



Evaluating Math Competency Challenges Among Diagnostic Medical Sonography (DMS) Students: The Role of Supplemental Lab Support

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Abstract: This study investigates instructional strategies to improve mathematical readiness among prospective Diagnostic Medical Sonography (DMS) students at a private four-year university. The DMS program, an intensive, hands-on imaging discipline, requires students to demonstrate proficiency in mathematics as part of the admissions process. Specifically, students must pass a Mathematics Competency Exam during their freshman year. To support student success, the university implemented a structured pathway that began with a two-week summer math bootcamp, followed by enrollment in quantitative courses including Applied College Algebra and Physics. Students were also provided weekly assignments and supplementary instructional resources throughout the academic year to reinforce learning and exam preparation. During the first academic year of implementation, a significant portion of students did not pass the Mathematics Competency Exam. In response, the university introduced a College Algebra Lab in the second year to offer additional, integrated instructional support. This lab featured diagnostic assessments, targeted remediation, and real-time application of algebraic concepts aligned with the DMS curriculum. Results from the second year demonstrated a statistically significant improvement in student outcomes. More students successfully completed Applied College Algebra and Physics, and the Mathematics Competency Exam pass rate increased. These findings suggest that the addition of the College Algebra Lab contributed meaningfully to enhancing academic performance and readiness for entry into the DMS program.

Keywords: Applied College Algebra, Diagnostic Medical Sonography (DMS) Program, Lab-Based Intervention, Math Competency Exam, Pre-algebra Bootcamp

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Introduction

As a co-educational, non-profit institution, Regis College offers more than 100 academic programs, including Diagnostic Medical Sonography (DMS) within its School of Public Health (American Registry for Diagnostic Medical Sonography [ARDMS], 2024). The college is committed to providing accessible, high-quality education that equips students for success in health care and related fields. Emphasizing student empowerment and career readiness, Regis College supports aspiring nurses, health professionals, and public health scholars through affordable academic programs grounded in excellence and real-world application.

Diagnostic medical sonography, commonly known as ultrasound, is a cornerstone of modern health care. It is a non-invasive, real-time imaging modality that supports early diagnosis, guides treatment decisions, and enhances patient safety. This versatile profession encompasses a range of specialties, including abdominal, obstetric, gynecologic, vascular, musculoskeletal, and cardiac imaging, and plays a critical role in both routine screenings and urgent clinical assessments. According to the American Registry for Diagnostic Medical Sonography (ARDMS, 2024), sonographers are highly trained professionals who contribute significantly to the quality and accuracy of patient care.

Sonography programs are designed to prepare students for the dynamic and evolving nature of the medical imaging field. These programs provide hands-on training in ultrasound equipment, image interpretation, and patient communication, while also emphasizing critical thinking and clinical decision-making. Students develop the diagnostic expertise required to work in hospitals, outpatient clinics, physician offices, and specialty labs. As technology continues to advance, introducing innovations such as 3D and 4D imaging and expanding applications in interventional procedures, the demand for skilled sonographers is expected to grow. With each scan, these professionals play a vital role in shaping medical outcomes and contributing to the overall health and well-being of their communities.

At Regis College, the Diagnostic Medical Sonography (DMS) program is considered competitive due to its limited enrollment capacity of 13 students, which is determined by clinical placement availability (Regis College, n.d.). To qualify for admission, students must earn at least a B-minus in MA 100A Applied College Algebra and PY 101 Introductory Physics for Health Professions, typically completed during the fall and spring semesters of their first year. In addition, students are required to complete weekly assignments and pass a Mathematics Competency Exam with a minimum grade of B administered during the spring semester of their first year.

To support student success, the college offers a two-week math bootcamp before the fall semester of freshman year. The session is designed to refresh students' high school math skills and prepare them to begin Applied College Algebra course with confidence. A 2024 report by Paul Meinz found that students who participated in math bootcamp after earning a C in a previous math course had higher success rates when retaking or advancing to the next level than those who did not participate.

In a typical 15-week semester, students starting a new course often need time to adjust, re-acclimate, and review foundational concepts. However, the goal is to equip students with the tools they need from the outset. Allowing them to struggle early on can undermine both their confidence and long-term success. By completing the summer bootcamp session, students reach a shared baseline of preparation, enabling them to engage fully and equally from day one.

