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EVALUATING THE LENGTH OF CLINICAL ROTATIONS IN MEDICAL LABORATORY SCIENCE EDUCATION

Kendal Beazer

EVALUATING THE LENGTH OF CLINICAL ROTATIONS IN MEDICAL LABORATORY SCIENCE EDUCATION

By

Steven Kendal Beazer

B.S., Weber State University, 2010
MHA, Weber State University, 2014

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The members of the Committee appointed to examine the Dissertation of Steven Kendal Beazer find it satisfactory and recommend that it be accepted.

DocuSigned by:
Victor Huber
A16CC650D6164C5...

Chairperson

DocuSigned by:
[illegible]
DD24ABA0A6CC441...

DocuSigned by:
Sabina Kuperschmidt
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DocuSigned by:
Amy Nelson
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Abstract

Medical laboratory scientists and technicians play a crucial role in healthcare by utilizing advanced methods to aid in the diagnosis, monitoring, and prevention of a wide range of diseases. Certifying as an MLS or MLT professional is detailed and specific, requiring years of laboratory training that is crucial to accurately perform testing that impacts patient care. Shortages of qualified medical laboratorians have persisted for decades, causing laboratory administrators to hire individuals who lack basic laboratory training. Laboratory education programs are not keeping up with the staffing demands, in part due to the lack of clinical rotation placements needed for MLS and MLT students to complete their degrees. The opportunity for clinical rotations is a requirement of NAACLS, the main credentialing body for medical laboratory education, however, there are no specific requirements for the time students spend on rotation. Clinical rotations are used for different purposes across medical laboratory education programs, and this research focused on their perceived impact from major stakeholders in MLS education, and key quality outcomes from individual programs. The first chapter sets the landscape of medical laboratory education with details provided from 167 of the 469 directors of NAACLS-accredited programs. Chapter one established averages for hours spent on clinical rotation and in didactic education across all MLS and MLT programs. Chapter two surveyed 155 individuals from various sizes of laboratories, job titles, geographic locations, and ages, which were used to evaluate how differences in facilities and opinions influence the training from clinical staff working with students. Chapter three evaluated certification pass rates against time spent on clinical rotation using regression analysis. This research shows the value of the clinical rotation for hospital-based programs while demonstrating that it may not be crucial for other programs. The findings of this report should be used to seek harmonization of clinical rotation standards across the profession while still recognizing the unique differences between programs. The shortage of medical laboratorians has reached a critical point which threatens the existence of the profession, and findings in this report strengthen the evidence base that is foundational to meaningful actions that will address the issue.

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Chapter 1: Introduction

Background

The origins of the medical laboratory science (MLS) profession can be traced back to early scientists like Rudolf Virchow, Karl Landsteiner, and Robert Koch who provided the foundation upon which medical laboratory science would be built (Farhud, 2018; Blevins & Bronze, 2010). At the close of the 19th century, advances in microscopy and staining techniques allowed for more detailed examination of biological specimens and there was a gradual shift from an observational approach in medicine to a scientific, evidence-based approach (Duffy, 2011). The contributions to knowledge about human anatomy and physiology became rooted in modern medicine and became a crucial part of medical diagnostics, which resulted in the emergence of clinical pathology as a distinct field of medicine (Schultz, 2008). As these tests gained acceptance, there was greater demand for medical laboratory scientists to collect and test patient specimens to look for any abnormalities (Duffy, 2011).

Healthcare requires teamwork from a large group of educated individuals to run efficiently and deliver quality healthcare the public can rely upon and trust to take care of their loved ones. This group includes physicians, physician assistants, nurse practitioners, nurses, radiological technicians, respiratory therapists, and medical laboratory scientists among many others. Each of these healthcare professions have the opportunity to further specialize, making them highly trained and educated people within their respective fields. For most healthcare workers, the patients have direct contact and interactions with them, validating the great work they do on the healthcare team. However, medical laboratory scientists are often located in remote areas of the hospital or clinic and have very little patient interaction as part of their routine work.

Members of the MLS profession are often an unknown part of the healthcare team, but it is estimated that they are responsible for roughly 70% of medical diagnoses through their work (Wilson & Badrick, 2016). Nearly all samples collected from patients in hospitals or clinics are sent to the laboratory to look for any abnormalities. Most hospital laboratories are segmented into smaller sections of hematology, chemistry, microbiology, immunohematology (blood bank), and urinalysis. These major disciplines are foundational to most of the testing performed within the laboratory, but there are other methodologies to support each of these groups, like the proliferation of molecular testing that has expanded in all facets of the lab (Buckingham, 2019). Each of these individual disciplines comes with skills and knowledge needed to perform the testing.

Hematology requires a technologist to know about the size, shape, color, and proportions of red and white blood cells, because small variations in those cells can indicate different pathologies. Hemostasis refers to the ability of blood to clot and stabilize bleeding, which happens daily throughout the body, and is another complex area of specialization that often falls under the purview of a hematology technologist. A technologist in chemistry will run many of the tests that can be crucial to the function of cells in the body. Potassium, calcium, sodium, alanine aminotransferase (ALT), thyroid stimulating hormone (TSH), urea, and glucose are examples of analytes tested to look for imbalances in the body that could indicate potential problems like diabetes, liver failure, kidney failure, or hormonal issues. Immunohematology, or blood banking as it is commonly referred to, is tasked with determining the antigens and antibodies that exist on the red blood cells and in the serum. Most individuals are familiar with the A, B, and O blood groups, but there are many more blood antigen groups that must be evaluated to make sure that a patient in need of a transfusion can safely receive the blood without causing further complications (Mitra et al., 2014). Blood banking looks for minor discrepancies in aliquots of patient blood to determine larger incompatibilities that may arise from the blood of a donor. A technologist performing urinalysis testing can quickly screen for diabetes, urinary tract infections, kidney dysfunction, and kidney stone formation.

Clinical microbiology is the last major discipline and is a vast section that requires the technologist to know details about each organism they may encounter, the conditions and environments those organisms can grow in, how to identify those organisms, and how to effectively kill those organisms. Clinical microbiologists must be skilled enough to differentiate between microorganisms that are common in a healthy individual, and those that are considered pathogenic, which can be difficult when individual serovariants of the same species can be considered normal or pathogenic. Physicians rely on clinical microbiologists to let them know what the pathogenic organism is, and what antimicrobials they can use to rid the patient of that pathogen. In addition to the foundational sciences and techniques that must be mastered by a medical laboratory scientist, molecular technologies have expanded laboratory testing capabilities in each of the major disciplines, adding to the skills required for the profession (Buckingham, 2019). On top of these highly specialized disciplines, medical laboratory professionals must also be versed in healthcare laws and the regulations of the clinical laboratory to stay accredited and be able to continue testing samples (Genzen, 2019).

Testing samples is a major part of what medical laboratory scientists do; determining diagnosis and treatment is often contingent upon the results produced by MLS professionals, and it requires great attention to detail. Medical laboratory scientist or medical laboratory technician (MLT) programs are required to teach specimen integrity and testing requirements for each test routinely performed in the laboratory, because the test is only as good as the sample collected. Quality assurance and quality control are taught within medical laboratory education because the tests themselves must be adjusted and aligned to make sure they are working properly. Errors in testing can occur if the testing systems and environment are not continually monitored (Plebani, 2006). Programs must also teach students about the laws that govern the clinical laboratory because lab work is highly regulated by federal laws and accrediting bodies (Genzen, 2019). The errors of a single individual in the laboratory could result in the loss of the laboratory license to collect and test samples for the patient population they serve. Collectively, the testing and quality assurance performed by trained medical laboratory scientists make this a complex field that is continually evolving and makes the education of the technologist an important aspect of patient safety (Sciacovelli et al., 2017).

Shortages of New Laboratory Personnel

Medical laboratory science plays a critical role in healthcare that requires years of education and training to safely practice within the profession but staffing shortages across the profession have made it difficult for laboratory administrators to find qualified personnel (Garcia et al., 2022). This is not a new phenomenon as laboratories have been understaffed for decades, but the problem continues to worsen (ASCP, n.d.). The MLS profession has been coping with a staffing shortage that has evolved for numerous reasons that are now converging at a difficult time in healthcare. The baby boomer generation, which encompasses people born from 1946 through 1964, started reaching retirement age in 2008 and the last of the group will reach full retirement age by 2031 (ASCLS, 2012). The retirement of baby boomers in the laboratory has decreased the institutional knowledge needed to operate sections of the laboratory like microbiology and blood bank. In 2020, the American Society for Clinical Laboratory Science (ASCLS) cited retirement as a major concern for the shortage of MLS professionals, with estimates of 12.3% more expected to retire over the next 5 years (Deaton-Mohney et al., 2023). An increasing rate of retirement, coupled with low numbers of new MLS graduates entering the workforce, continues to exacerbate MLS shortages. These factors have occurred at a time when an aging population has placed increased testing demands on an already strained system (Scott, 2015). On top of the generational transition, the COVID-19 pandemic also strained laboratory testing personnel, overworking many skilled laboratorians and causing them to leave the profession (Miller, 2021). The workers that remain have reported high levels of burnout, and turnover in the profession is expected to continue (Miller, 2021). A vacancy rate survey prior to COVID-19 revealed that there was a 7%-11% vacancy rate in medical laboratory scientists across the United States, with up to 25% vacancy rates in some areas (Garcia et al., 2019). The Bureau of Labor Statistics estimates that there are currently 329,200 medical laboratory scientists across the United States, with a 7% increased need expected over a ten-year span (Bureau of Labor Statistics, 2021). According to the BLS data (2021), this is an anticipated expansion of 21,800 new medical laboratory scientists needed over the next ten years. The growth of the industry is ominous since the profession is already operating at a vacancy rate above the average of all professions.

