically significant (p = 0.000), with R^2 values ranging from 0.404 to 0.549, suggesting that approximately 40% to 55% of the variance in students' learning skills development is explained by their exposure to technological pedagogical tools.

. Among the predictors, Learning Platform showed a small but positive effect across all learning skills (β = 0.009–0.039), indicating that this platforms provide foundational support by facilitating access to course materials, assignment submission, and peer-instructor interaction, though their contribution is incremental compared to more interactive approaches (Rosário & Dias, 2022).

Simulation-based learning activities demonstrated a moderate predictive effect, particularly on critical thinking and clinical reasoning (β = 0.137), highlighting the value of simulation in fostering analytical thinking, reflective practice, and decision-making in safe, controlled clinical environments (French et al., 2026; Hazell et al., 2020).

Multimedia and interactive instructional materials exerted the strongest predictive effect, especially on digital literacy (β = 0.440), self-directed learning (β = 0.340), and communication and teamwork (β = 0.393), indicating that interactive resources enhance comprehension, independent study, and collaborative skills by engaging students with dynamic and multimodal content (Haleem et al., 2022; Amores, 2025).

Similarly, online collaborative learning tools showed strong predictive effects on critical thinking and clinical reasoning (β = 0.304), self-directed learning (β = 0.292), and communication and teamwork (β = 0.275), suggesting that platforms for peer discussion, group tasks, and feedback foster both cognitive and interpersonal competencies (Elshami et al., 2020; Rawashdeh et al., 2025).

These results indicate that students' exposure to technology-enhanced instructional strategies, particularly interactive multimedia and collaborative tools, significantly contributes to the development of technical, cognitive, digital, self-directed, and teamwork skills. The findings highlight the importance of integrating multiple technological pedagogies in Radiologic Technology education to promote holistic skill development and prepare students for both academic success and professional clinical practice (Firman et al., 2025; Aripradono, 2025).

Summary of Findings

1. Level of Students' Perceived Exposure to Technological Pedagogy

1.1 Learning Platform – Students reported a high level of exposure to the learning platform with a mean of 4.24. They regularly accessed lecture materials, submitted assignments, participated in online assessments, and interacted with instructors and peers through the platform.

1.2 Simulation-Based Learning Activities – Students indicated a high level of engagement with simulation-based learning, with a mean of 4.05. They practiced radiologic procedures, applied patient care protocols, and gained confidence in performing tasks in a controlled environment.

1.3 Multimedia and Interactive Instructional Materials – This pedagogical tool showed the highest level of student exposure, with a mean of 4.25. Students actively used videos, interactive presentations, and other multimedia resources to enhance understanding, engage in lessons, and review content independently.

1.4 Online Collaborative Learning Tools – Students reported high exposure, with a mean of 4.11. They used digital platforms to collaborate on group projects, participate in discussions, coordinate tasks, provide feedback, and improve teamwork and communication skills.

2. Level of Students' Learning Skills Development

2.1 Critical Thinking and Clinical Reasoning – Students perceived a high level of development (mean = 4.00). They reported improved abilities to analyze clinical scenarios, make informed decisions, evaluate patient conditions, identify errors, and reflect on their performance.

2.2 Technical and Procedural Competence – Students demonstrated a high level of competence (mean = 3.84). They reported improved skills in handling radiologic equipment, performing imaging procedures accurately, applying techniques independently, and reducing procedural errors.

2.3 Digital Literacy – Students reported a high level of digital literacy (mean = 4.19). They were able to effectively use software, digital tools, and apps, adapt to new technologies, integrate digital resources into independent learning, and solve learning-related problems.

2.4 Self-Directed Learning – Students perceived a high level of self-directed learning (mean = 4.08). They took initiative in planning and managing their learning, set goals, evaluated their understanding, sought additional resources, and maintained motivation to learn independently.

2.5 Communication and Teamwork – Students reported a high level of development in communication and teamwork (mean = 4.13). They were able to communicate effectively with peers and instructors, contribute to group tasks, coordinate activities, resolve conflicts, and enhance overall teamwork skills.

3. Relationship Between Students' Perceived Exposure to Technological Pedagogy and Learning Skills Development

The study found significant positive relationships between all technological pedagogy variables (LMS, simulation-based learning activities, multimedia and interactive instructional materials, online collaborative learning tools) and students' learning skills development. Correlation coefficients ranged from moderate to strong, showing that higher exposure to technological pedagogies is associated with improved technical, cognitive, and interpersonal skills.

4. Predictive Effect of Students' Perceived Exposure to Technological Pedagogy on Learning Skills Development

The analysis revealed that technological pedagogy significantly predicts students' learning skills development across all domains. Multimedia and interactive instructional materials and online collaborative tools were the strongest predictors, particularly for digital literacy, communication and teamwork, and self-directed learning. Simulation-based learning activities were the strongest predictor for critical thinking and clinical reasoning, while Learning Platform had a lower but still positive predictive effect.

CONCLUSIONS

Based on the findings of the study, the following conclusions can be drawn:

1. Radiologic Technology students at UPHSD Calamba Campus have a high level of exposure to technological pedagogies, with multimedia and interactive instructional materials being the most frequently used.
2. Students' learning skills development is generally high, with digital literacy showing the greatest improvement, followed by communication, self-directed learning, technical competence, and critical thinking.
3. There is a significant positive relationship between students' exposure to technological pedagogy and their learning skills development, indicating that greater engagement with digital tools enhances technical, cognitive, and interpersonal competencies.
4. Technological pedagogy significantly predicts students' learning skills, with multimedia and collaborative tools being strong predictors for digital literacy, self-directed learning, and communication, while simulation activities strongly influence critical thinking and clinical reasoning.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed:

1. To reinforce students' high exposure to technological pedagogies, faculty members are suggested to consistently integrate multimedia resources such as videos, animations, and interactive presentations in lessons to enhance comprehension and engagement.
2. Given the positive impact of simulation on critical thinking and clinical reasoning, the program is recommended to expand simulation opportunities and provide structured scenarios that allow students to safely practice radiologic procedures and develop technical competence.
3. To support the development of digital literacy, self-directed learning, and communication skills, instructors is suggested to optimize the use of learning platforms and online collaborative tools for group projects, discussions, and interactive activities.
4. To further improve overall learning skills and ensure technological pedagogies predict student development effectively, the program should embed technology-enhanced instruction throughout all courses, complemented by faculty training to maximize effective implementation.

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