The bootcamp covers essential topics, including solving equations and working with several types of functions, both in their creation and application, laying the foundation for the quantitative reasoning skills required in the program and beyond. It also helps students acclimate to the course systems they will use throughout the semester. Activities mirror what students will encounter in the fall, aiming to ease the transition into the academic year. For example, ungraded diagnostic assessments simulate quizzes and tests in the remote learning environment, helping students become comfortable with the format before grades are involved. Additionally, the summer bootcamp session gives students a chance to familiarize themselves with the textbook and online platforms used for homework. The goal is to resolve any technical or logistical issues during the summer so that when the fall semester begins and coursework is formally graded, students are confident, prepared, and fully engaged.

In response to low pass rates on the Mathematics Competency Exam, a lab component was introduced into the College Algebra course. This addition provides students with an extra 75 minutes of instructional time each week, aimed at reinforcing key mathematical concepts. The decision to implement this component was informed by previous institutional success with the corequisite model in other mathematics courses, such as Precalculus and Calculus. The corequisite model, wherein students enroll in college-level courses while simultaneously receiving just-in-time remediation, has been shown to be an effective strategy for promoting student success, particularly among those needing additional academic support (Kashyap & Mathew, 2017). At our institution, incorporating lab-based learning into Precalculus and Calculus has not only enhanced student engagement but also fostered a deeper conceptual understanding of mathematical principles. Encouraged by these positive outcomes, we adopted a similar instructional strategy in Applied College Algebra to improve student performance and retention. This approach aligns with national trends emphasizing active, applied learning and targeted support to improve student outcomes in gateway mathematics courses (Easterling, 1991; Jarvis, McCullough, & McParland, 2021).

Another study by Porter, Ofodile, and Carthon (2015) demonstrated that a redesigned section of College Algebra, which incorporated instructional best practices including a required lab component, resulted in significantly improved student outcomes. This section achieved the highest passing rate in the department and the highest average score on the departmental final exam. Moreover, the faculty member teaching the redesigned course reported a higher student success rate compared to the courses she had taught in the previous semesters. Based on these performance metrics, the course was considered successful. Lazari and Simons (2003) found that students with weaker mathematics backgrounds who enrolled in College Algebra with supplemental Instruction performed comparably on the final exam to their peers in traditional sections of the course.

Method of Study

This study examined two cohorts of students intending to major in Diagnostic Medical Sonography (DMS) during the 2023–2024 and 2024–2025 academic years. The goal was to evaluate whether additional structured mathematical support, specifically, a pre-semester algebra bootcamp and the addition of a lab component to Applied College Algebra, was associated with improved performance in mathematics, physics, and the DMS Math Competency Exam. A comparative cohort design was used to assess differences in course completion and exam outcomes across the two academic years.

Research Instrument

Several assessment instruments were used to measure students' mathematical proficiency. The algebra bootcamp utilized WebAssign modules based on *College Algebra* by Abramson et al. (n.d.), which provided structured review assignments with built-in feedback mechanisms. Students demonstrated mastery by achieving at least 80% on each assignment.

Summative assessments included instructor-developed tests, quizzes, and a final exam in Applied College Algebra. Student performance in Applied College Algebra was assessed using the following student learning outcomes:

- 1: Perform algebraic operations
- 2: Solve linear and quadratic equations
- 3: Factor and evaluate polynomials
- 4: Use functions and apply mathematical modeling
- 5: Graph various functions
- 6: Solve exponential and logarithmic equations

The first cohort of students completed the Applied College Algebra course without a lab component, while the second cohort completed the same course with an added lab component. In both cases, the final course grade was determined using a weighted average across several performance areas.

For the cohort without the lab, the grade was composed of 20 percent WebAssign homework assignments, 15 percent in-class worksheets and projects, 5 percent attendance and participation, 45 percent tests, and 15 percent final exam. For the cohort with lab, the DMS program has reduced the weight of homework in course grading, as the previously higher weighting may have inflated grades without accurately reflecting students' mastery of the material. For this cohort, the grade breakdown was adjusted as follows: 15 percent WebAssign homework assignments, 8 percent in-class worksheets and projects, 15 percent labs, 5 percent attendance and participation, 42 percent tests, and 15 percent final exam.