When faced with a lack of qualified laboratory staff, administrators are forced to make difficult decisions about whom they hire for open positions. While someone with an education in laboratory sciences would be preferred within the clinical laboratory, individuals without education in laboratory medicine are often hired to ensure that there are enough staff to keep up with testing demands (ASCP, 2018). Studies have shown that laboratory employees without education in medical laboratory science have higher error rates which leads to risk of inaccurate lab results, resulting in diagnostic errors and patient safety concerns (Lawson & Ledesma, 2018). Laboratory administrators are doing their best with the resources they have available, but the shortage of qualified MLS professionals in healthcare is a serious problem that needs to be addressed.

Explanations for the Shortage

There have been many explanations for the shortage of MLS professionals, including minimal visibility of the profession, conflicting credentialing bodies, wages, workplace stress, and inconsistent licensing requirements across the states (Halstead & Sautter, 2023). While all these explanations have merit, ultimately there are not enough students graduating from medical laboratory programs to keep up with increasing laboratory testing needs (ASCLS, 2018). Medical laboratory education programs need to graduate more students to alleviate the staffing shortages in clinical laboratories, creating opportunities for laboratory administration to improve quality testing and ensure patient safety.

There are many support staff in the laboratory responsible for collection and processing of clinical samples, but the testing is usually performed by medical laboratory technicians and medical laboratory scientists. Medical laboratory technician (MLT) education is an Associate of

Science degree, whereas the MLS is a Bachelor of Science degree, and they both use the certification exam administered by the American Society for Clinical Pathology (ASCP) to become credentialed. Both MLT and MLS professionals are qualified to perform high-complexity testing in a clinical laboratory, though the MLT is limited in professional advancement opportunities and is not qualified to serve as a technical supervisor under the Clinical Laboratory Improvement Amendments (CLIA) that regulate testing of human samples (Code of Federal Regulations, 2022).

As of August 2023, there were 246 MLS educational programs and 243 MLT programs offering accredited medical laboratory education across the United States (NAACLS, 2022). Some of these programs are housed within hospital systems while others are on college campuses. Within these programs, students learn hematology, clinical microbiology, clinical chemistry, immunohematology, urinalysis, immunology, and molecular diagnostics. Though there can be differences in the way the education is delivered, most are accredited by the National Accrediting Agency for Clinical Laboratory Sciences (NAACLS). NAACLS does not have a detailed system that it requires laboratory education programs to adhere to, but it does have guidelines to ensure the education delivered in the programs will adequately prepare students for the work they will encounter in hospitals and clinics (NAACLS, 2021). This flexibility allows for variation in the MLS education delivered, whether that be in a hospital program, or a college program.

One aspect of medical laboratory education that is similar across all programs is a clinical rotation, or internship, that accompanies the didactic course material. It is a NAACLS requirement that MLS and MLT programs provide “an opportunity” for students to have a clinical experience, but they do not provide any more detail (NAACLS, 2021). This guideline has been interpreted in numerous ways across laboratory education programs because there is limited information on "when" or "how long" is an acceptable clinical rotation through the accrediting body. The ambiguity allows programs to set clinical rotation requirements that address the program's individual needs. Some programs require a year of clinical internship at the conclusion of didactic coursework while others will require two weeks of clinicals performed concurrently within the courses. What is unclear is if the length of time on clinical rotation set by these programs is proportional to the value added to the education of the student.

There is little doubt that the time a student spends in the laboratory will be educational to that student, but these rotations come at a cost to both the students, and the facilities they are operating in. NAACLS requires the clinical rotation to be educational and not "service work", meaning that the time a student is on clinical rotation should not be paid by the organization. The student is not supposed to be working in the laboratory because it is meant to be educational and if a student is placed at the bench and expected to work, then the learning opportunities are limited.

Technological advancements over the last couple of decades have made it easier to reach students where they are, both in their geographic location, and in their stage of life. This has been a success for the small, rural access hospitals that have historically struggled to recruit and keep skilled MLS professionals because it is no longer necessary for students to move away for education when the material can be delivered to their location, and on their time. While the didactic MLS education can be delivered from a distance, the clinical rotation is performed on site. A clinical rotation can be an insurmountable burden for students who are interested in MLS, but found the career path later in life and have obligations beyond their educational pursuits. These “non-traditional” students may rely on the paychecks and health insurance provided by their employers, and it is a difficult prospect to potentially lose their current employment in order to perform a clinical rotation for an extended period of time.

Students should be operating under the supervision of a qualified MLS professional, from whom they are able to learn the details of working in a laboratory. However, this mentoring process can be demanding for the MLS professional, impacting their focus and daily workload. Teaching students requires time that might not be accounted for in their regular duties, potentially delaying laboratory operations. In a profession that is already short staffed and overworked, assigning additional tasks can contribute to burnout among laboratory workers. Programs that utilize clinical rotations beyond the average of their peer institutions may limit program completion of non-traditional students while placing a heavier burden on clinical staff. This represents an inherent cost associated with the educational opportunity of clinical rotations. Determining the optimal amount of time students should spend on rotation for their clinical laboratory education is difficult because there is considerable variability. However, it is important to assess if the additional burden on students and clinical laboratories is appropriate for the education of the student.

This research seeks to answer a fundamental question that remains unanswered. *Is there a direct correlation between the length of time spent on clinical rotations and the quality or value of the medical laboratory science education*? The stakeholders with vested interest in this research include education coordinators who represent the hospital and clinical staff, and program directors who represent the didactic education side. Both parties oversee different aspects of clinical education and are important participants in this dissertation research.

Conceptual Framework

The conceptual framework of this research is built upon game theory, systems theory, and constructivism. Prior research has applied these theories to healthcare in various ways, yet none have attempted to apply these models in medical laboratory sciences (Centers for Disease Control and Prevention, 2023). This is an innovative approach constructed to address the specific needs of this subsection of healthcare with the underlying theories recognized as a framework for the research.

Game theory was developed nearly a century ago with much of the early work done during World War II at Princeton and can best be defined as the study of mathematical models of conflict and cooperation between rational decision-makers (Myerson, 1997). The mathematical techniques developed with game theory offer insights on how two or more parties can make decisions that impact another group of individuals. In game theory, the game refers to the social situation in which individuals are making decisions that are in pursuit of their own objectives, and that the pursuits are the options with the greatest expected reward (Myerson, 1997). The game in this application refers to medical laboratory education where programs can thrive or fail depending on the decisions implemented by MLS or MLT program administrators. The measurable units within medical laboratory education are the number of students that can be enrolled to help maintain viability of the program. This is a simplified look at what maintains viability of a medical laboratory education program, but a lack of students can quickly lead to closure. In contrast, many other issues can be addressed if the enrollment numbers keep above a certain threshold.

Advancements in the internet and personal computers have made it simple to deliver didactic material to students around the world, spreading the availability of medical laboratory curriculum to regions that were once geographically isolated. These technological advancements have also created an environment where medical laboratory programs are competing for the same students across the country instead of limiting it to their immediate geographical area. This is particularly important for university programs because of the predicted reductions in students attending college over the coming decades, thus reducing students considering MLS (Alexander, 2020). The extended reach of medical laboratory programs brings more students into the profession, but it also increases competition for students, no matter where they reside.

Many decisions are outside the control of program directors, but one thing they have the power to address is the length of time students need to spend on clinical rotation for the completion of their program. This is a decision they are expected to make in the best interest of the students, the profession, and the program itself. The increased competition has created an environment where students are discerning consumers who have options in the programs they want to attend (Levine & Van Pelt, 2021). Discussion boards for laboratory science are frequently abuzz with questions about which school to attend, and why. A common response to school choice is that certain programs require shorter clinical rotations than others, and for students who are looking for the shortest and easiest path to certification, this could be enough to sway them. Program directors have a difficult task in making sure the program is properly training students to be ready in the workforce, but also in recruiting new students to the program.

While it is expected that training students is the number one priority for medical laboratory programs, it is also important to draw in new students to keep the program viable, and if students are being recruited to other programs because of their time required on clinical rotation, then this aspect is worth investigating further. Game theory provides an explanation for this complex relationship and the decisions facing the program director.

There have been many notable constructivist theorists over the last 100 years, like Immanuel Kant, Thomas Kuhn, Jean Piaget, Linda Alcoff, Elizabeth Potter, and John Dewey (Phillips, 1995). Each of these authors and theorists come to the same basic understanding, that learning is not passive and that the learner constructs meaning through their own experiences. Education is not the same for each individual learner and the lessons delivered will have a different impact on the student that is dependent upon their prior experiences (Mcleod, 2023).

