Increased Skills and Student Retention After Additional Clinical Chemistry Laboratory Implementation: An Intervention of an Enrichment Pilot Program in Medical Laboratory Science

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ABSTRACT

The Medical Laboratory Science (MLS) Department was awarded a grant to create a pilot program for sophomores to increase retention in the junior year clinical chemistry course, MLS 342. Assessment was performed using 2-sample *t*-test to compare the averages of laboratory practical grades and final course grades between students who took the program and those who did not and additionally compared them to the previous 3-year average. Students who took the program did statistically significantly better [86.669%, $P = 0.0156$, 95% confidence interval (CI) −9.3547, −1.0206] compared to the previous 3-year average (81.481%) for the MLS 342 final course grade than those who did not participate in the program (82.996%, $P = .5388$, 95% CI −6.4593, 3.4313). Retention within MLS 342 was 100% for those who took the program. Within the same cohort, MLS 444 senior clinical chemistry course grade average for the entire class was higher than the course average for the previous 3 years, (87.001 and 81.365, respectively), which was statistically significant ($P = .000012$, 95% CI −7.9023, −3.3679). After assessment of the program, a degree-required course, MLS 242: Clinical Chemistry Applied Diagnostic Technique Laboratory, was added to the curriculum. The attrition rate in MLS 342 has been 0% since implementation of MLS 242.

ABBREVIATIONS: CI - confidence interval, MLS - medical laboratory science.

INDEX TERMS: education, medical laboratory science, chemistry, clinical.

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BACKGROUND

In 2016, faculty in the Medical Laboratory Science (MLS) Department at the University of Massachusetts Dartmouth applied for and were awarded the Curricular Redesign and Innovation Grant by the Dean of the College of Arts and Sciences, where the department was housed at the time. The purpose of the grant was to increase student retention, learning, and degree completion by identifying deficits within the curriculum, with the goal of addressing identified curricular needs by redesigning and assessing course(s)/curriculum. As part of the grant, faculty in the MLS Department initiated the instrument enrichment pilot program. The objective of the pilot program was to enhance the fundamental laboratory and instrumentation techniques of MLS sophomores and increase student success and retention within the major in the junior year, particularly in junior-level clinical chemistry. After MLS 242: Instrumentation Analysis Laboratory (a sophomore-level course) was removed as a course and degree requirement in 2004, sophomores had only 1 MLS laboratory course, MLS 222: Pathophysiology Laboratory. As a result, exposure to clinical laboratory techniques prior to junior year was lacking overall. As sophomores, students had MLS 241: Instrumentation Analysis, but this course is purely theoretical with no accompanying laboratory course for practical application of theory. Because of the reduction in laboratory experiences during the sophomore year, an increased student-to-faculty ratio over the past several years, and a decreased semester length, faculty noted students had difficulty developing and maintaining adequate laboratory skills and manual dexterity early in the curriculum. Retention rates within the junior-year clinical chemistry course had a 3-year unsuccessful average of 17.79%. Student post-graduate surveys and department faculty both consistently indicated a need for a second laboratory course within the sophomore year, specifically with an earlier introduction to clinical chemistry practice to enhance skills before entering junior year. One study noted that MLS faculty should fill in any gaps in preclinical education that students who have transitioned from the classroom setting to the laboratory have identified.[1] This pilot program was the first step towards implementing another sophomore-level,

degree-required laboratory course and addressing important needs indicated by faculty and students in postgraduate surveys.

