Picture This: Integrating Radiology Case Based Learning in Gastrointestinal Physician Assistant Education

Anna Lalande PA-S2[1], Elizabeth Randolph PA-C[2], Angelique Dueñas PhD[2]

Northwestern University Feinberg School of Medicine Physician Assistant Program

Master of Medical Science in Physician Assistant Studies Research Project

Submitted: May 4th, 2026

Presented on Capstone Research Day: April 17, 2026

Abstract

Introduction: Physician assistants (PA) are expected to order and interpret diagnostic images in nearly every medical specialty. Yet there is significant variation across PA programs in how radiology is incorporated into the curriculum. This study aims to explore the use of case-based learning (CBL) as a strategy for teaching gastrointestinal radiology to first year PA students, using Vygotsky's theory of zone of proximal development to adequately challenge students.

Methods: A two-hour gastrointestinal CBL session integrating radiology, anatomy, and clinical medicine content was presented to first year PA students (n=42). Students completed a pre-test (n=38) and a post-test (n=33) assessing five learning objectives for the biliary, enteric, and hepatic systems. Following the posttest, students also completed confidence ratings and provided feedback (n=33). Pretest and posttest scores were analyzed for overall performance, organ system performance, and learning objective performance using paired t tests. Confidence ratings were analyzed using pooled Z tests, and feedback responses were assessed with basic content analysis.

Results: Students demonstrated significant improvement from pretest to posttest on overall scores (71% vs. 88%, $p < 0.001$). Significant improvement was also noted on each organ system and across nearly every learning objective. Students also reported significantly increased confidence with their anatomy and radiology skills after attending the CBL session. Student feedback on the session was overall positive, with 100% of students agreeing or strongly agreeing that the session better prepared them to interpret images in clinical year.

Discussion: Significant improvement was noted from pretest to posttest overall and across learning objectives for each organ system, suggesting that CBL may be an effective way to teach radiology skills to first year PA students while simultaneously integrating the content with their anatomy and medicine curriculum.

Introduction

The Expectations and Reality of Physician Assistant Radiology Curriculum

Regardless of specialty, most physician assistants (PAs) are responsible for reviewing and interpreting imaging within their clinical practice. This is of utmost importance in fields such as emergency medicine, where it may be necessary to make informed clinical decisions based on imaging findings prior to a final read from a radiologist. However, physician assistants in specialties such as internal medicine, surgical specialties, urgent care, obstetrics and gynecology, primary care, pediatrics, and most other specialties, also order, review, and interpret diagnostic imaging daily.

Furthermore, imaging interpretation skills are becoming more important in the context of procedural skills. Many PAs are expected to perform invasive procedures such as image-guided paracenteses and central venous access, primarily within the field of interventional radiology, but also within emergency medicine, inpatient medicine, and some outpatient clinics [1,2].

In alignment with these expectations for practicing PAs, the Accreditation Review Commission on Education for the Physician Assistant (ARC-PA) outlines clear standards related to the ordering and interpretation of diagnostic studies that all PA students graduating from accredited PA programs are required to meet [3]. The Physician Assistant Education Association (PAEA) works collaboratively with the ARC-PA to meet these standards, and they have established specific learning objectives for each standardized exam taken by PA students across all PA Programs during the clinical year [4]. In the context of radiology, these learning objectives include: selecting the appropriate initial and subsequent diagnostic study based on a clinical case, understanding the indications for a specific diagnostic study, interpreting the results of diagnostic studies, and determining the gold standard diagnostic study for a particular medical condition. The ARC-PA and PAEA therefore expect physician assistant graduates to enter the work force with a solid understanding of diagnostic studies, and the assessments administered by the PAEA during the clinical year of PA school reflect these core competencies.

While the ARC-PA and PAEA outline explicit required competencies for diagnostic imaging, there are currently no specific requirements regarding radiology education within PA school curriculum in the United States [1,5]. The ARC-PA very intentionally allows "programs to remain creative and innovative in program design and the methods of curriculum delivery and evaluation" to best suit the specific needs and goals of students and programs and to adapt to emerging beneficial teaching strategies. [3]. In other words, the structure, design, and time allocation of radiology curriculum is intentionally left up to individual PA programs, with the expectation that all PA students achieve certain competencies by graduation.

Despite these clear expectations for graduates, the 2020 PAEA curriculum report notes that on average, PA programs designated only 46.3 hours of lecture time (SD=34.2, n=228) and 22.3 hours of laboratory time (SD=26.6, n=101) to all of laboratory medicine/imaging/diagnostics [6]. It is unclear how much of that time was specifically designated for imaging. The PAEA also reported specifically on point-of care ultrasound (POCUS), a mode of imaging that is becoming increasingly utilized within clinical practice as a safe, fast, effective, and relatively affordable imaging option [5]. Only 66.4% (n=235) of the PA programs surveyed offered POCUS training, and of those programs, they reported an average of only 7.1 hours of lecture time (SD =11.4, n=131) and 10.4 hours of lab time (SD=18.3, n=118) throughout the entire PA program designated to teaching POCUS [6]. Therefore, current presentation of data suggests that despite the expectation that graduating PA students are competent in the foundations of radiology, there is significant variability between PA programs in classroom time allotted to radiology education.

This variation likely results in PA program graduates entering the workforce with a wide range of skillsets and confidence levels with ordering and interpreting diagnostic images. PAs with less thorough radiology training may order unnecessary or inappropriate imaging studies. Patient care may be delayed if additional studies need to be ordered, and patients may be exposed to additional radiation [1]. There are also increased healthcare costs associated with ordering inappropriate imaging studies. Additionally, PAs may not feel confident interpreting the findings documented in a formal radiology report, despite PAs being

responsible for conveying these findings to patients and making appropriate clinical decisions based on the results. This may lead to delayed or inappropriate medical decision making. Ideally, all students graduate from PA school feeling confident in the basics of clinical radiology, recognizing that their skills will continue to develop with exposure in the workforce.