Constructivist theory is multifaceted when it comes to medical laboratory education, not only in the concept of clinical rotations and the impact they have on the education of the student, but also in the way educators perceive their role in education. Most laboratory education programs will utilize some form of didactic education to prepare students for what they will see while on their clinicals in the laboratory, yet there is great variation in what that would look like within each program. Some students are required to be working in the laboratory to even enroll in an MLS program, so the experiences they bring with them to the didactic education would provide a different lens through which to view the didactic education. The background of the student is a further application that will influence their learning because most students have personal connections with health and disease that make meaningful connections to the material.

Constructivism as a learning theory for students in medical laboratory education is apparent. Constructivism as a learning theory for medical laboratory educators is an aspect that does not often get much consideration even though educators are always learning. When educators are confronted with new information, constructivism posits that they will process it through their own experiences (Mcleod, 2023). The MLS profession has gone through many changes in the time since seasoned educators were enrolled in educational programs, and these changes can be difficult to process through their experiences in how programs were structured years prior. These experiences can be varied and perspectives can be influenced by individual experiences in healthcare. Those with experience in short-staffed, rural laboratories would likely see changes in laboratory education differently than those in urban centers near numerous medical laboratory programs. In a similar thread, educators who themselves went through programs that required longer clinical rotations than the average program have a different experience than those who completed an abbreviated clinical rotation.

Constructivism is a lens through which to understand the way that people understand their environment and the education they consume. Opinions about clinical education will be impacted by their past experiences and the actions developed from those experiences. These experiences position educators to fall into the fallacy of tradition, where an emphasis is placed on the way it was done before, making it more difficult to adapt to changes facing the profession (Michaud, 2018). Education does not happen in a vacuum and constructivism is an important theoretical framework in understanding the decisions made in medical laboratory science education.

Like other theories utilized in this research, General System Theory (GST) was mostly developed in the mid-20th century (Gibson, 2023). Ludwig von Bertalanffy was one of the key founders of GST and lectured on the limitations of Newtonian closed systems of study early in his career (Anderson, 2016). Bertalanffy argued that systems cannot be reduced to a series of functioning parts operating in isolation, rather, to understand the system, one needs to understand the relationships between the parts. Over the decades since Bertalanffy developed this theory, it has spread across disciplines in psychology, sociology, and management because it accounts for the influence played by others within the system, recognizing the variables that act upon fluid systems (CDC, 2023). GST hinges on the idea that most people attempt to do their best at work, but they are impacted by a diverse set of influences, and efficient systems should not only account for these influences, but should also embrace them as a way to predict changes to the system and make strategic interventions (Anderson, 2016).

The root of systems theory seems obvious in a profession that is completely intertwined with other health professionals, and it has a strong application in both the clinical laboratory, and in clinical laboratory education. The work performed in the laboratory is dependent upon the physician knowing the correct signs to look for in the patient to be able to order the correct tests. The tests are ordered, and now the laboratory relies on physicians, phlebotomists, nurses, or medical assistants to properly collect and transport the specimens to be tested. No matter the test, there are multiple health professionals involved before the sample even gets to the testing technician and it is important to understand how each of these roles can influence the other. The labs are not only impacted by the healthcare providers around them, they also influence the work that is done by physicians and nurses. The interconnectedness of the work done in a hospital has been under the spotlight in the last couple of decades with the adaptation of interprofessional education (IPE), which at root is an acknowledgement of GST in healthcare (Reeves et al., 2013).

GST is evident within the laboratory and healthcare as a whole, so it is reasonable that it would be present in the education of healthcare professionals. The actions taken by accrediting bodies, adjacent health professions, working professionals, colleges and universities, healthcare systems, the government, and individual patients will all have an influence on the education of the individual students and how the program leaders feel they can effectively teach students. While some founders believed that GST was an ever-evolving path towards a perfect state, others theorized the concept of social differentiation where systems are not necessarily moving towards a perfect state, but are instead being pushed into deeper complexity (Gibson, 2023). In laboratory education, the system has become more complex over the last several decades through changes made from adjacent groups that directly impact the enrollment and education of medical laboratory students. Medical laboratory education has variability developed through professional evolution with few attempts to standardize because of the threat that would pose to individual programs in a profession that is already struggling to educate enough students to keep up with workforce demands. This research attempts to first identify these influences that exist in medical laboratory education to present a broader picture of the system before moving on to the collective opinions of those that work closely with students, whether clinically, on the didactic education side, or both.

Dissertation Research Overview

Medical Laboratory Science is a complicated profession that is critical to the delivery of modern healthcare and it has evolved over the years to cover more diseases as medical science continues to advance. The ways in which we educate new medical laboratory scientists can be just as varied and is also continuing to evolve, yet the questions remain on what is best for the students and the profession regarding clinical rotations for medical laboratory science. This dissertation research created two surveys built by the doctoral candidate, one of which was administered to program directors of medical laboratory science education programs, and the other that was administered to working laboratory scientists who directly work with students on clinical rotations. Both surveys were built on a conceptual framework influenced by game theory, systems theory, and constructivism to help understand the decisions made within medical laboratory education programs across the country.

Medical laboratory science relies on new professionals entering the workforce every year to keep the laboratory functioning properly and safely for the patients served by each institution. There is an urgent need to identify more efficient ways to educate new laboratory students or the shortage will force interventions that further undermine the specialty of this healthcare field, ultimately impacting patient care and safety. The researcher aims for the survey results to drive positive changes within the MLS profession, preserving high standards of testing while improving the culture for those who pursue this career path.

In the following chapter, this dissertation research will present the results of the survey administered to program directors of medical laboratory science educational programs across the United States. The program director survey research is presented first to establish the foundation of the medical laboratory education profession, and to understand the variability and similarities across educational programs. The variation in programs is important because they are built differently to address the needs of their own students and must be understood before looking at correlations in the data. Beyond a holistic evaluation of all medical laboratory education programs, the program director survey asks specific questions about the length of time students spend on didactic education, and on the clinical rotation.

After establishing the landscape of MLS education, chapter three will present the results of the clinical educator survey to get a deeper understanding of the perceived needs of those working directly with the students at the bench. Program directors should consider those working with students at the bench to better understand how to serve the clinical sites that eventually hire the students in training. These conversations frequently happen at a program level as it is a requirement for NAACLS accreditation, but the reach of MLS education necessitates a larger conversation about the needs of the overall profession and not just those within the immediate geography of the school (NAACLS, 2024).

Chapter four of this dissertation research will directly address the length of the clinical rotation in relation to the NAACLS outcomes of those individual programs. There are many different variables that go into clinical education, so it is worth investigating if the variability of length of clinical rotation has any impact on the ability of students to pass their certification exam to become certified laboratory employees. Lastly, the final chapter of this research will integrate all chapters and individual themes to demonstrate the impact the clinical rotation has on the education of medical laboratory scientists and technicians. This dissertation research provides decision makers in medical laboratory science with data to make informed decisions about their own programs or departments. The MLS profession is at a crucial point and the decisions made today will have lasting impacts on the quality of care we are able to deliver in the future.

Chapter 2: The Landscape of Medical Laboratory Education

Abstract

Medical laboratory education programs are responsible for producing new graduates capable of the high standards of testing required of laboratorians on the healthcare team. The main accrediting body of laboratory education programs, NAACLS, does not have specific requirements for time spent on curriculum or in clinical rotations, leaving these decisions to the leadership of individual programs. A Qualtrics survey was developed, validated, and then distributed to all NAACLS program directors asking questions related to the style, structure, limitations, and length of their program regarding the didactic education and clinical rotation required by Medical Laboratory Science (MLS) or Medical Laboratory Technician (MLT) programs. The survey yielded a 34% response rate from the 469 program directors on the distribution list. Programs were separated into MLT, hospital-based MLS, and university-based MLS to identify differences among the programs and develop statistical averages. University-based MLS programs average 713 hours (range: 1610, median: 675) in didactic education and 656 hours (range: 1424, median: 640) on clinical rotation, while hospital-based MLS programs require 527 hours (range: 1823, median: 451) in didactic education and 904 hours (range: 1484, median: 840) on clinical rotation. MLT programs require students to perform an average of 532 hours (range: 805, median: 500) on didactic education and 550 hours (range: 840, median: 536) on clinical rotations. Data show a trend toward reduction of clinical rotation hours required over the last ten years, along with the specific disciplines decreased in the process. These data capture the current landscape of medical laboratory education and are important for decision-making and planning of the didactic and clinical education for future laboratorians.