Introductory laboratory skills are essential for building practical skills and enhancing theoretical knowledge in clinical laboratory sciences. As freshmen, students start with MLS 116: Fundamentals in Medical Laboratory Science Techniques during their first semester, which covers laboratory safety, laboratory basics (glassware, pipetting, specimen collection, etc.) and introductions to clinical chemistry, hematology, and microbiology disciplines. The chemistry components include spectrophotometry and urinalysis, which form the basis of many laboratory skills such as pipetting, pour offs, microscopy, dilutions, and instrumentation, among others. While the second semester freshman year and second semester sophomore years do provide laboratory courses that build on some of these foundational skills, the next chemistry-related course is not until second semester junior year. In MLS 342: Clinical Biochemistry in Diagnostic Techniques, students needed to relearn many basic laboratory skills before starting the instrumentation section. The first half of MLS 342 included spectrophotometry, dilutions/pipetting, and laboratory math, while the second half focused on an introduction to instrumentation and clinical correlations. The emphasis on rebuilding foundational skills in MLS 342 prevented students from grasping new skills in the second half of MLS 342. This caused the laboratory portion of the senior-level course, MLS 443: Clinical Biochemistry I, to be more challenging and burdensome. MLS 443 is a senior-year intensive course that runs for 4–5 weeks. It is set up similar to a hospital clinical rotation: students have a 4-hour laboratory and a 4-hour lecture. Since there was only 1 laboratory course sophomore year, students entering the junior-year and subsequent senior-year chemistry sequence did not have the necessary foundation in such skills as dilutions and laboratory math, instrumentation practice and troubleshooting, clinical chemistry correlations, or quality control and assurance. The enrichment pilot program was developed to include additional dilution and laboratory math skills, pipetting, quality control/assurance, spectrophotometry, and microscopy skills. These skills could then be sharpened in subsequent clinical chemistry and other discipline laboratory courses and allow for the junior-level clinical chemistry course to focus more on instrumentation and correlations. While microscopy is not often performed in chemistry aside from urinalysis, faculty chose to increase these laboratory skills as well since there was an opportunity within this pilot program and a need was seen in upper division courses.

In "A review of bachelor's degree medical laboratory scientist education and entry level practice in the United States," Scanlan discusses entry-level competencies for clinical chemistry, some of which include the ability to perform unit conversion and dilutions and the ability to properly use spectrophotometers, quality control, and standard curves.[2] The instrument enrichment program emphasized development of laboratory math skills as well as pipetting skills, spectrophotometry, and microscopy.

Leibach established critical thinking behaviors (competencies) exhibited by expert medical laboratory scientists within the field. Leibach suggests that MLS educators must recognize the critical thinking behaviors in the MLS practice domains and use them to guide their development of the curriculum. This will enhance the growth of these behaviors within the student population. Critical thinking behaviors found in the cognitivist learning domain discussed by Leibach were covered in the pilot program. These include assuring test accuracy, precision, and validity; monitoring for errors: evaluating specimen integrity; evaluating quality control; and interpreting instrument data. In the behaviorist domain, emphasis was placed on focusing on good patient care and accepting responsibility for learning new tasks. In the humanist/affective and situated/contextual domains, demonstrating self-discipline at work and balancing multiple tasks, managing one's own time at work, and using experience to make judgments about tasks, respectively, were highlighted.[3]

METHODS

The instrument enrichment pilot program ran in the spring semester of 2017, with two 6-week sessions, January 25–March 1 and March 22–April 26. Session I had 18 sophomores enrolled, and Session II had 10 enrolled (total $n = 28$). Each laboratory session ran for the standard 3 hours per session; the laboratory lecture was presented asynchronously online as a blended program. This was to allow full use of scheduled laboratory time to perform the skills for that day and to allow students to review the material multiple times. The program was cotaught by 2 MLS faculty members. Participation in the pilot program was voluntary, as a mandate to participate was not allowed. The program was graded as pass/fail. Sophomores who attended all laboratory sessions for the pilot program and passed the pilot program laboratory practical exam were given the opportunity to waive the first laboratory practical exam grade in junior-year MLS 342: Clinical Instrumentation Analysis Laboratory. Students were still required to take the first laboratory practical in MLS 342, but regardless of the grade they would pass. This was because the first practical in the junior-level MLS 342 included topics that were reintroduced from freshman year and were now covered in the pilot program. The waiver did not include the written practical in MLS 342; students were still required to take it and earn a passing grade of 70 (C–).