Overall, there appears to be a disconnect between the somewhat limited and significantly varied radiology curriculum time reported by the PAEA and the clear learning outcomes and accreditation standards related to the ordering and interpretation of diagnostic studies set forth by the ARC-PA and PAEA [3,6]. It is therefore appropriate to explore current strategies for teaching basic radiology skills within PA program curriculum, the effectiveness of these methods, and possible strategies to improve PA students' understanding of radiology that align with good pedagogical practice. By better understanding the pedagogy of radiology teaching, it may lead to smoother transitions to clinical practice.

Active Learning Strategies for Teaching Radiology

In recent years, active learning strategies were explored as one method for improving the effectiveness of radiology education. Across many aspects of medical education, active learning methods have been demonstrated to improve student engagement and enthusiasm, learning performance, student satisfaction, and problem-solving skills compared to traditional lecture style learning [7,8]. There are several types of active learning, including case-based learning, problem-based learning, and team-based learning [9]. Case based learning specifically has been extensively researched as a supplemental teaching tool for the radiology components of medical education.

As a broad overview, case based learning (CBL) involves presenting a clinical case to a group of students and allowing them to work collaboratively through the case, applying content they've already learned through lecture or readings to the case at hand, simulating future clinical practice [9]. The facilitator plays an active role guiding the discussion, providing additional information and answering questions

until the students arrive at the correct answer. Case based learning often works best when the case is followed by a wrap up in which the facilitator summarizes the case and key learning points [10].

Several studies examined the use of CBL within radiology education. In one study that implemented a case based learning radiology elective into the first year medical school curriculum, they found that students preferred the opportunity to look at radiological images themselves as opposed to be being walked through images on slides, and they enjoyed working in groups rather than alone [11]. Other studies replicated this finding that students feel more confident reviewing imaging after having the opportunity to read scans themselves [10]. They also feel more motivated to learn and more satisfied with the educational experience [8]. However, most of these CBL studies were completed with medical students, not with PA students. There is limited literature exploring the use of radiology CBL within PA curriculum specifically.

As such, the present study explores whether a CBL session with a radiology emphasis is an effective method for teaching diagnostic imaging foundations to first year PA students. It aims to investigate the following questions:

- Does a gastrointestinal diagnostic imaging case based learning session improve student understanding of radiology, anatomy, and clinical medicine?
- Does the CBL session improve student confidence?
- What are students' subjective feelings and perceptions towards the CBL session?

Session Design and Context

Case Based Learning (CBL)

As several previous studies have already demonstrated the efficacy of CBL for teaching radiology concepts to medical students, it can be reasonably inferred that similar results may be achieved with PA students. Additionally, of the active learning methods, CBL likely lends itself best to radiology

instruction, especially as a one-off supplement to traditional lecture. CBL was therefore chosen as the active learning method for this radiology session.

CBL allows students the opportunity to practice ordering and reading diagnostic images prior to the clinical year, effectively linking what they learn in lecture with what they will be expected to do in clinical year and in clinical practice after graduation [8]. When it comes to learning to read diagnostic imaging, it is particularly important that students are given opportunities to look at images and make their own assessment prior to being given the final read, mimicking real clinical practice [8,10]. CBL effectively gives students this opportunity to practice, can be delivered in a single session, requires minimal additional preparation for the facilitator compared to a traditional lecture format, and can be designed such that a single session incorporates multiples cases with a variety of pathologies and imaging modalities.

Vygotsky Theory of Zone of Proximal Development

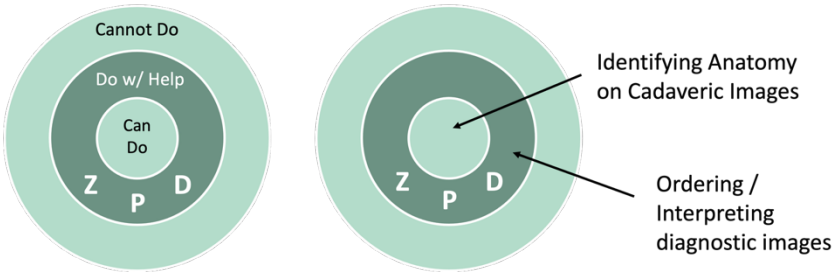
The radiology CBL session administered for the present study was designed with consideration of the theory of zone of proximal development (ZPD), developed by Lev Semenovich Vygotsky. Explained simply, the ZPD is the gap between a student's actual current understanding and what they're capable of understanding with the aid of resources, peer to peer learning, and faculty guidance [12,13] (see Figure 1). The goal is to keep students in the ZPD to maximize learning and student potential.

To execute this goal, the educational task should be designed to be more challenging than what a student could complete independently, yet attainable with assistance from peers and faculty. Following the session, students should be able to complete similar tasks on their own, effectively advancing their ZPD for that subject matter. Vygotsky's theory informed both the pre and posttest surveys as well as the CBL session to maximize student growth. For example, throughout the session, slide icons indicated whether content aligned with anatomy, laboratory medicine, or clinical year coursework. Because the session occurred just before an anatomy exam, students were likely already proficient in that material.

Laboratory medicine content was designed to fall within students' ZPD, encouraging collaborative problem-solving with peer and facilitator support (also noted in Figure 1). Clinical content was also intended to fall within students' ZPD, while recognizing that some of the material may extend beyond the current level of understanding of didactic year PA students.