Abbreviations

National Accrediting Agency for Clinical Laboratory Science (NAACLS), Program Directors (PDs), Medical Laboratory Science (MLS), Medical Laboratory Technician (MLT), American Society for Clinical Pathology (ASCP)

Keywords

Medical Laboratory Education, National Accrediting Agency for Clinical Laboratory Science, Clinical Rotations, Medical Laboratory Science, Hospital-Based Programs, University-Based Programs, Minimum Time Requirement, Changes in Clinical Rotations

Introduction

Medical laboratory science plays a crucial role in healthcare by providing diagnostic information for patient care. Laboratory testing can be critical in the diagnosis of many diseases but can also be detrimental to the care of the patient if the testing is not performed properly, allowing erroneous results to become part of the patient care plan (Lawson & Ledesma, 2018). As laboratory testing was expanding in the early 20th century, medical institutions started developing laboratory training programs to keep up with these testing demands (Kotlarz, 1998). Early laboratory education programs were hospital-based programs, with the University of Minnesota being the first on record to grant a baccalaureate degree in medical technology (University of Minnesota, n.d.). The formation of the American Society for Clinical Pathology (ASCP) in 1922 played a crucial role in overseeing and standardizing laboratory practices and education in the early years of the profession (The History of ASCP, 1971; Sunderman, 1993). The role of medical laboratory sciences continued to expand over the next decades, with strong growth in demand for laboratory services during World War II (Burke, 2000). In 1973, the

National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) was established to inspect and provide credentials to programs that met certain benchmarks. This was done to further add validity to laboratory education and to the field of laboratory medicine (NAACLS, 1979).

The early 2020s marked one hundred years since the inception of medical laboratory training programs, with many advancements that have changed how testing is done in the laboratory, as well as what is taught to students (University of Minnesota, n.d.; Plebani, 2005). ASCP exists to standardize clinical laboratories, while NAACLS was born out of ASCP as the accrediting body for medical laboratory education (The History of ASCP, 1971). NAACLS celebrated its 50th year in 2023, meaning half of the existence of this profession was before the development of a credentialing body that reviews the program to ensure it is operating at a high standard (James, 2023). If NAACLS had been established at the same time as laboratory education programs were starting, then there could have been more conformity in the educational standards. However, MLS educational programs were already established and had been built for the needs of the institution long before NAACLS was established to guide these programs. Already having established programs meant that NAACLS was accrediting successful programs from all over the country that all operated differently. To maintain all these programs under one accrediting body, there had to be broad definitions of what was required to be a successful laboratory education program.

There are many differences between laboratory education programs across the United States. Some laboratory education programs are hospital-based, while others are college or university-based, which is a major difference that sets these types of programs apart in other areas. In addition to the differences in the educational setting, there are key differences in how MLS programs are structured. Some programs only offer an associate degree, which can lead to certification as a Medical Laboratory Technician (MLT), while others only offer the Medical Laboratory Scientist (MLS) degree or certificate which requires a baccalaureate degree. The format can differ from one program to the next with some programs integrating their curriculum throughout with a baccalaureate degree which is commonly called a 2+2 format, or integrated format (Conroy, 2018). Other programs will wait until all other curriculum is completed, leaving the MLS curriculum to the end of the didactic years which is commonly called a 3+1 format (Seavey, 2020). Some programs will only accept students who have already completed a baccalaureate degree, exclusively offering the laboratory science education which qualifies that student to sit for the ASCP certification exam, and this is referred to as a 4+1 program (Conroy, 2018). With the shortage of qualified laboratory scientists, some programs have opted to train students in specific laboratory disciplines, like microbiology or immunohematology, an option known as categorical training.

There are many other differences in programs, which are important aspects in recruiting new students and maintaining a successful medical laboratory program. The time that students spend on didactic education, the time students spend on clinical rotations, degrees and certifications offered, time spent on each of the major scientific disciplines, geographic location, and the proportion of the degree that can be completed online, are all important factors in educating laboratory students. There is little understanding of these program differences in the current landscape of MLS/MLT education.

The inherent variability in medical laboratory education adds confusion from students on how to complete their education, and is also confusing for laboratory education programs about how to adapt to changing didactic and clinical requirements of their clinical affiliates (ASCLS and ASCP BOC, 2020). Since NAACLS does not collect these data as part of their accreditation process, program directors are the only source to further understand where medical laboratory science education currently stands. This research answers timely and relevant questions about the educational landscape of the laboratory profession to serve as a reference for program directors in management, and in charge of their own programs.

Literature Review

A literature review was performed across Proquest, Google Scholar, Onesearch, CINAHL, and PubMed. Medical laboratory education topics were searched over a span of 20 years, from 2003-2023. The following terminology and phrases were used to search the available articles and papers: "medical laboratory education", "medical laboratory technician", "medical laboratory science", "laboratory clinical rotation", "clinical rotation length", "laboratory education", "medical laboratory science AND education", and "medical laboratory science AND clinical rotation". Initial inclusion criteria were limited to laboratory science education, and clinical rotations within health professions. When both broad and narrow searches for MLS articles did not reveal research on the specific topic of interest, then nursing, emergency medicine, respiratory therapy, and radiology health professions were searched, using the specific health profession name "AND clinicals", "clinical rotations", or "internship". Additionally, a Google search was performed, producing grey literature for review. A preferred reporting items for systematic reviews and meta-analyses (PRISMA) model was used to summarize the screening of articles, and is provided in Figure 1. There were 228 articles identified; articles were then removed because they were in adjacent healthcare fields with substantial differences, had limited rigor, or were not specific to the dissertation topic. After processing the articles with the aforementioned exclusionary criteria, 8 articles remained that were influential to the dissertation research topic.

The literature search did not reveal any articles characterizing the number of hospital-based programs versus university-based programs, or the number of students that graduate from these types of MLS education. One article briefly discussed the number of hospital-based programs across the United States, but no mention of the number of graduates from these programs (L. Wilson, 2022). No articles could be found that discussed the structure of MLS programs, the location of the programs, or the time spent in crucial areas of medical laboratory education. Articles were found that broached the individual topics of interest, however, no articles were found that connected the individual topics to reveal the larger landscape of medical laboratory education, or the perceptions of those working directly with these students in didactic and/or clinical rotations.

Methods

A cross-sectional study of NAACLS-accredited MLS and MLT programs was used with a questionnaire developed and validated by the investigator using a Qualtrics survey and SPSS statistical software (IBM Corp, 2021). The questionnaire is a summative survey asking quantitative questions of program directors from different laboratory educational programs (Appendix A). Each NAACLS-accredited MLS or MLT program must have a program director who oversees all important decisions regarding curriculum, accreditation, clinical rotations, and graduates. The program director is the person with the most knowledge about the structure of the program, the time required in core areas of medical laboratory education, and the reasoning behind the decisions for their respective MLS or MLT program.

Research Instrument

The Qualtrics survey was reviewed for face validity by the dissertation committee of this research project with feedback used to edit the survey tool. Further testing was performed using an expert panel of 10 professionals with an average of 23 years of experience in medical laboratory science, and an average of 16 years as educators in the MLS profession (see Appendix B). Eight of the expert panel members work in higher education across four different institutions, four have served as program directors, one is a NAACLS administrator, and nine have worked with students on clinical rotations. Three expert panel members possess a bachelor's degree as their highest level of education, five hold master's degrees, and two have earned a doctorate. The expert panel determined the reliability and validity of the survey by answering the questions as accurately as they could for their respective programs, or for those they have worked with previously. Respondents then answered questions developed by Cobern and Adams (2020) upon completion of the survey (see Appendix C), which covered the clarity and quality of the questions asked (Cobern & Adams, 2020).

Completion of the survey by the expert panel duplicated the internal validity of the dissertation committee and established the external validity of the survey instrument. Cronbach's alpha coefficient was computed in SPSS to determine the internal consistency reliability of the survey questions. Cronbach's alpha calculations were 0.862 from the expert panel responses, showing a high degree of internal consistency across the survey. Additional adjustments were made to the surveys based on recommendations from the expert panel.

Since the investigator is affiliated with two different academic institutions, IRB approval was first sought from the University of South Dakota (USD), where the dissertation coursework was being completed, to serve as the primary IRB. Exempt approval was granted from USD on 6/8/2023, with secondary IRB approval granted on 6/26/2023 from Weber State University, where the investigator is employed.

Research Participants and Sampling Procedures

NAACLS publishes the names and contact information of all 479 MLS and MLT program directors on their website, email addresses were collected and added to a contact list in an Excel spreadsheet (NAACLS, n.d.). Emails were copied from the Excel spreadsheet and added as a blind carbon copy so participants could not see the other emails in the study. Recruitment used a voluntary response sample by sending the survey to every program director in the United States, giving every director an equal opportunity to participate in the survey. The surveys were sent by email on July 5, 2023, and a follow-up email was sent two weeks after the initial email as a reminder to complete the questionnaire before closing the survey on August 2, 2023. There were 10 individuals who served as program directors for both an MLT and MLS program, meaning they were duplicate values. After removing the duplicate emails, a total of 469 emails were sent to program directors representing all NAACLS-approved MLT and MLS programs in the United States.

With considerable variation across the profession, and only 469 qualified individuals available for this survey, a medium effect size was used. A power of 95 percent was set for this research, requiring 134 participants for a medium effect size with a set alpha level of 0.05 (Cohen, 1988). The power and effect size were met in this research with 167 total responses out of the possible 469 total programs, for an overall response rate of 35.6%. After eliminating partial responses, the completion response rate was 34%.