Topics within the pilot program included pipetting, specimen requirements, centrifugation, spectrophotometry, and microscopy, which was added to address faculty concerns about poor microscopy skills observed in upper-level courses. To address long-standing deficits in laboratory math skills, lab math units and assignments were posted on the course website each week, and students

Table 1. Program schedule

Date	Lab #	Topics
January 25 or March 22	Lab 1	Introduction, pipetting, samples, centrifugation, dilution math
February 1 or March 29	Lab 2	Spectrophotometry I, colorimetry math
February 8 or April 5	Lab 3	Spectrophotometry II, graphing and standard curve math
February 15 or April 12	Lab 4	Microscopy I, metric math
February 22 or April19	Lab 5	Microscopy II, math review
March 1 or April 26	Lab 6	Written and practical exam

were required to complete practice questions and an online quiz prior to the laboratory session. The lab math units were applicable to the topic that was to be performed for each laboratory session (Table 1). At the beginning of each lab session, the students were called to the blackboard to do the practice problems and discuss how they arrived at the answer. The instructors would then review the lab math topics of the week with the class. Upon completion of the pilot program, the students had to complete a practical exam that included a Biuret total protein assay with quality control and 2 patient specimens. Students were given a standard of total protein stock solution that needed to be diluted and aliquoted into 4 new standards of 2, 4, 6, and 8 mg/dL. The laboratory practical emphasized critical foundational skills for clinical chemistry such as: laboratory math, dilutions, pipetting, specimen integrity, spectrometry/Beer's law/instrumentation, quality control, clinical significance, and time management. The practical mirrored the laboratory practical in the junior-year clinical chemistry course, MLS 342, which is why it was performed in the pilot program.

The first half of MLS 342 was dilutions and spectrophotometry, so by increasing this sophomore year, faculty hoped to increase student understanding and skills in junior year and decrease failures. Retention was an issue more so in the first half of MLS 342; since the first half covered dilutions, manual tests, and spectrophotometry, it was designed to reduce the attrition in the first half of MLS 342. By increasing skills sophomore year, it would also decrease attrition for the second part of MLS 342 and other MLS courses as well.

Assessment was performed by measuring pilot program and MLS 342 practical grades, MLS 342 final course grades, and the previous 3-year average for both MLS 342 practical and final course grades. Senior-level clinical chemistry courses, MLS 443: Clinical Biochemistry I and MLS 444: Clinical Biochemistry II, do not have laboratory practical exams, so only the final course grades and previous 3-year average were measured. Additionally, student surveys were collected for course assessment after the pilot program, following the completion of MLS 342: Clinical Instrumentation Analysis Laboratory and after completion of senior-level clinical chemistry courses. Surveys were anonymous to encourage honest and unbiased answers. The 2-sample *t*-test was used to compare the averages of MLS 342 Practical 1 grades and MLS 342 final course grades between students who took the pilot program and those who did not within the same graduating class as well as compared to the previous 3-year average. Furthermore, the 2-sample *t*-test was used to compare the averages of MLS 443 and MLS 444 final course grades between students who took the pilot program and those who did not within the same graduating class as well as compared to the previous 3-year average. Statistical significance was set a priori at the .05 level, and all interval estimates were calculated for 95% confidence.

RESULTS

Students participating in the pilot program who went on to take MLS 342 ($n = 15$) the following spring semester (2018) had a higher pilot program laboratory practical average than those who did not go on to take MLS 342 ($n = 13$) the following spring (80.333% and 78.654%, respectively), although this difference was not statistically significant. Of those who did not take MLS 342 the following spring semester, 5/13 (38.46%) changed their majors, 7/13 (53.85%) did not pass a prerequisite course for MLS 342, and 1/13 (7.69%) did not enroll in spring semester courses.