Following the successful completion of Applied College Algebra, students enrolled in Introductory Physics for the Health Sciences (PY 101) in the spring semester. This algebra-based course introduces key physics concepts relevant to allied health professions. Topics include motion, forces, energy, waves, sound, electricity and magnetism, the electromagnetic spectrum, optics, and the basics of nuclear and radiation physics.

The primary textbook for PY 101 was *College Physics* from OpenStax (2016), an open-access resource licensed under a Creative Commons Attribution license. Homework was completed through Edfinity (n.d.), an online platform providing affordable access to instructional content. All quizzes and tests were administered in person under the supervision of the course instructor.

Student performance in the PY 101 course was assessed using the following student learning outcomes:

- 1: Explain key physical concepts
- 2: Integrate physics concepts with health science topics
- 3: Analyze health-related issues using physical principles
- 4: Use appropriate physics terminology
- 5: Apply physics concepts to solve problems

In PY101, the final course grade was calculated using a weighted structure: quizzes accounted for 20 percent, tests made up 30 percent, Edfinity homework contributed 15 percent, class presentations were worth 5 percent, and the final exam comprised 30 percent of the overall grade. Both student cohorts completed the Math Competency Exam during the spring semester while enrolled in PY101.

Finally, the DMS Math Competency Exam served as a standardized program benchmark requiring a minimum score of 83%. This standardized assessment consisted of 40 questions designed to measure students' mastery of the key algebraic skills and concepts presented in the College Algebra course. Content validity was supported through alignment with weekly assignments and the essential algebraic competencies required for progression in the DMS curriculum. All summative assessments including algebra tests, physics exams, and the competency exam were administered in person to ensure uniform testing conditions and maintain assessment integrity.

Design of Bootcamp

As noted, one goal of the summer bootcamp is to reinforce the math skills and concepts students learned in high school. The bootcamp is a self-paced program using materials hosted on WebAssign (<https://webassign.com>). Similar online, self-directed models have been used in other health science majors to improve students' math competency and confidence, according to Jarvis, McCullough and McParland (2021).

The program uses *College Algebra, 2nd Edition with Integrated Review* by Jay Abramson. Students complete bootcamp modules through WebAssign by finishing two online modules named Module A and Module B. Each module includes about five lessons or assignments from the textbook. To complete a module, students must score at least 80% on each assignment and can retake assignments as many times as needed to reach this benchmark. WebAssign offers support tools such as digital textbooks, instructional videos, and practice problems with hints and worked solutions.

Module A covers exponents, prime numbers, least common multiples, multiplication and division with fractions, addition and subtraction with fractions, proportions, decimals and percents. Module B includes real numbers, arithmetic of algebraic expressions, properties of exponents, properties of radicals, and polynomials. Students are encouraged to complete Module A in the first week and Module B in the second week of the bootcamp, which takes place one week before classes begin. They receive two weeks of free access to WebAssign, and the bootcamp session is offered at no cost.

The instructor plays a key role in the bootcamp process. Before it begins, students must be reminded to participate. Once the bootcamp starts, two weeks before classes, the instructor is available to help with any questions. A few days before classes, the instructor compiles a report on student participation, noting who completed all lessons, who did not, and the percentage of assignments finished. This helps track engagement and allows timely intervention if needed.

For example, if a student enrolled in College Algebra has not started the bootcamp, the instructor may follow up with the student and their program director. Participation is required for DMS students; if a DMS student hasn't started within a few days, the program director is alerted, and the student is contacted via email. Also, students facing course challenges are encouraged to attend tutoring sessions provided by the college.

While structured supports like the bootcamp, reminders, and assignments have helped some students succeed, significant challenges remain especially in the shift from assignment-based learning to high-stakes testing like the Math Competency Exam and Board Exam. These findings carry important implications for both instructional methods and support strategies as students advance toward board certification.