Results

The data were exported from the Qualtrics platform into SPSS and Excel spreadsheets for analyses focused on four main areas of medical laboratory education programs: the type of program, the degrees or certifications offered, the time spent in didactic education, and the time spent on clinical rotation. Each of these categories is further broken down to reveal statistical averages among programs, and to differentiate between hospital-based programs and university/college-based programs.

NAACLS Data

NAACLS was contacted for help in acquiring data to present in this dissertation research but available data were limited. The only data NAACLS was able to provide was the institution type and the number of programs operating in each category. Table 1 is adapted from the data provided by NAACLS and shows the institution types separated by the two program types of interest, with the last column showing the response rate for those within this research. Using the NAACLS published data for accredited MLT and MLS programs, addresses were entered in Google Maps, showing the geographic location of each program. This interactive map can be sorted by MLT programs, university-based MLS programs, and hospital-based MLS programs, and can be found through the following link. Most hospital-based MLS programs are located on the East Coast with only seven of the hospital-based programs located in the western United

States, mostly around Denver and Los Angeles, making large gaps for students who are interested in hospital-based programs.

The vast majority of MLT programs are administered through colleges and universities, with only 5 that are military programs, hospitals, or academic health centers. MLS programs show more variation with around 44% of these programs administered by a hospital or academic health center. This is an important delineation because the structures of the programs can be different in a hospital-based program versus a university-based program. Figures 3 and 4 show the overall proportions of all MLS and MLT programs in the United States.

Qualtrics Survey

There were 167 PDs (program directors) that started the survey and 159 that completed the survey. From the completed responses, 137 of the PDs identified as female with 21 who identified as male. The average age of respondents was 51 years of age with a range of 50 years between the oldest and the youngest program directors (see Table 2). The education level of respondents showed 117 with master's degrees, 37 with doctorate degrees and 4 with bachelor's degrees as their highest earned degree. Respondents were also highly likely to be working in the same type of program (hospital or university-based) they went through to earn their credentials. Of the 56 working as a PD for a university-based program, 82% had gone through a university-based program themselves. The same was true for 79% of hospital-based program directors having been trained in a hospital-based program.

Graduates

The respondents of this survey collectively accounted for a total of 2,812 graduates each year. The number of graduates comprises 927 MLT level students, 1765 MLS level students, and

120 categorical students. The majority of MLT level graduates come from two-year colleges or universities, with 167 MLT level graduates from 4-year colleges/universities. The 4-year colleges/universities accounted for 18% of the total graduates even though they only account for 10% of the schools reporting MLT graduates. Two hospital-based programs accounted for 13 graduates at the MLT level. Figure 4 shows the relative percentages of graduates among MLT programs.

There is more variability in the graduates at the MLS level of education when split between hospital- and university-based programs. There were 100 schools that reported graduates at the MLS level, 53 of those were at 4-year colleges/universities, 43 were hospital-based programs, and four were 2-year colleges/universities. Figure 4 shows the relative percentage of MLS graduates by program type. The average number of MLS level graduates was 25.8 students in 4-year colleges/universities, and 10.8 per year in hospital-based programs.

There were 13 different programs that reported training students in specific subjects through categorical training. Two programs accounted for 83 of the 120 categorical students. One of those two schools reported 35 graduates from their microbiology categorical program, and the other did not specify the section of the laboratory their students were trained in. Two programs showed a large turnout for categorical training; however, it remains a smaller proportion of the overall training for students interested in the clinical laboratory.

Format of MLT/MLS Programs

The format of the program (2+2, 3+1, 4+1, categorical) was another area of interest because it impacts the delivery of content and how the programs are structured. MLT programs do not have as much variation in the format, so the question was not asked of PDs for those programs. For university-based MLS programs, the majority (64%) are operating on a 3+1 structure where the student takes their didactic courses and clinical rotation as part of the degree-granting process, and the MLS courses are taken after most of the general education courses have been completed. The 4+1 format was the second most common format and requires the student to have a bachelor's degree before starting the program, this allows the student to focus exclusively on the MLS courses for 1-2 years. The 2+2 format is the last style asked about in the survey with the relative percentages presented in Figure 5.

The format of the hospital-based programs is split from the university-based programs because there are significant differences in the degree-granting process through these types of programs. Most program directors of the hospital-based programs clarified that they are not responsible for issuing degrees, and they will grant a certificate of completion from their programs. Many sites have university or college affiliations that accept the hospital-based program certificate and the corresponding credit hours toward a bachelor's degree at their institution. Relative percentages of formats used in hospital-based MLS programs are presented in Figure 5. The programs offering both formats can do so because of their affiliations with different institutions, making it possible for a student to earn a bachelor's degree, while also accepting those who already have a bachelor's degree and only need the MLS education. This structure provides flexibility for potential students who want to work in the laboratory but need the required education on top of their completed degree.

The last format is categorical training for those wanting to work in a specific section of the clinical laboratory, without learning the other disciplines for MLS or MLT education. The ASCP Board of Certification offers categorical exams for individuals who have a bachelor's degree in science and have completed accredited laboratory education, certifying them to work in those specific areas. Out of the 159 respondents, 10 programs offered categorical training, with microbiology being offered in each one. Additionally, 8 had hematology categorical programs, 7 had chemistry categorical programs, and 7 had immunohematology programs. The structure and program type are good indicators for how the program is put together and how the curriculum is administered, yet it is better to directly compare programs through the time spent with students on both didactic education and the clinical portion of their rotation.

Didactic Education

Respondents were asked how many face-to-face teaching hours of didactic education students get in their programs in microbiology, hematology, chemistry, immunohematology, urinalysis, molecular diagnostics, laboratory operations, point of care testing, STAT lab testing, immunology, and hemostasis. The question was further clarified stating it could be through online videos or in-person presentations, and provided an example calculation to help standardize the responses. This question required a very detailed response; 14 did not provide an answer at the MLS level, and 5 did not answer this question at the MLT level. Answers from one participant were removed after doubts arose about the validity of the answer.

The responses from the 55 MLT program directors showed an overall average of 532 hours of didactic education in their programs (Table 3). The lowest number of hours spent on didactic education was 209 hours, and the most time spent was 1,014 hours, with a range of 805 hours and a standard deviation of 207 hours. Microbiology had the highest average time used in didactic education at 104 hours, followed by chemistry and hematology which both averaged roughly 91 hours. Immunohematology was the fourth highest with 80 hours spent on didactic education, there was a considerable drop in hours after those disciplines with urinalysis averaging 50 hours, followed by immunology and hemostasis at 45 hours and 30 hours, respectively. The responses for molecular diagnostics, laboratory operations, point of care testing, and STAT lab testing saw a substantial decrease in responses, which is understandable because these are not typical stand-alone disciplines and were likely included in other disciplines.

Of the 55 university-based MLS programs, 45 PDs completed the discipline-specific time requirements, and one respondent was removed after it was determined the hours reported were credit hours, giving 44 total responses. The data showed 713 total hours spent on didactic MLS education in university-based programs with programs spending the most time on microbiology, averaging 151 hours spent on that specific discipline (Table 4). The remaining order from most to least time spent on didactic education was chemistry (125 hours), hematology (114 hours), immunohematology/blood bank (106 hours), and immunology (57 hours). After these sections, a reduction in responses indicated there was not consistent time allocated for these topics across all programs, or that they were included in other areas. Zeros were entered for disciplines left blank by respondents who had answered for other disciplines, indicating that they had required times for some disciplines and no requirement for others. From the remaining disciplines, molecular diagnostics showed the most time spent on didactic education (43 hours), followed by urinalysis (41 hours), laboratory operations (41 hours), and hemostasis (31 hours).

There were 43 total responses from hospital-based program directors, with only 4 that did not complete the didactic education sections. Program directors reported spending an average of 527 total hours on didactic education in hospital-based programs (Table 5). Like MLT and university-based programs, microbiology was the discipline that programs spent the most time on, accounting for 111 average hours. Hematology (90 hours), chemistry (85 hours), and immunohematology (77 hours) were again the primary disciplines that programs would spend the bulk of their time on. Immunology (42 hours), laboratory operations (34 hours), urinalysis (33 hours), and hemostasis (32 hours) were the remaining disciplines.

Clinical Rotation Time

Program Directors were asked how many hours they require their students to perform on clinical rotation for their degree or certificate. Survey participants were also asked if they require their students to perform a minimum amount of time in hematology, immunohematology, microbiology, chemistry, urinalysis, molecular diagnostics, laboratory operations, point of care testing, STAT lab testing, immunology, and hemostasis. Nearly every program answered this question at the MLT level, and most responded to this question from the hospital-based MLS programs, but there was a diminished response (86% responding) from the university-based MLS programs.