After completion of the pilot program, students completed a survey to allow for instructor assessment of the program (Figure 1). Only 57.14% of students liked that the laboratory lectures were given online instead of face to face, and 75% of students felt that the online material aided in their learning experience. Student comments expressed the feeling that face-to-face lectures would be better so they could "ask more questions and receive immediate answers." Laboratory math exercises were viewed favorably. The majority of students felt that the laboratory math helped prepare them for the laboratory and exams. Students' comments included: "The math problems were good examples of what to expect in lab," "Math quizzes helped students understand previous week's math and how to calculate dilutions," and "Quizzes helped students study for the exam" *(sic)*. Students noted that they liked reviewing lab math with the instructors at the beginning of lab. In total, 92.86% of students felt that the enrichment program increased their laboratory skills; students "felt more comfortable going into junior year with a better understanding on

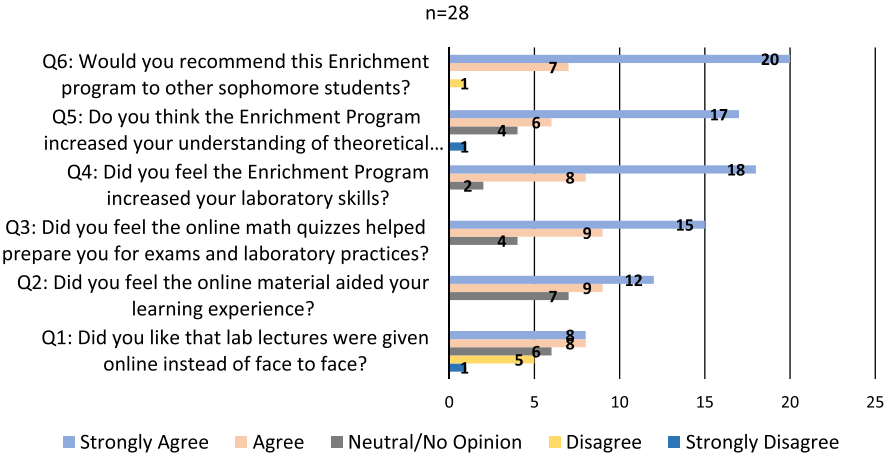

Figure 1. **Post–pilot program survey.**

the instruments." Students also noted, "We learned pipetting technique and gained better understanding of the spectrophotometer," "The program helped students to understand the procedures better," and "The program helped us learn how to detect issues with the tests." Most of the students said they would recommend the program to other sophomores. Students suggested that it would be more helpful if the program took place in the first semester of sophomore year instead of during their spring semester because there is no MLS laboratory course in the fall semester. They also suggested that the program should be for an entire semester with multiple labs to practice the same concepts and techniques.

There was no statistically significant difference in the average MLS 342 Practical 1 grades between students who took the pilot program (83.000%) and those who did not (80.067%). These students were in the same graduating class and took MLS 342 in the same semester. Within this same group of students, the average final course grade for MLS 342 was higher for students who took the pilot program (86.669%) than those who did not (82.996%), although this difference was also not statistically significant. When compared to the previous 3-year average ($n = 118$) for MLS 342 Practical 1 grades, there was no statistically significant difference between students who took the pilot program and those who did not. Students who did not take the pilot program had a lower average for the MLS 342 Practical 1 grade (80.067%) when compared to the previous 3-year average (86.008%), which was statistically significant ($P = .0518$). Importantly, students who took the pilot program did statistically significantly better (86.669%, $P = .0156$, 95% CI −9.3547, −1.0206) when compared to the 3-year average (81.481%) for the MLS 342 final course grade than those who did not (82.996%, $P = .5388$, 95% CI −6.4593, 3.4313). In addition, 100% of the students who took the pilot program were successful in MLS 342. Two students were unsuccessful in MLS 342 (6.67% unsuccessful rate); these students did not participate in the pilot program.