Figure 1

Vygotsky's Theory of Zone of Proximal Development (ZPD)



Gastrointestinal Focus

For the purposes of this study, the CBL session was implemented into the gastrointestinal (GI) subunit of the Northwestern University Physician Assistant Program didactic curriculum. GI was chosen due to the variety of diagnostic imaging modalities relevant to GI pathology. The session therefore offered a comprehensive overview of x-ray, ultrasound, computed tomography (CT), endoscopic retrograde cholangiopancreatography (ERCP), and magnetic resonance cholangiopancreatography (MRCP). The CBL session was narrowed to focus specifically on pathology related to the biliary tree, hepatic system, and enteric system.

Prior to attending the case-based learning session, students should have some foundational gastrointestinal and diagnostic imaging knowledge to maximize class time [8,9]. For example, for this CBL session discussing gastrointestinal (GI) diagnostic imaging, students should already be familiar with relevant gastrointestinal pathology and indications for diagnostic imaging. Thus, this CBL review session

was imbedded into the Basic Science curriculum of the course, after key anatomy, clinical medicine, and laboratory medicine lectures had already been delivered.

Research Goal and Learning Objectives

The overall goal of the CBL session was to improve learning outcomes in anatomy, clinical laboratory medicine, and diagnostic imaging interpretation, as well as improve students' confidence in anatomy and image interpretation.

Five learning objectives were developed in alignment with this goal to guide the CBL session. For the biliary, enteric, and hepatic systems, students were expected to:

1. Identify the relevant anatomy pertaining to common GI pathology on cadaveric images.
2. Identify relevant anatomy on diagnostic imaging.
3. Identify the appropriate diagnostic imaging to order for a particular GI clinical case.
4. Apply clinical knowledge to differentiate pathology from typical anatomy on diagnostic imaging.
5. Synthesize GI anatomy, clinical medicine, and laboratory medicine fundamentals to answer questions about a clinical case.

Method

Participants and Context

The CBL GI radiology session was delivered to a class of 42 first year didactic PA students at Northwestern University's Feinberg School of Medicine. Each participant was assigned a participant ID so that pre and posttest data could be paired while maintaining participant confidentiality. The GI CBL session was housed in the Basic Science course within the GI subunit. The session was incorporated into a previously planned GI anatomy review session in preparation for an upcoming GI anatomy exam.

Of note, Northwestern's PA program utilizes a problem based learning (PBL) curriculum model, meaning that students spend a portion of their curriculum time each week in small groups engaging in largely student-driven learning related to a clinical case with a faculty facilitator providing input and guidance as needed [9]. The rest of the program's curriculum consists largely of traditional lecture-style learning.

CBL Session Structure

The GI CBL radiology session was conducted over two hours. The session was divided into three simulated patient cases on the gallbladder, liver, and colon respectively. The cases were presented along with additional supplementary lecture material on anatomy, clinical medicine, and diagnostic imaging to solidify concepts previously learned and introduce some new content. This approach of integrating CBL with traditional lecture content is especially "helpful early in the learning process to introduce information and solidify concepts learned in the same lecture" [8].

For each case, students developed a differential diagnosis, worked through the relevant anatomy on diagrams and cadaveric images, ordered the appropriate diagnostic imaging, identified relevant anatomical structures on imaging, interpreted the imaging within the clinical context, and reached a conclusion on the most likely diagnosis. At the conclusion of each case, students worked through a higher order multiple choice style question that required them to synthesize their knowledge of anatomy, clinical medicine, and clinical laboratory medicine. An audience response system (ARS) called Point Solutions that integrates with PowerPoint allowed students to interact with the material on the slides[10]. Point Solutions allowed students answer multiple choice questions and select structures on diagrams, cadaveric images, and diagnostic images.

Throughout each case, there was time built in for peer-to-peer discussion, open class discussion, as well as more formal instructor-led explanations and walk-throughs. Ample time was allocated to explaining the approach to reading and interpreting diagnostic studies, as this may have been less familiar

to didactic year PA students. By the end of the two-hour session, students had covered all five learning objectives for the biliary, enteric, and hepatic systems.

Evaluation Measures

Pre and Posttest Measures

A pretest was posted online one week prior to the CBL session for students to optionally participate in anytime up until the start of the CBL session. A posttest was posted online immediately following the CBL session and remained open for two weeks for students to optionally participate in any time before the deadline.

The pre and posttest included 15 multiple-choice style questions, delivered via the learning management system (LMS, Canvas). There were five questions about the biliary system, five questions about the enteric system, and five questions about the hepatic system. Each of those five questions correlated with one of the learning objectives listed above. The same style of question was repeated for each organ system. Pre and posttests consisted of different questions, but the questions were matched in terms of content and difficulty. The questions were reviewed for accuracy and difficulty by three second year PA students and two faculty members prior to being distributed to the first-year PA students. Students could take as much time as they needed to complete the pre and posttest.

Confidence Ratings and Student Perceptions

Following the multiple-choice questions assessing their understanding, students completed confidence rating questions. Using a Likert scale of 1-5 (with 1 being no confidence and 5 being highly confident), participants were asked to rate their confidence with the following tasks: identifying anatomy on cadaveric images of the biliary system, bowels, and hepatic system respectively, reading/interpreting gastrointestinal ultrasound, x-ray, and CT images respectively, and knowing which imaging to order for a given GI clinical presentation. These questions were designed to assess the students' confidence with the tasks outlined in the learning objectives.