Out of the 56 MLT program directors who completed the survey, each answered the question about the minimum hours they require on clinical rotation. According to the survey, the average MLT student spends 550 total hours on clinical rotation (Table 6). While most of the programs seemed to have a set total number of hours, responses decreased for the minimum number of hours required in specific disciplines. Of the 56 programs that reported a minimum, only 42 of those reported a minimum in hematology, microbiology, blood bank, and chemistry. Urinalysis, hemostasis, and immunology had 32, 25, and 18 programs that responded with minimum amounts of time, respectively. Of the 42 that responded with minimum amounts of time on rotation, microbiology was the longest time required on rotation at 129 hours, blood bank at 123 hours, chemistry at 119 hours, and hematology at 109 minimum hours required. Though fewer programs have required minimums in the other disciplines, those that reported had an average of 44 hours in urinalysis, 43 hours in hemostasis, and 39 hours in immunology.

Forty-six out of 55 university-based MLS programs had responded to the question of how many total hours their students spent on clinical rotation, with an average of 656 total hours required for their degrees (Table 7). Four additional participants did not supply the minimum hours required for the individual disciplines, suggesting that they may have a minimum time requirement, but maybe not for each section. Those that responded had microbiology with the longest required rotation (159 hours), followed by blood bank (140 hours), chemistry (127 hours), hematology (125 hours), and urinalysis (37 hours). The remaining disciplines saw a considerable drop in the completion rate and are reported in Table 7.

Hospital-based programs had 39 of the 42 programs respond to the question of total time required on clinical rotation, reporting an average of 904 total hours required to complete their program (Table 8). Of the 39 that answered the total time required, only 32 provided the required hours for the individual disciplines. Microbiology was again the discipline requiring the most hours at 221 minimum hours, followed by chemistry (180 hours), blood bank (177 hours), hematology (168 hours), and urinalysis (60 hours). Similar to the University-based programs, there was a drop in the response rate after these disciplines, which are reported in Table 8.

Changes to the Clinical Rotation

Program Directors were asked whether they had made any adjustments to the length of time students spend on clinical rotations in their programs within the last ten years. If PDs answered that they had made a change, then they were asked what percentage of change was made for each of the individual disciplines, whether increasing or decreasing. Proportionally, all different types of programs saw similar results to the question asking if they increased the time, decreased the time, or kept the time the same for students on clinical rotations. Across all programs, 76 said they had decreased the time required for students on clinical rotations, 64 kept the time the same, and 6 had increased the time.

Of the 76 programs reporting a decrease in clinical rotation hours over the last decade, microbiology decreased the most with 59 reporting a decline in hours for the discipline (Table 9). Chemistry was the second most reported section seeing a decrease (53 responses), followed by hematology (48 responses), blood bank (45 responses), immunology (27 responses), hemostasis (26 responses), and urinalysis (25 responses). The four main disciplines with the highest response rates saw a similar result, all averaging a near 30% reduction in hours. Urinalysis, hemostasis, and immunology all had diminished response rates, but still averaged 30%, 33%, and 37% reductions in rotation times, respectively.

Only 6 programs of the 146 reported that they had increased the time their students spent on clinical rotation in the last 10 years. The responses were evenly dispersed for each of the program types, with two of them reporting from the MLT level, and two from each of the hospital-based and university-based MLS programs. Four programs reported increases in blood bank rotation time, with an average increase of 12%. Two programs increased their time spent in microbiology, averaging a 9% change in the rotation time. One program increased hematology by 8% while another program increased their molecular rotation by 100% over the last ten years.

Program directors were asked if clinical rotations were a limiting factor in accepting more students into their programs. Responses were similar among MLT, hospital-based MLS, and university-based MLS with only a 4% difference in the affirmative response. On average, 57% of program directors indicated that clinical rotations are a limiting factor in accepting more students into their programs. The majority of responses indicating the difficulty of getting time for students on clinical rotations adds context to the reduction in hours seen over the last ten years for students on clinical rotations.

Program directors were additionally asked whether they would increase, decrease, or keep the same number of hours required for students on clinical rotations if all limiting factors were removed. Across all MLT and MLS programs, 64% would keep the clinical rotation the same, 24% would decrease the hours required for clinical rotation, and 12% would increase the hours if there were no limiting factors to their decision. When further broken down into hospital versus university groups, the MLT and hospital-based programs were similar, with a difference in a few percentage points, averaging 58% to stay the same, 28% to decrease, and 14% to increase the time required on rotation. University-based MLS programs responded with 73% to keep the rotation length the same, 17% to decrease the length of time, and 10% to increase the time required on clinical rotation for their program.

Remote Learning

Program directors were asked if their programs offer a fully online option for the didactic educational material, with the exclusion of the clinical rotation. Additional clarification was provided that the only face-to-face time needed would be in the clinical rotation. At the MLT level, 52 programs did not have a fully online option, while 7 were able to provide all didactic material online. At the MLS level, 86 program directors indicated they do not have a fully online option versus 12 programs indicating they did provide that option. There was a small difference between the two when broken into hospital-based (7%) versus university-based programs (16%) in affirmative answers to providing fully online didactic education.

Discussion

This research exposes the landscape of medical laboratory education in terms of didactic education, clinical rotations, the number of graduates, and the changes made to clinical rotations. Additionally, this research adds context to the differences in the structure of programs and their requirements for their students to be successful. It is important to understand how others in this profession manage their programs, and how the average program operates to know where adjustments can be made or to come to a collective understanding about what normal should be in this profession. The average time spent on clinical rotations and didactic material established in this research are an excellent tool for PDs to compare their programs. The breakdown in discipline-specific time spent on didactic education and clinical rotation also helped show the curriculum emphasized across laboratory education programs.

Hospital-based MLS programs show lower proportions of average time spent on didactic education (527 hours) than university-based programs (713 hours). However, the didactic time is better understood when comparing the difference in clinical rotation hours between the two, where hospital programs spend 904 total hours versus 656 at university programs. When looking at the entire program, university programs average 1369 total hours in an educational capacity to 1,431 hours in a hospital-based program, with a difference of 62 total hours between the two. A

62-hour gap is a relatively small difference in the time spent on overall education, showing that the programs may use different methods but end up similar in the total hours required.

There was a remarkable difference in the number of graduates in hospital-based programs versus university-based programs. University-based MLS programs averaged 26 graduates per year, while hospital-based MLS programs averaged 11 per year. After review of hospital-based program admissions, the lower enrollment is not a lack of interest in their programs, for most it is because they have limited capacity to take additional students, often capping their programs to no more than 10 students. With nearly half of MLS programs being hospital-based programs, it could also prove difficult to drastically increase the numbers of new MLS professionals even if there was an increased interest in careers in medical laboratory science.

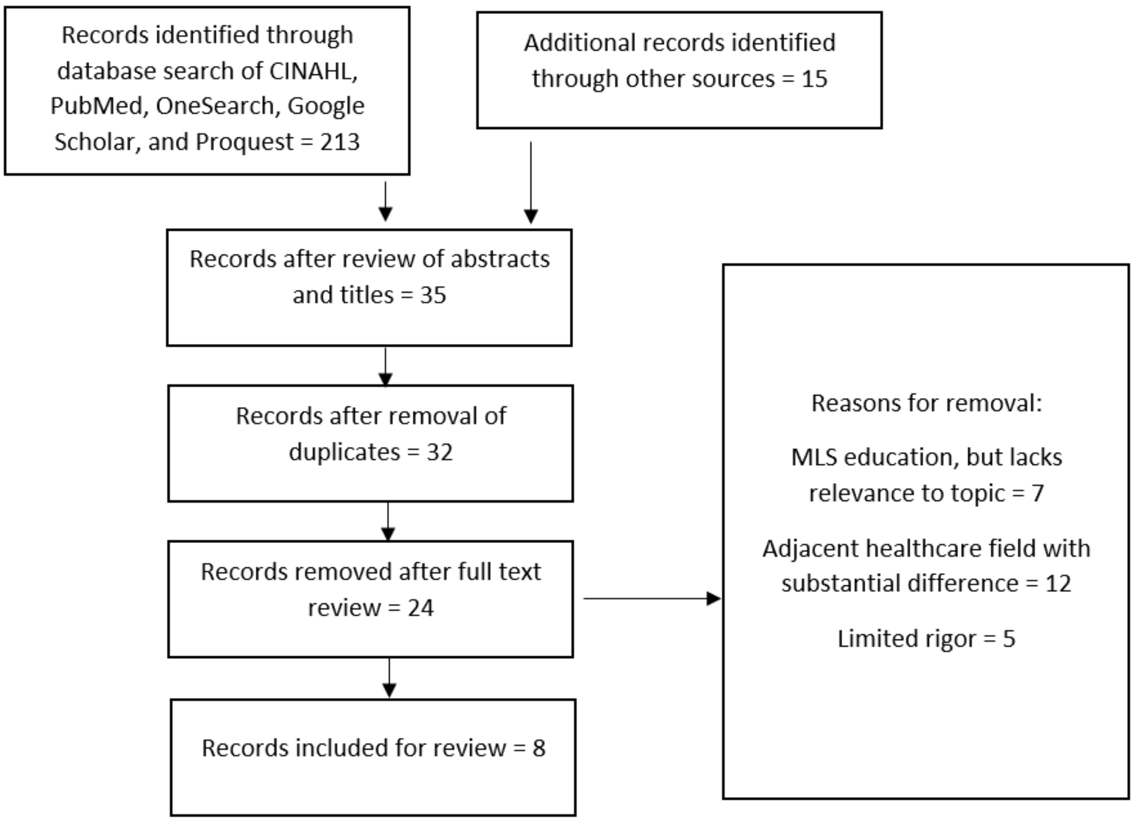
Across all different types of programs, there was a substantial decrease in the number of hours students are spending on clinical rotations just in the last ten years. Over half of all programs had decreased the hours required for their students on clinical rotations compared to the six programs that had increased the time. This shows a trend over the last ten years that might continue, especially when considering that more program directors lean towards a decrease in hours rather than an increase. The majority of PDs answered that they want to keep clinical rotations the same length for their programs, but 24% would decrease the hours compared to 12% who would increase the hours. Even though there has been a reduction in clinical rotation hours for medical laboratory education, there is still a greater percentage of PDs supporting a reduction in hours as opposed to increasing the hours spent on rotation.