Junior-level students who participated in the pilot program as sophomores completed a survey for program assessment after finishing MLS 342. The majority (88.89%) of students indicated that they would strongly recommend the pilot program to future sophomore students (Figure 2).

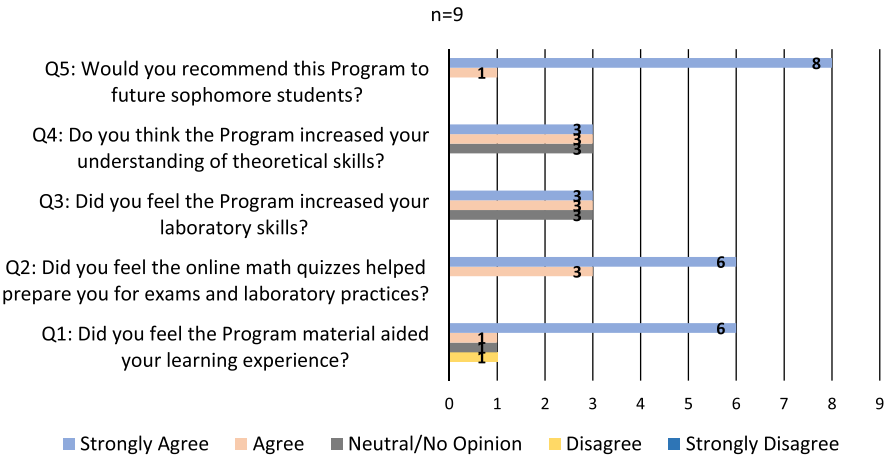

Figure 2. **Post–MLS 342 survey.**

Table 2. MLS 443: Clinical Biochemistry I course grades Fall 2018

Cohort	Average Course Grade	Previous 3-Year Average	*P* Value	95% Confidence Interval
Entire MLS 443 class (including those who did not take the pilot program) $n = 28$	78.591	79.663	*.434158	−1.5931, 3.6783
Students who took the pilot program $n = 14$	79.551	79.633	*.960596	−3.2993, 3.4641
Students who did not take the pilot program $n = 14$	77.630	79.633	*.204331	−1.1438, 5.1494

*Statistically significant (*P* value at .05).

Table 3. MLS 444: Clinical Biochemistry II course grades Spring 2019

Cohort	Average Course Grade	Previous 3-Year Average	*P* Value	95% Confidence Interval
Entire MLS 444 class (including those who did not take the pilot program) $n = 28$	87.001	81.365	*.000012	−7.9023, −3.3679
Students who took the pilot program $n = 14$	88.205	81.365	*.000000	−8.6589, −5.0201
Students who did not take the pilot program $n = 14$	85.704	81.365	*.046963	−8.6084, −0.0676

*Statistically significant (*P* value at .05).

Student survey comments were generally positive and revealed the areas in which they felt particularly prepared for junior-level clinical chemistry because of their participation in the pilot program were pipetting and dilution skills, spectrophotometer skills, total protein assays, standard curves, and exam preparation.

When Fall 2018 MLS 443 course grades were analyzed, there was no statistically significant difference found between different groups of students in the course (those who took the pilot program as sophomores versus those who did not) and no statistically significant difference between the Fall 2018 course grades and the previous 3-year average ($n = 102$; Table 2).

MLS 444 Spring 2019 course grade analysis did reveal statistically significant differences. The MLS 444 course grade average for the entire class was higher than the course average for the previous 3 years ($n = 100$; 87.001 and 81.365, respectively). This difference was statistically significant ($P = .000012$, 95% CI −7.9023, −3.3679). MLS 444 students who took the pilot program as sophomores had a higher course grade average when compared with the previous 3-year average (88.205 and 81.365). This difference was statistically significant ($P = .000000$, 95% CI −8.6589, −5.0201). MLS 444 students who did not take the pilot program had a higher course grade average when compared with the previous 3-year average (85.704 and 81.365). This difference was statistically significant ($P = .046963$, 95% CI −8.6084, −0.0676). Students who took the pilot program as sophomores had a higher course average than those who did not take it (88.205 and 85.704), although this difference was not statistically significant ($P = .242005$, 95% CI −6.8786, 1.8757; Table 3).