On the posttest only, a few additional questions were asked. Participants were asked to rate how much they agreed on a Likert scale of strongly disagree to strongly agree with statements related to whether they felt the session better prepared them to interpret GI radiology images in the clinical year, whether they appreciated the integrative nature of the CBL session, and whether they enjoyed the CBL format more than a traditional lecture style format. Lastly, students were asked open-ended questions on the posttest regarding aspects of the CBL session they thought went well, aspects of the CBL session they think could be improved upon, and any feedback on the instructor's teaching.

Data Analysis

Data collection was completed in September 2025. The data was entered into Excel. All statistics and data analysis were completed in Excel. Paired t-tests were used to compare pre and posttest scores for each student overall, by organ system, and by learning objective. Student confidence was assessed by first arranging the data to look at the percentage of people who felt confident or highly confident completing a given task before versus after the CBL session. It was then analyzed using pooled Z-tests. Qualitative feedback was analyzed by using simple content analysis to identify common domains for session strengths and areas for improvement.

Personal Beliefs and Axiology Statement

This research is driven by my personal experience as a PA student, where I found a disconnect between didactic year foundational knowledge—such as anatomy and clinical laboratory medicine—and the practical application and interpretation of imaging in real patient scenarios during the clinical year. I recognize the value of integrated learning and believe that case-based learning, especially with a radiology focus, can help bridge this gap.

My goal is to help first-year PA students develop stronger clinical reasoning skills by connecting anatomy, clinical medicine, and clinical laboratory medicine through realistic, image-centered cases. I

value applied, contextual knowledge that not only enhances learning outcomes but also improves confidence and preparedness for clinical practice.

I approach this project with a value-laden perspective, understanding that my own educational experiences shape my research priorities. I am committed to conducting this work ethically, with the aim of contributing to more meaningful, practical education for future clinicians.

Results

Effects of Gastrointestinal CBL Session with Radiology Focus on Learning Objectives

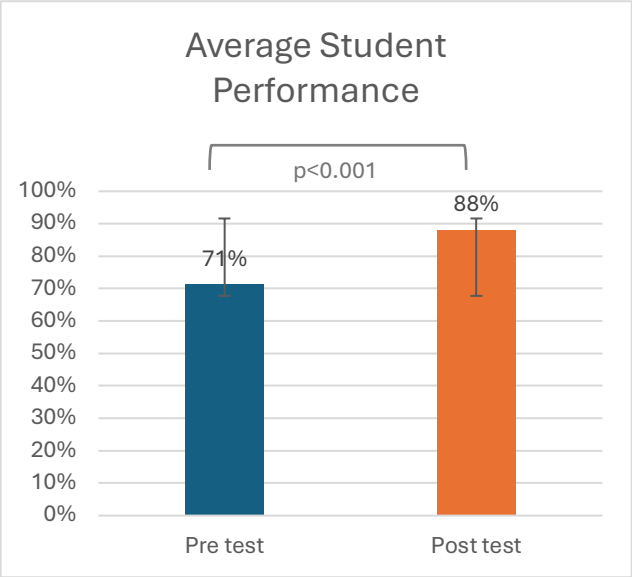
A total of 42 learners participated in the CBL activity. Of those learners, 32 completed both the pretest and posttest materials and therefore were included in the item analysis. 38 students completed the pretest confidence ratings, and 33 students completed the posttest confidence ratings. Pooled statistical tests were utilized for confidence rating analysis to account for this discrepancy in sample size. All 33 students who took the posttest were included in the analysis of student perceptions and feedback.

Pretest vs Posttest Overall Performance

Students showed statistically significant improvement overall from the 15-question pretest to posttest, scoring an average of 71% (SD = 0.16) on the pretest and 88% (SD = 0.095) on the posttest. A paired samples t-test demonstrates that this increase was significant, $t(31) = 4.96$, $p < 0.001$ (see Figure 2).