Design of Applied Algebra Lab

As mentioned in the introduction, in response to the low pass rates on the Mathematics Competency Exam, a dedicated 75-minute weekly lab session was added to Applied College Algebra. Universities, including Harvard, have been exploring ways to provide additional instructional time and support in mathematics courses without requiring extra credits or full-length classes (The Harvard Crimson, 2024).

These lab sessions offered real-time, targeted support aligned with current course content. As noted in the methods section, the lab component was implemented during the fall 2024 semester. Each session began with a diagnostic assessment to evaluate students' proficiency in the foundational math skills. Based on the assessment results, students received supplemental instruction tailored to their specific needs. This approach focused on addressing gaps in algebraic operations, functions, and mathematical modeling.

We relied on this integrated support model that differs from traditional prerequisite remediation, where students complete developmental math courses before enrolling in college-level mathematics. Instead, the Applied College Algebra Lab was embedded directly into the college-level course.

This model allowed students to receive “just-in-time” instruction in key areas, including:

- Solving equations and inequalities
- Understanding and manipulating functions
- Applying properties of exponents and logarithms
- Modeling real-world scenarios using algebraic tools

Instructional materials included carefully selected worksheets and assignments that promoted both conceptual understanding and procedural fluency. These resources were aligned with current course topics, making the lab a timely and practical form of academic support.

At this point, we would like to share a specific example that illustrates how lab sessions reinforce key mathematical concepts through real-world applications. To support students' understanding of exponential and logarithmic functions, the Applied College Algebra Lab incorporated practical problems that connect theory to everyday scenarios. One such activity used Newton's Law of Cooling to deepen comprehension and engagement.

Example: A cheesecake is removed from the oven at an internal temperature of 165°F and placed into a refrigerator set at 35°F . After 10 minutes, the cheesecake has cooled to 150°F . To be safely consumed, it must reach an internal temperature of 70°F . Using Newton's Law of Cooling, determine how long it will take for the cheesecake to reach the desired temperature.

This problem challenges students to apply exponential decay models and reinforce key concepts such as solving exponential equations and performing logarithmic transformations. Since these mathematical tools were introduced and scaffolded earlier in the course, students approached the challenge with greater confidence. By embedding math within a meaningful and relatable context, the lab fosters both conceptual understanding and increased student motivation.

The effectiveness of the Applied Algebra Lab was evaluated using multiple indicators, including:

- Diagnostic and post-assessments to measure gains in foundational math skills
- Performance on lab assignments targeting key algebraic concepts
- Quizzes and exams aligned with overall course outcomes
- Student course evaluations assessing confidence and perceived skill development

In summary, the Applied Algebra Lab delivered essential remediation and enrichment within the structure of a college-level algebra course. By integrating targeted instruction and real-time support, the lab improved student engagement, boosted confidence, and enhanced academic performance in mathematics.

Data Analysis, Results and Discussion

As previously outlined, we tracked the academic progress of a cohort of 18 students intending to major in Diagnostic Medical Sonography (DMS) who were admitted in fall 2023. These students were enrolled in a structured academic support pathway, which began with a two-week bootcamp designed to refresh their high school-level algebra skills. All 18 students participated in the bootcamp, which was accompanied by ongoing support in the form of reminders from the instructor and the DMS program director. As a result of this structured support, 16 of the 18 students successfully completed the bootcamp.

In fall 2023, 17 of the students enrolled in the Applied College Algebra course. Out of these, 12 achieved the required minimum grade of B- for continued progression in the DMS program, while four others had to repeat the course during Summer 2024 to meet the standard. In the subsequent spring 2024 semester, 15 students attempted the required Physics course. However, only 4 students earned the minimum B- grade necessary for progression. Consequently, nine students repeated this course in summer 2024.

The DMS Math Competency Exam was also administered in spring 2024. A total of 14 students took the exam, which required a minimum score of 83% to pass. While weekly assignments were provided as preparation and students generally performed well on these, six students failed the exam on their first attempt. Of these, one student failed again on the second attempt. Notably, the exam was closely aligned with the assignments, suggesting a disconnect between performance on homework and high-stakes exams. This trend points to a larger issue, students appear to excel on assignments but underperform on exams, a pattern that has also been observed in classroom settings. This raises concerns about the authenticity of assignment completion, particularly when testing conditions are not enforced. Unlike assignments, board exams demand high performance (typically requiring an 85% or higher to pass) and offer no second chances or extra credit, further emphasizing the need to bridge this performance gap.