Senior-level students who participated in the pilot program as sophomores completed a survey after finishing MLS 444: Clinical Biochemistry II in the spring semester (Figure 3). The majority felt that the program aided their learning experience and increased their laboratory skills.

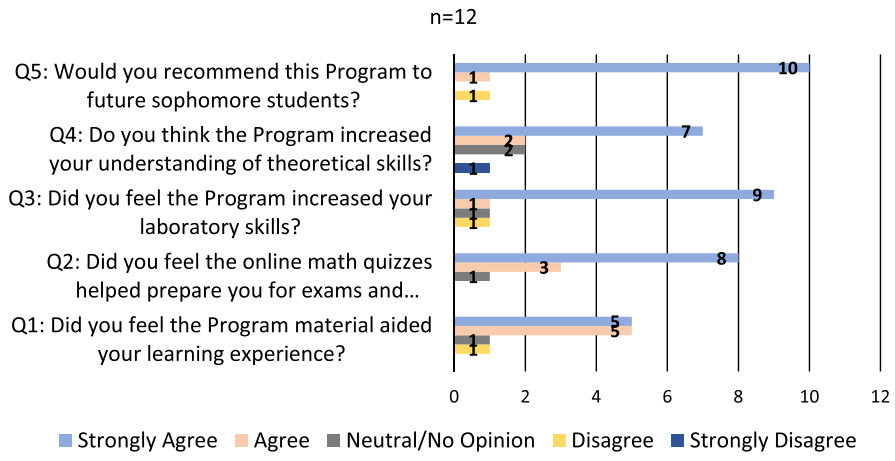

Figure 3. Post–MLS 444 survey.

Most of the comments were positive: "Helped greatly in chem labs (junior + senior years)"; "Math has always been my weakest point, so all of the practice during this class benefitted me greatly"; "Good hands-on practice"; "I felt much more comfortable in the chemistry lab, which set me up for the following year"; "Very beneficial in preparation for junior year"; "I don't think I would have passed junior year without it." Some students felt that the program was lacking in experience with some of the instruments they use junior year: "I think it would be helpful to introduce students to the other instruments in the lab"; "I think more helpful lab activities could have been added to transition to junior year (instruments, etc.)"; "Use instrumentation more." Some students felt that it would have been more beneficial to have the program run for the entire semester. Suggestions from students to the survey question "Is there anything you would change about the Enrichment Program?" were to apply more of the instruments that are used junior and senior year and include more lab math.

DISCUSSION

The goals of the pilot program were to increase retention in the junior year, increase junior-year clinical chemistry laboratory course grades, increase student exposure to clinical chemistry practice and theory in the sophomore year to better prepare students for junior year, increase the academic rigor in the sophomore year, and increase student satisfaction with the major. All these goals were accomplished. Students who took the pilot program did statistically significantly better than the previous 3-year average for MLS 342 course grades, and 100% of these students were successful in passing (earning a C– or better) the MLS 342 course. Overall, most students rated the program as strongly recommended and felt that the program enhanced their laboratory skills and better prepared them for junior-level clinical chemistry.

Although no statistically significant difference was seen senior year in MLS 443 between the first cohort of students who took the pilot program and the previous 3-year average, this was unimportant, as the goal of the program was to increase retention and success in the junior year; retention was not an issue in senior-level clinical chemistry courses. Regarding MLS 444, both students who took the pilot program and those who did not performed statistically significantly better than the previous 3-year average for the course grade. Although there is no definitive explanation for this phenomenon, most of the students were perhaps more prepared for senior-year clinical chemistry courses. Also, this cohort of students might have been academically stronger than the cohorts of the previous 3 years.