Figure 2

Average Student Performance Overall

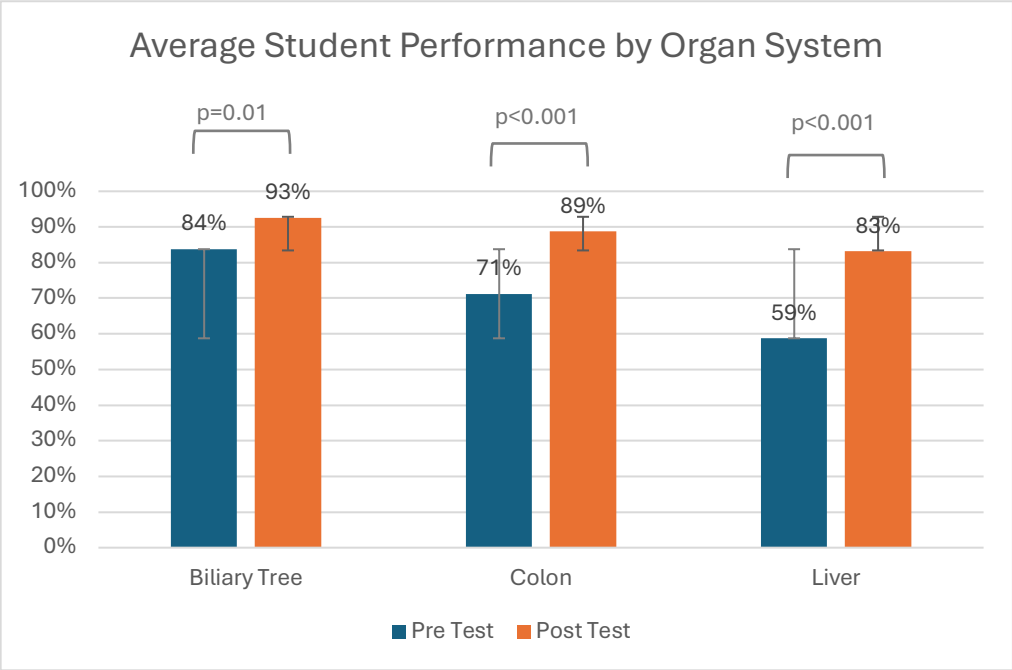


Pretest vs Posttest Results by Organ System

Students showed statistically significant improvement from the pretest to posttest when looking at organ system as well. For the biliary tree questions, students scored an average of 84% (SD = 0.18) on the pretest and 93% (SD = 0.12) on the posttest, which was a statistically significant improvement $t(31) = 2.37$, $p = 0.01$ (see Figure 3). For the colon questions, students scored an average of 71% (SD = 0.20) on the pretest and 89% (SD = 0.14) on the posttest, which was also a statically significant improvement $t(31) = 3.92$, $p<0.001$. Lastly, students had statically significant improvement on the liver questions, scoring an average of 59% (SD = 0.30) on the pretest and 83% (SD = 0.20) on the posttest $t(31) < 0.001$.

Figure 3

Average Student Performance by Organ System



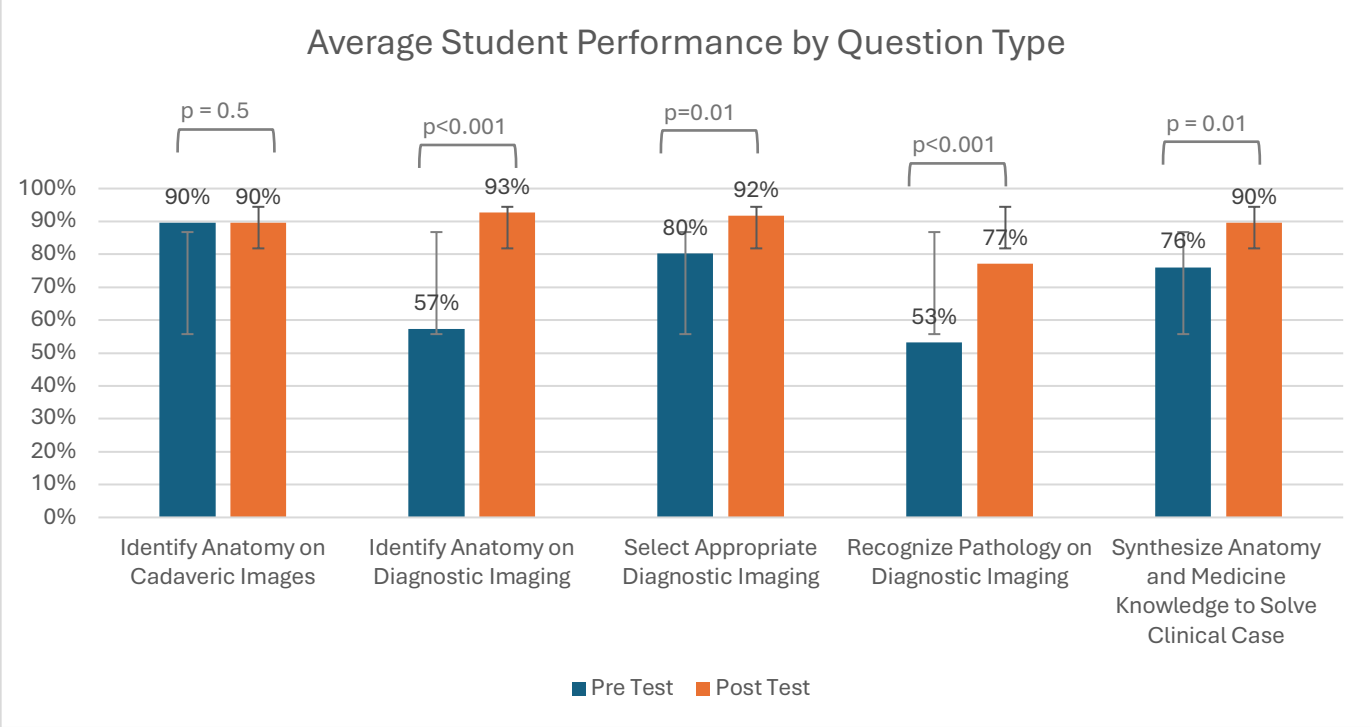
Pretest vs Posttest Results by Question Type

Students also largely improved from pretest to posttest when looking at performance on specific question types (see Figure 4). Paired sample t tests were performed to compare student performance for each of these five question types. Students demonstrated no improvement in identifying anatomy on cadaveric images from pretest to posttest, with an average score of 90% (SD = 0.18) on both the pre and posttest $t(31) = 0$, $p = 0.5$. All other question types had statistically significant improvement from pretest to posttest. Students improved from an average score of 57% (SD = 0.34) to 93% (SD=0.14) on questions asking to identify anatomy on diagnostic imaging $t(31) = 5.44$, $p<0.001$. Students improved from an average score of 80% (SD = 0.25) to 92% (SD = 0.15) on questions asking students to select the appropriate diagnostic imaging $t(31) = 2.47$, $p = 0.01$. Students improved from an average score of 53% (SD = 0.25) to 77% (SD = 0.27) on questions asking students to recognize pathology on diagnostic

imaging, t(31) = 3.75, p<0.001. Finally, students improved from an average score of 76% (SD = 0.27) to 90% (SD = 0.16) on synthesis questions about a clinical case, t(31) = 2.35, p = 0.013.