Conclusion

While there are many differences in medical laboratory education, each program faces similar difficulties in educating its students within the changing landscape. Adapting to changes is important to keep programs open, and to graduate enough students to keep up with shortages across the field. Decisions are being made about medical laboratory education, whether the program director is in support of these decisions, or not. This research provides data to use when making decisions for each program, giving justification for the stance of the program director in defense of their matriculating students. Medical laboratory education has existed for 100 years with numerous changes along the way, and more changes can be expected.

Figure 1

PRISMA Flowchart



Note. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) used to search for relevant articles in medical laboratory education. The "additional records identified through other sources" were found via Google search.

Table 1

Response Rate by Institution Type

Institution Type	All MLS Programs	All MLT Programs	Survey Response Rate
2-year College or University	4	209	29%
4-year College or University	130	24	36%
Academic Health Center/Medical School	17	1	Combined with Hospital
Hospital or Medical Center	88	2	36%
Military Facility	1	2	0%
Total Programs	240	238	34%

Note. Number of programs in MLS and MLT education overall, compared with the response rate from each type of institution.

Table 2

Demographics of PD Survey Respondents

		MLT (n=60)	University Based MLS (n=56)	Hospital Based MLS (n=43)	Full Sample (n=159)
Gender					
	Female	88.3%	80.0%	93.0%	86.3%
	Male	11.7%	20.0%	7.0%	13.3%
Education Attained					
	Bachelors	0.0%	5.5%	2.3%	2.5%
	Masters	86.7%	49.1%	88.4%	74.1%
	Doctorate	13.3%	45.4%	9.3%	23.4%
Program Type of Earned MLS Education					
	Four-year College/University	63.3%	82.1%	16.3%	57.6%
	Hospital or Medical Center Based	16.7%	10.7%	79.1%	31.6%
	Two-year College/University	18.3%	3.6%	2.3%	8.9%
	Other	1.7%	3.6%	2.3%	1.9%
Age					
	Mean	50.6	51	50.7	50.7
	Standard Deviation	9.85	12	10.9	10.9
	Minimum	32	26	31	26
	Maximum	70	76	67	76

Note. Demographics are broken down by MLT, University-Based MLS, and Hospital-Based MLS with total sample also reported.

Figure 2

Proportion of All MLS Education Programs by Institution Type (N=240)

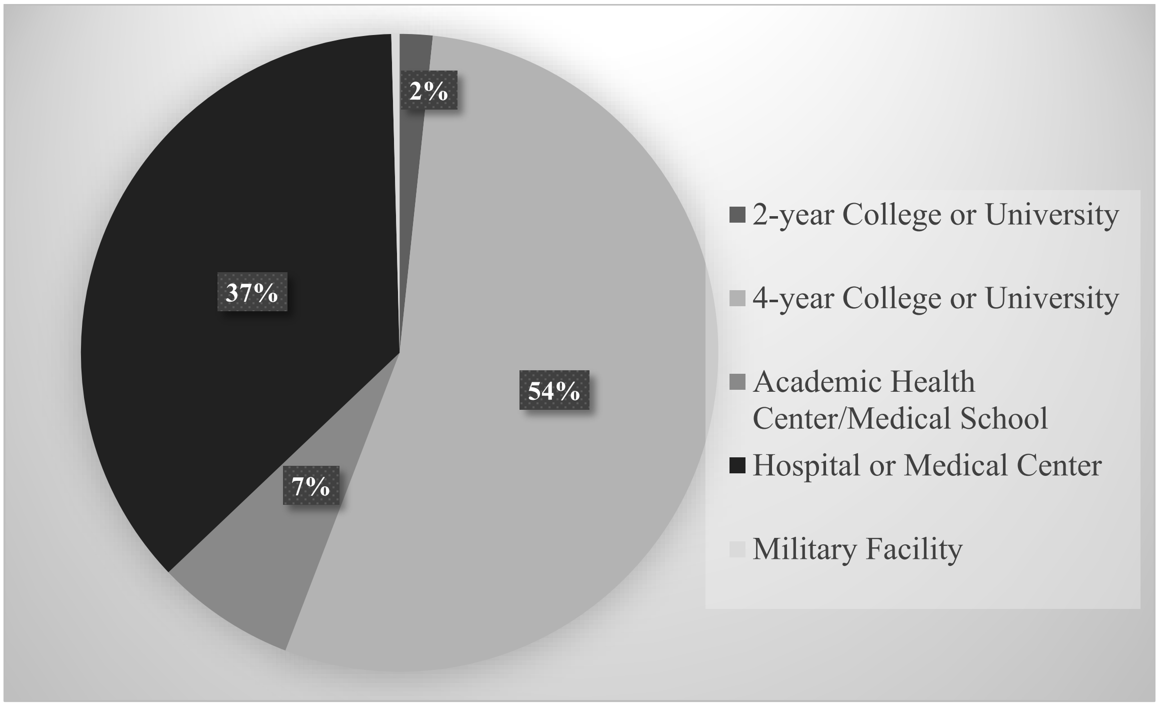


Figure 3

Proportion of All MLT Education Programs by Institution Type (N=238)