Conway-Klaassen et al found that MLS students preferred online delivery of course materials, but interestingly, many students in our cohort viewed it unfavorably.[4] This is surprising because online delivery is generally more convenient; students could review the material at their own pace and were able to review the same materials multiple times. Online delivery of prelab lecture also provided more time in the laboratory for hands-on practice. Increasing hands-on laboratory skills was one of the goals of the pilot program.

While students in the pilot program suggested delivering laboratory lecture in-person, the University has pushed for more blended and online delivery modalities, even prepandemic, and the faculty agreed having the ability to review material multiple times and devote the entire laboratory time to skill building was helpful in this course. Although students in the pilot program suggested there should be a laboratory course in the fall semester of sophomore year, faculty decided to request MLS 242 be placed back where it originally was, in the spring semester of sophomore year. This allowed MLS 242 to coincide with MLS 241: Instrumentation Analysis lecture. MLS 242: Clinical Chemistry Applied Diagnostic Technique Laboratory was requested as a full-semester course so more laboratory skills could be developed. With the implementation of MLS 242 as a full-semester course, there was a change in both MLS 242 and MLS 342 structure. MLS 242 took the first half of the MLS 342 laboratory course (dilutions, spectrometry, manual testing) and still included microscopy while adding some instrumentation and basic electrophoresis techniques in the second half of the course. MLS 342 was then able to concentrate more on quality assurance and control, advanced instrumentation and electrophoresis, and correlation of clinical chemistry laboratory results. Recently, MLS 242 switched from an online, asynchronous lecture component to an in-person lab lecture format. The lab lecture is scheduled before the lab session so that students have the full scheduled lab time to complete the procedures and develop hands-on skills.

Implementing measures to increase retention is essential. Undergraduate enrollment has generally decreased, and there is a workplace shortage of medical laboratory scientists, which has become particularly evident during the COVID-19 pandemic.[5-7] In the American Society for Clinical Pathology's 2020 Vacancy Survey, one of the top concerns regarding the staffing shortage was the availability of "qualified laboratory professionals" and the requirement for more graduates from accredited programs.[6] MLS educators must ensure that they are graduating as many competent medical laboratory scientists as possible to fill in these workplace gaps. MLS educators must also work at identifying and filling any gaps within the curriculum and increasing student satisfaction within the MLS major. It is important to note that since MLS 242 was implemented in the spring semester following the pilot program, the attrition rate in MLS 342 has been 0%.

Future research should address whether implementation of the new laboratory course (MLS 242) influenced Board of Certification clinical chemistry exam scores and if there is a difference in grades in other MLS courses

wherein some of the laboratory skills learned in the pilot program carry over. Further assessment of MLS 242 should be performed to determine whether it continues to have a positive impact on student retention in junior-year clinical chemistry.

Limitations of this study include a small sample size, potential selection bias, and recall bias.

CONCLUSIONS

These data suggest that the pilot program contributed to increased student success and retention in junior-year clinical chemistry. Positive student comments and ratings on survey data also support the utility of the pilot program. After evaluation of the instrument enrichment pilot program upon its completion, it was made into a full-semester laboratory course and degree requirement, MLS 242: Clinical Chemistry Applied Diagnostic Technique Laboratory.

Based on the findings of this study, the following recommendations are made:

- Sequence the curriculum so the skills covered in the pilot program, such as dilutions, pipetting, quality control/assurance, spectrophotometry, and microscopy, are introduced early on in lower-level courses.
- Scaffold math skills, particular to laboratory practice.
- Build and reinforce laboratory skills covered in the pilot program throughout the upper curriculum courses.

By taking these measures, it is possible to decrease attrition rates and support student growth within MLS departments and ultimately help fulfill the workplace need.

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