Figure 4

Average Student Performance by Question Type

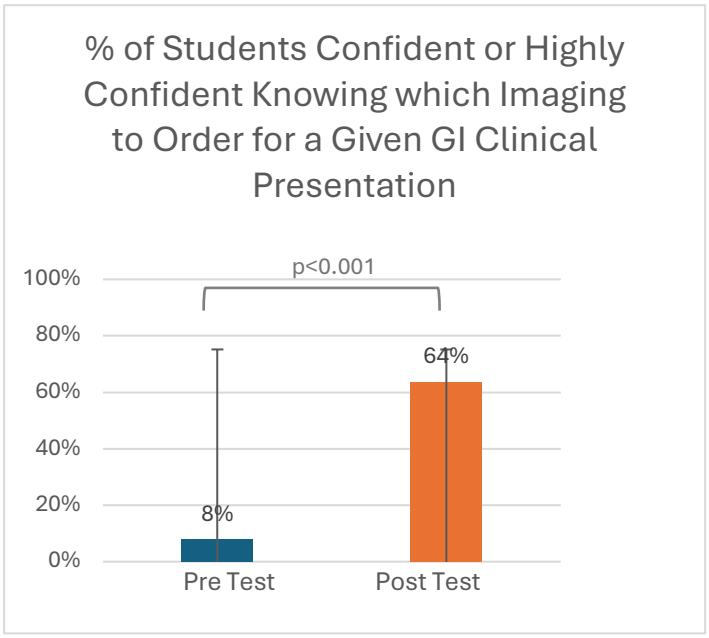


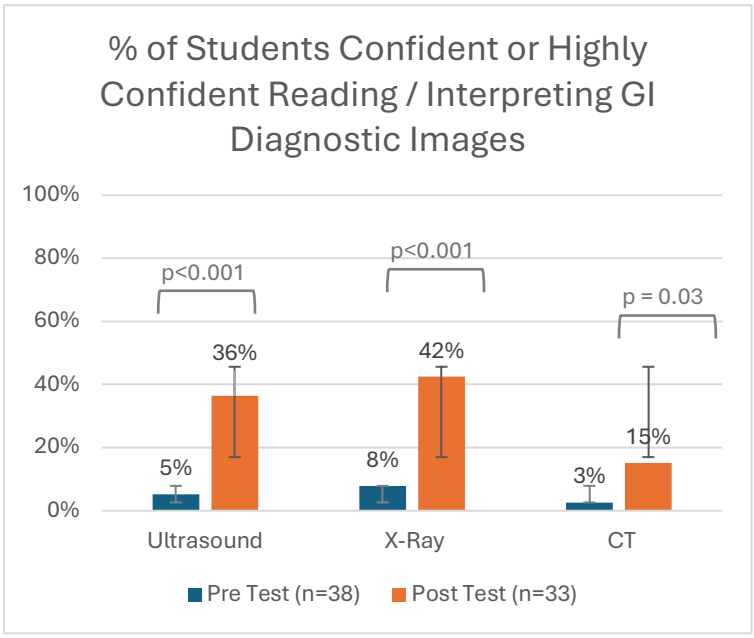
Effects of Gastrointestinal CBL Session with Radiology Focus on Student Confidence

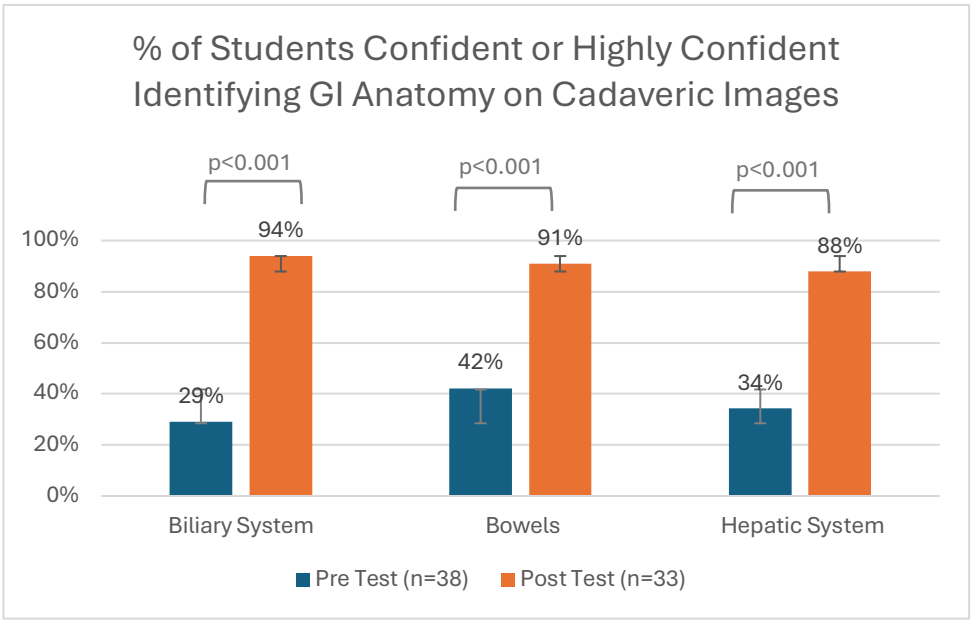
Given the difference in sample sizes on the pre and posttest, pooled Z tests were used to assess whether student confidence changed following the CBL session. Across all tasks, the percentage of students who felt confident or highly confident performing that task increased significantly from pretest to posttest (see Figure 5).