The results for this cohort are summarized in Table 1.

Table 1

Performance of students in Bootcamp, Applied College Algebra, Physics, and Math Competency Exam during AY 2023-24

Number of intended DMS	Percentage of students completing Bootcamp	Percentage of students completing Applied College Algebra with minimum B-	Number of students completing Physics with minimum B-	Number of Students passing the Math Competency Exam
18	88.9 % (16/18)	70.6 % (12/17)	26.67% (4/15)	57.14 % (8/14)

As in the previous year, two weeks before the start of the fall 2024 semester, a cohort of 16 intended Diagnostic Medical Sonography (DMS) students participated in a two-week algebra bootcamp designed to strengthen foundational math skills. The bootcamp was supported by regular reminders and guidance from both the instructor and the DMS program director, encouraging consistent engagement and timely completion of assignments. This structured support resulted in a 100% bootcamp completion rate, with all 16 students successfully completing the program.

In Fall 2024, all 16 students enrolled in the Applied College Algebra course, which included an additional lab component. Including this lab seems to have had a positive impact, as every student completed the course with a minimum B-grade, meeting the academic requirement for progression within the DMS program.

During the spring 2025 semester, the same group of students enrolled in the required Physics course. Of the 16 students, 15 earned a grade of B- or better, demonstrating a high success rate in this critical subject. Only one student fell short of this benchmark. That spring, all 16 students also took the DMS Math Competency Exam, which required a minimum score of 83% to pass. Fifteen students passed on their first attempt, while the one who initially did not pass succeeded upon retaking the exam, resulting in a 100% eventual pass rate for the cohort.

The results are summarized in Table 2 below.

Table 2

Performance of students in Bootcamp, Applied College Algebra, Physics, and Math Competency Exam during AY 2024-25

Number of intended DMS	Percentage of students completing Bootcamp	Percentage of students completing Applied College Algebra with minimum B-	Number of students completing Physics with minimum B-	Number of Students passing the Math Competency Exam
16	100 % (16/16)	100 % (16/16)	93.75% (15/16)	93.75 % (15/16)

To further examine the impact of course structure on student performance, we analyzed the outcomes of the DMS Math Competency Exam by comparing students from two different academic years, those enrolled in Applied College Algebra without a lab component (fall 2023 cohort) and those who completed the course with a lab component (fall 2024 cohort). The goal was to determine whether the inclusion of a lab, which offers more structured, hands-on support, correlates with improved exam outcomes.

Specifically, we focused on students' performance on their first attempt at the Math Competency Exam, which is a critical benchmark in the DMS program. For each group, we recorded the number of students who earned a passing grade (B or above, requiring a score of at least 83%) and those who earned a failing grade (below B).

We then conducted a chi-square test of independence to assess whether there is a statistically significant association between the cohorts (with lab vs. without lab) and exam outcome (pass or fail). This test helps determine whether any observed differences in student performance can be attributed to the presence of the lab component rather than random variation.

The results, shown in Table 3C below, demonstrate a statistically significant relationship between the cohorts and exam outcomes. Specifically, the chi-square test produced a p-value of 0.0281, which is below the conventional 0.05 threshold. This leads us to reject the null hypothesis that the cohorts and exam outcome are independent. Instead, we

conclude that including a lab component is significantly associated with a higher likelihood of passing the Math Competency Exam on the first attempt. Similar tests also found statistically significant relationships between the cohorts and success rates in both the Applied College Algebra and Physics courses.