Figure 5

Effects of GI CBL Session on Student Confidence







Student Perceptions of CBL Session

On the posttest only, there were questions asking students how they felt about various aspects of the CBL session and whether they had any constructive feedback about the session. 33 students responded. 100% of students agreed or strongly agreed that the session better prepared them to interpret GI radiology images in the clinical year. 100% of students agreed or strongly agreed that they appreciated the integrative nature of the presentation, connecting content from anatomy, clinical medicine, and clinical laboratory medicine. 94% of students agreed or strongly agreed that they enjoyed the interactive case-based learning format more than a traditional lecture format.

Student Feedback on CBL session

Lastly students were asked free response style questions asking for positive and constructive feedback on the session. 20 students left feedback.

In terms of positive feedback, students generally enjoyed that the session was interactive (n=13), integrated content from several courses (n=13), incorporated student-led image interpretation (n=11), included detailed explanations following interactive questions (n=10), focused on practical and high yield content (n=9), and was peer to peer taught (n=4). Student comments included:

> *"This was very effective for my learning, and I hope opportunities like this happen again in the future. This brought all the information for GI together for me and helped things click."*
>
> *"I love the interactiveness of the session… it was a lot of fun."*
>
> *"I enjoyed learning from a fellow student perspective. Having them integrate their own experience and alluding to their clinical experiences kept me engaged."*
>
> *"It was really helpful to have the integration of clinical cases, imaging, and anatomy knowledge integrated together."*

For constructive feedback, some students implied that they would like the session to be longer (n=8) to allow for additional cases, additional image examples, or more detailed walk throughs of images, including scrolling through a CT as a class (scrolling through a CT to orient students to the anatomy was a planned part of the session but was skipped due to time constraints). As this session took place during the scheduled slot for the gastrointestinal anatomy exam review session, some students wanted additional time allocated to anatomy (n=3) and embryology (n=2) content. One student thought the clinical vignettes were too straightforward, and one student wished the anatomy and laboratory medicine components of the session were separated.

Discussion

The present study aimed to assess whether a gastrointestinal CBL session with a radiology emphasis is an effective teaching method for first year PA students to further prepare them for clinical year. Using Vygotsky's theory of the zone of proximal development as a guide, a CBL session was designed to fit into the Northwestern PA Program's gastrointestinal curriculum. The goal of the session was to engage students in gastrointestinal radiology while integrating content that students had already been learning in their anatomy, clinical medicine, and laboratory medicine classes.

There are numerous benefits to utilizing CBL to teach radiology foundations to medical students. It promotes self-directed learning, critical thinking skills, and teamwork [8]. Further, working through a case and deciding the next most appropriate imaging modality teaches students to more deeply consider the appropriateness of additional imaging studies, potentially reducing unnecessary healthcare costs and improving patient care and safety. It also simulates the real world, effectively blending concepts learned in the classroom with real clinical medicine.

Prior studies found that medical students feel more confident in their radiology skills after having opportunities to practice interpreting images independently, and that they find interactive case-based learning activities more enjoyable, motivating, and satisfying [8,10]. The present study suggests that this

finding translates to PA student learning. Not only did students demonstrate significant improvement objectively with student overall scores increasing from 71% to 88% from pretest to posttest ($p<0.001$), but following the session, students also reported significantly increased confidence identifying anatomy on cadaveric images ($p<0.001$), reading and interpreting diagnostic images on ultrasound ($p<0.001$), x-ray ($p<0.001$), and CT images ($p=0.029$), and knowing which imaging modality to order for a given GI clinical presentation ($p<0.001$). 100% of students felt the session better prepared them to interpret GI radiology images in clinical year, 100% of students enjoyed the interactive nature of the session, and 94% of students preferred the CBL style over a traditional lecture. When asked for open ended feedback, the most common suggestion was to make the session even longer to allow time for additional cases and image examples. This study clearly supports that the benefits of CBL for teaching radiology that are documented in the literature for medical students are also seen with PA students.

With regards to Vygotsky's theory of the zone of proximal development [13], it appears that this CBL session was of appropriate difficulty. Prior to the session, students were competent with their anatomy knowledge, with students scoring 90% accuracy on the pretest anatomy questions. This makes sense as students were only one week away from their anatomy exam at the time of this session. However, the rest of the session, which was largely tied to the ordering and interpreting of diagnostic imaging within a given clinical context, was largely within students' zone of proximal development. In other words, the content was difficult for students to complete on their own prior to the CBL session, but after working through cases with the support of a facilitator and their peers, students performed significantly better on the posttest across all organ systems and nearly all learning objectives. This suggests that the difficulty level was appropriate for first year PA students, and highlights how this educational theory can be used to scaffold a learning experience that aims to improve clinical acumen. The greatest improvements were seen in identifying anatomy on diagnostic imaging and recognizing pathology on diagnostic imaging, suggesting that students benefited from the opportunity to view and interpret diagnostic images on their own and with their peers during the CBL session. It appears that

student-led and facilitator guided learning is an effective means of teaching radiology skills to PA students.

Limitations

One limitation of the study is that it is difficult to ascertain whether the improvements from pretest to posttest are attributable to the CBL session alone or in combination with external factors. For example, between the date the pretest opened and the posttest closed, the students were continuing to learn about some of the concepts covered in the CBL session in other classes, independent study, and in their problem-based learning curriculum. The significant improvement on the posttest compared to the pretest may be partially explained by these other learning experiences and should not be assumed to be entirely the result of the CBL session. However, this was the only teaching session the students received in which they had the opportunity to look at images in depth, so much of the improvement seen in image interpretation can be reasonably attributed to the CBL session.

The study also had a limited sample size. There are only 42 students in the PA class, and while all of them attended the CBL session, only 32 students completed both the pretest and posttest. The small sample size limits the generalizability and power of the study. Still, the findings are promising and might prove a valuable educational model for others, particularly those in PA programs with similar cohort sizes.

Finally, another limitation of this study was the limited time allocated to the CBL session. Given the demanding schedule of the first year PA students, the review session was capped at two hours. Several students in their feedback wished that the session had been longer. This is feedback that could be considered if the session is repeated in future years.

Future Research

Future research should be conducted to continue to explore the effectiveness of CBL in PA school in general and more specifically as a tool for teaching anatomy, clinical medicine, and radiology.

Currently, much of the research on CBL in medical education has been conducted with medical students. Future research should continue to explore the use of CBL amongst PA students specifically.

Additionally, as discussed earlier, PAs are expected to order, interpret, and explain diagnostic images on a regular basis. However, there are no studies to the author's knowledge that explore how confident practicing PAs feel interpreting radiologic images. This would provide a starting point to evaluate the effectiveness of the current strategies utilized by PA schools to teach radiology fundamentals.

Lastly, the present CBL session included many radiologic images. However, when discussing CT scans specifically, still images of CT scans were presented. Students could not scroll through the images themselves, as they will be able and expected to do in the clinical year and future careers. One suggestion to more closely mimic real practice is to include QR codes on the slides with links to Pacsbin.com or other similar radiology resources, so students can scroll the CTs themselves on their phone [10]. Future research could aim to explore whether students gain a better understanding of radiology when they are allowed to navigate the image independently.

Conclusion

The present study explored the efficacy of case-based learning with emphasis on radiology for teaching gastrointestinal anatomy, clinical medicine, and laboratory medicine to first year PA students at Northwestern University. The two-hour case-based learning session was designed with Vygotsky's theory of zone of proximal development in mind to maximize student growth and encourage group collaboration. Learning outcomes of the session focused on identifying gastrointestinal anatomy on cadaveric images and diagnostic images, ordering appropriate imaging for a given clinical case, identifying pathology on diagnostic images, and synthesizing information from anatomy, clinical medicine, and laboratory medicine to answer a clinical question. The anatomical regions of interest included the biliary system, enteric system, and hepatic system.

The study results were promising. Students demonstrated significant improvement from pretest to posttest overall, for each organ system, and for nearly every learning objective. Students improved significantly on identifying both normal anatomy and pathology on diagnostic images, ordering appropriate imaging tests, and answering higher order synthesis questions. Students also reported increased subjective confidence in anatomy, interpretation of diagnostic images, and selection of appropriate imaging. Students largely felt that the CBL session better prepared them to interpret GI images in the clinical year, and they appreciated the CBL format as well as the integration of content from their anatomy, clinical medicine, and laboratory medicine courses. While these findings are promising, further research is needed to further explore how CBL can be utilized within the PA school didactic year to engage students in learning anatomy, clinical medicine, and laboratory medicine.

References

1. RiChard JL, Liu BP, Casalino DD, Russell EJ, Horowitz JM. Radiology Education of Physician Extenders: What Role Should Radiologists Play? *Acad Radiol*. May 2017;24(5):633-638. doi:10.1016/j.acra.2016.11.018

2. Santavicca S, Hughes DR, Rosenkrantz AB, Rubin E, Duszak R, Jr. Radiology Practices Employing Nurse Practitioners and Physician Assistants: Characteristics and Trends From 2017 Through 2019. *J Am Coll Radiol*. Jun 2022;19(6):746-753. doi:10.1016/j.jacr.2022.02.002

3. Accreditation Review Commission on Education for the Physician Assistant. *Accreditation Standards for PA Education Sixth Edition*. 2025.

4. Physician Assistant Education Association. PAEA Assessment's Core Tasks and Objectives. PAEA. https://paeaonline.org/assessment/core-tasks-and-objectives

5. Herzog R, Li T, Hryniuk A. A Curricular Review of Radiology Education in a Master of Physician Assistant Studies Program. *J Physician Assist Educ*. Mar 1 2025;36(1):e96-e101. doi:10.1097/JPA.0000000000000632

6. Physician Assistant Education Association. *By the Numbers: Curriculum Report 5: Data from the 2019 Didactic Curriculum Survey*. 2020.

7. Cen XY, Hua Y, Niu S, Yu T. Application of case-based learning in medical student education: a meta-analysis. *Eur Rev Med Pharmacol Sci*. Apr 2021;25(8):3173-3181. doi:10.26355/eurrev_202104_25726

8. Fromke EJ, Jordan SG, Awan OA. Case-based Learning: Its Importance in Medical Student Education. *Acad Radiol*. Aug 2022;29(8):1284-1286. doi:10.1016/j.acra.2021.09.028

9. Hopper MK. Alphabet Soup of Active Learning: Comparison of PBL, CBL, and TBL. *HAPS Educator*. 2018;22(2):144-149.

10. Sugi MD, Kennedy TA, Shah V, Hartung MP. Bridging the gap: interactive, case-based learning in radiology education. *Abdom Radiol (NY)*. Dec 2021;46(12):5503-5508. doi:10.1007/s00261-021-03147-z

11. Erinjeri JP, Bhalla S. Redefining radiology education for first-year medical students: shifting from a passive to an active case-based approach. *Acad Radiol*. Jun 2006;13(6):789-96. doi:10.1016/j.acra.2006.02.041

12. Shabani K, Khatib M, Ebadi S. Vygotsky's zone of proximal development: Instructional implications and teachers' professional development. *English language teaching*. 2010;3(4):237-248.

13. Vygotsky L. Social Development Theory (L. Vygotsky). 1978.