Table 3A

Contingency table and Chi-Square Test results for Applied Algebra Course

Cohorts	B- or above	Below B-	Total
Cohort I (2023-24)	12	5	17
Cohort II (2024-2025)	16	0	16
Total	28	5	33

Chi-Square test	
Statistic	P-value
Fisher Exact Test	0.0445

Table 3B

Contingency table and Chi-Square Test results for Physics Course

Cohorts	B- or above	Below B-	Total
Cohort I (2023-24)	4	11	15
Cohort II (2024-2025)	15	1	16
Total	21	12	33

Chi-Square test	
Statistic	P-value
Chi-square	.0002

Table 3C

Contingency table and Chi-Square Test results for Math Competency Exam

Cohorts	B or above	Below B	Total
Cohort I (2023-2024)	8	6	14
Cohort II (2024-2025)	16	1	17
Total	28	7	31

Chi-Square test	
Statistic	P-value
Chi-square	0.0281

Additionally, we compared the performance of students from both cohorts by examining the proportion of students who successfully completed the Applied College Algebra course, Physics course, and Math Competency Exam on their first attempt. The sample sizes and numbers of students who passed these courses and exams are presented in Tables 4A-C below. We then conducted hypothesis testing using two-sample independent proportion tests. The null

hypothesis stated that the proportions of success in both groups were the same, while the alternative hypothesis stated that the proportions were different. The test results were as follows: Applied College Algebra course (p-value = 0.01852), Physics course (p-value = 0.000127), and Math Competency Exam (p-value = 0.018028). Since the p-values in all cases were less than 0.05, we rejected the null hypothesis in favor of the alternative. Based on these results, we concluded that there are statistically significant differences in the proportions of students successfully completing these courses and the Math Competency Exam between the two cohorts of DMS students. The results are displayed in table 4A-C below.

Table 4A

Two-sample proportion Test results for Applied Algebra Course

Cohorts	Sample Size	B- or above	Z= -2.355041
Cohort I (2023-2024)	17	12	P-value = 0.018521
Cohort II (2024-2025)	16	16	

Table 4B

Two-sample proportion Test results for Physics Course

Cohorts	Sample Size	B- or above	Z= -3.832072
Cohort I (2023-2024)	15	4	P-value = 0.000127
Cohort II (2024-2025)	16	15	

Table 4C

Two-sample proportion Test results for Math Competency Exam

Cohorts	Sample Size	B or above	Z= -2.365035
Cohort I (2023-2024)	14	8	P-value = 0.018028
Cohort II (2024-2025)	17	16	

Conclusion and Recommendations

Our study reveals a statistically significant improvement in the performance of Diagnostic Medical Sonography (DMS) students following the addition of a lab component to the Applied Algebra course. This added support contributed to enhanced student outcomes across all quantitative subjects, including physics. Additionally, students demonstrated improved performance on the required Math Competency Exam.

The effectiveness of lab components in algebra courses has been widely documented at institutions across the United States (Easterling, 1991). At our institution, this instructional strategy has also been successfully implemented in

introductory-level math courses such as Quantitative Reasoning, as well as in Precalculus and Calculus. Given its demonstrated effectiveness, incorporating a lab component into the Applied Algebra course was a logical next step, and our findings are consistent with results reported in other studies.

According to the Annie E. Casey Foundation (2023), the COVID-19 pandemic significantly disrupted K–12 education and continues to impact students’ academic preparedness and confidence. In response to these ongoing challenges, it is critical to maintain open lines of communication, provide individualized support, and offer supplemental resources such as lab-based instruction and tutoring to promote student success.

Despite these encouraging outcomes, a persistent challenge remains: many students perform well on assignments but struggle with high-stakes exams. Unlike standard coursework, licensure and board exams typically require a minimum passing score of 85%, with no opportunities for retakes or extra credit. Bridging the gap between assignment performance and exam readiness is therefore essential as students approach program completion and certification.

To address this issue, it may be necessary to investigate why strong assignment performance does not always translate to success in exams. Potential strategies include integrating more exam-like assessments into the curriculum, expanding access to targeted exam preparation resources, and hosting workshops focused on test-taking skills. Ensuring that the content and expectations of assignments and exams are closely aligned could further enhance instructional coherence and student preparedness.

In support of this pedagogical shift, extra credit opportunities should be eliminated to encourage students to focus on mastering essential course content rather than relying on optional assignments to artificially boost their grades. Additionally, reducing the weight of homework from the current 15% to 10% could help ensure that final grades more accurately reflect demonstrated mastery of the material.

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