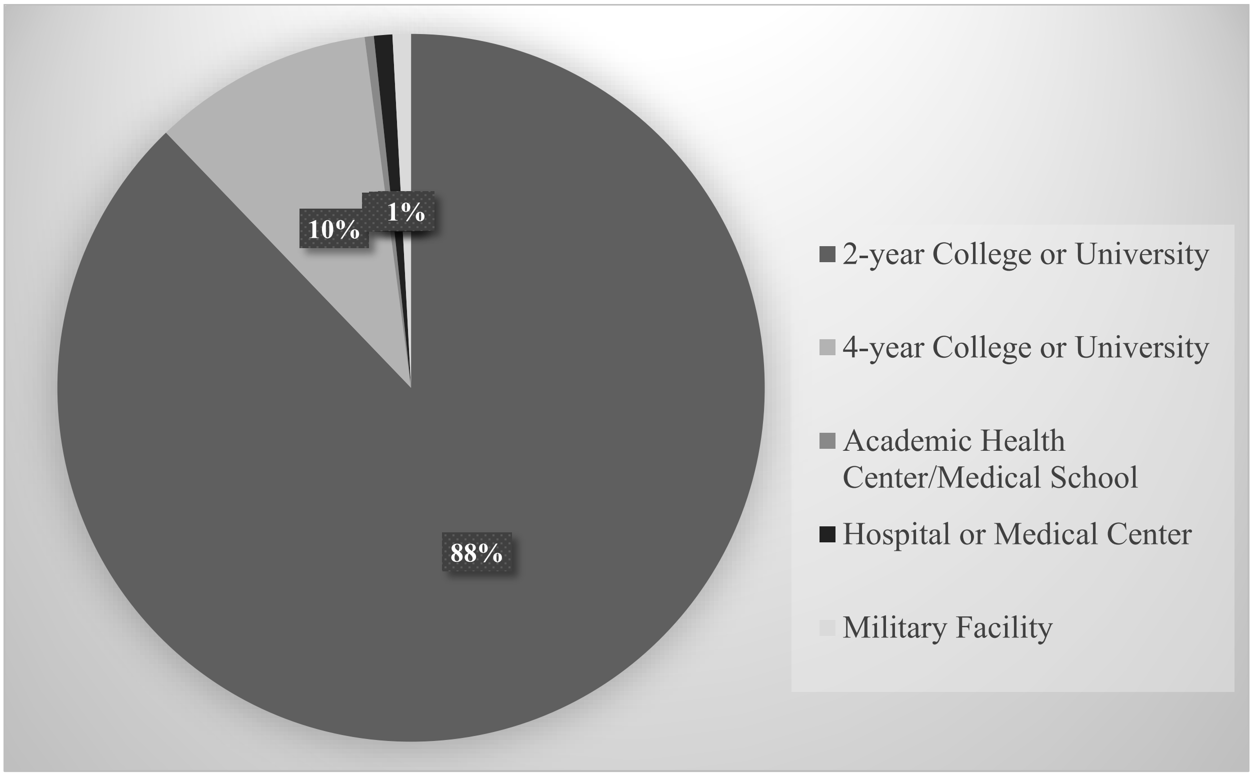
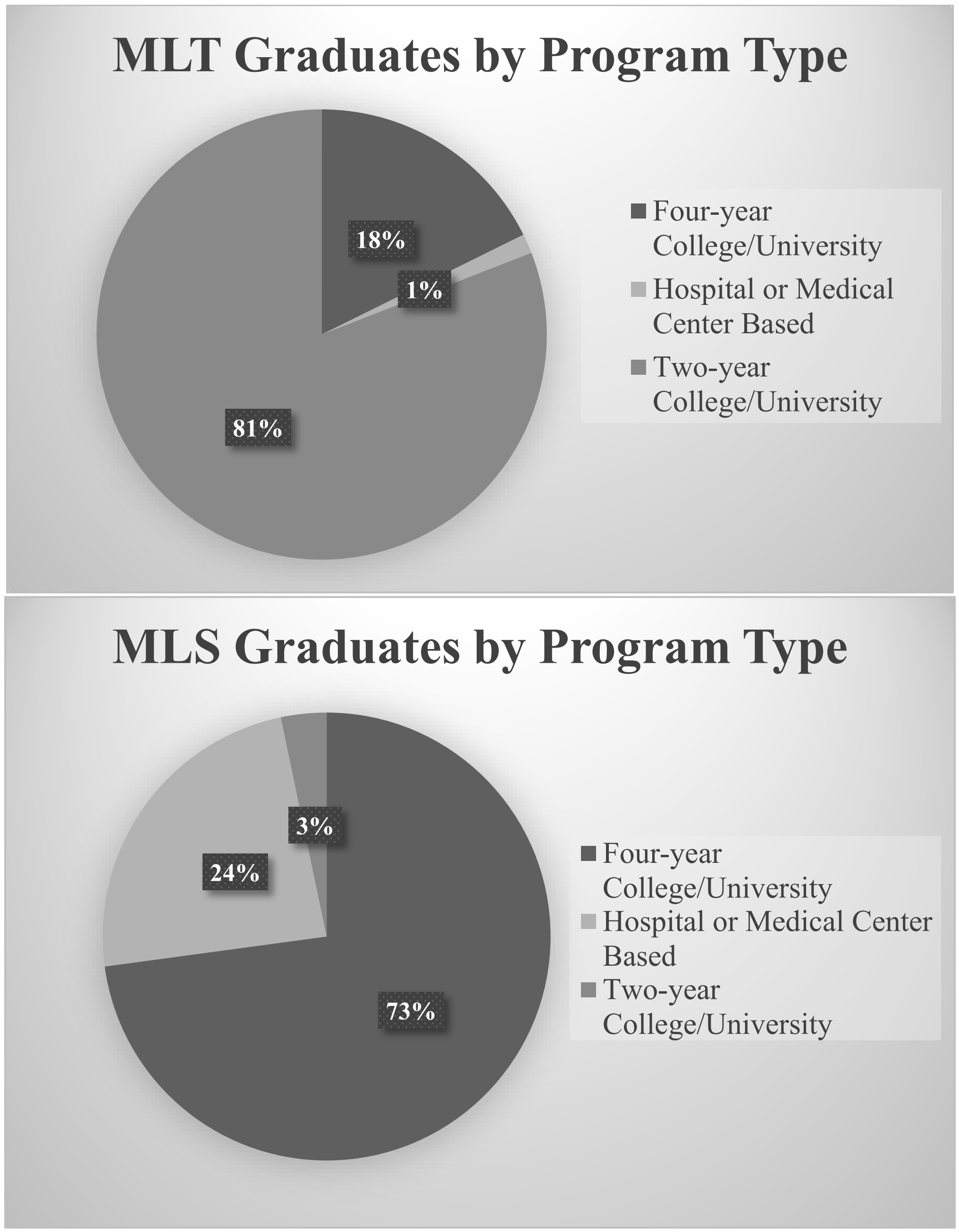


Figure 4

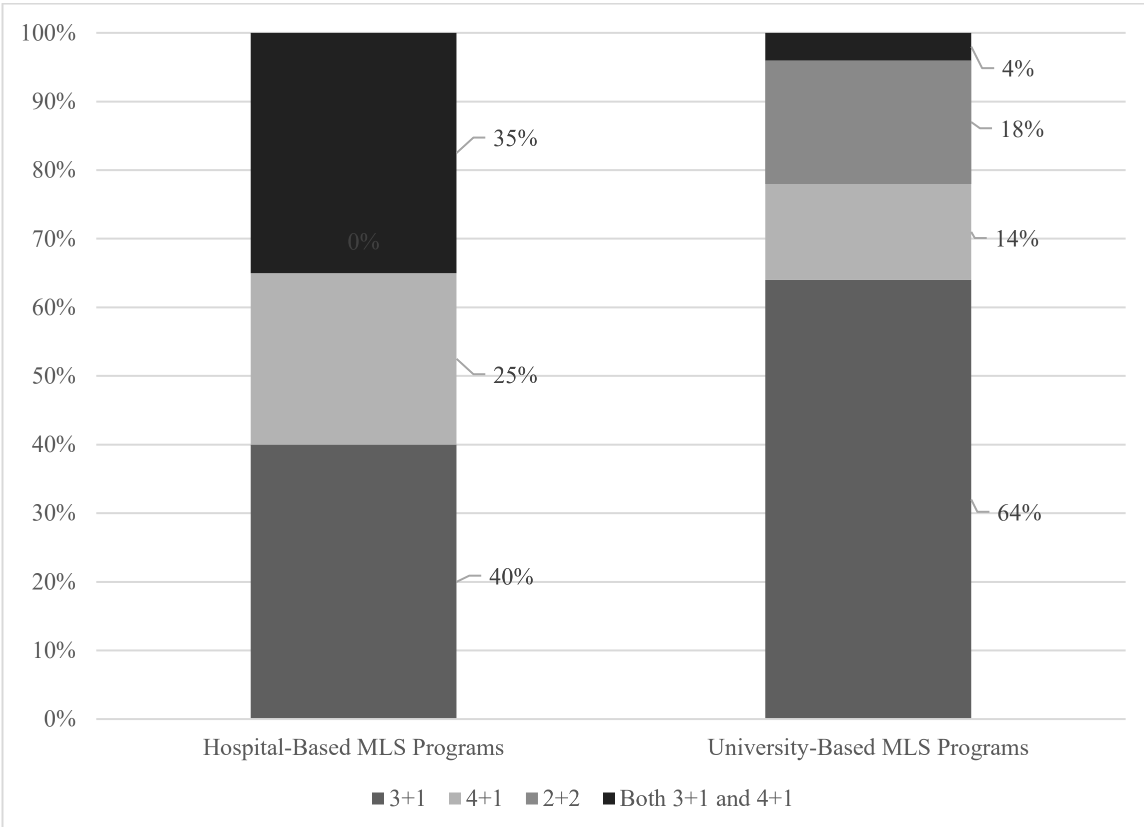
Percentage of Graduates from Different Program Types



Note. Percentage of graduates from different program types, separated to show differences at MLT and MLS levels of education. MLT (n=63), MLS (n=93)

Figure 5

Percentage of Different Program Formats Used



Note. Percentage of different program formats used among hospital-based and university-based MLS programs. Hospital-based MLS programs (n=42). University-Based MLS programs (n=50)

Table 3

Average Hours Spent on Didactic Education in MLT Programs

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis	Total
N	54	54	54	54	54	54	53	54	54	53	50	54
Average Hours	91.4	80.3	103.6	90.9	49.8	10.4	17.8	11.1	3.8	45.9	30.1	531.8
Range of Hours	224	164	191	198	133	64	90	90	90	152	116	805
Median	75	75	97.5	85	45	0.5	10	2	0	45	24	500
Mode	64	75	120	90	45	0	0	0	0	45	16	390
Minimum	32	20	40	30	15	0	0	0	0	8	4	209
Maximum	256	184	231	228	148	64	90	90	90	160	120	1014
Standard Deviation	48.6	35.3	44.8	40.9	27.1	17.1	23.5	20.6	14.1	28.3	22.1	206.9

Table 4

Average Hours Spent on Didactic Education in University-based MLS Programs

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular Diagnostics	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis	Total
N	45	45	45	45	45	44	45	45	45	45	45	45
Average Hours	114	106	151	125	41	43	41	4	2	57	31	713
Range of Hours	262	270	255	262	135	180	141	24	26	231	180	1610
Median	105	90	135	120	32	38	30	0	0	45	25	675
Mode	90	90	90	90	45	45	30	0	0	45	0	N/A
Minimum	38	30	45	38	0	0	0	0	0	15	0	225
Maximum	300	300	300	300	135	180	141	24	26	246	180	1835
Standard Deviation	51	63	65	64	28	34	32	6	5	38	31	305

Table 5

Average Hours Spent on Didactic Education in Hospital-based MLS Programs

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular Diagnostics	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis	Total
N	39	39	39	39	39	39	39	39	39	39	39	39
Average Hours	90	77	111	85	33	18	34	3	2	42	32	527
Range	265	265	300	270	135	135	135	21	15	259	260	1823
Median	76	56	98	70	30	10	20	2	0	32	22	451
Mode	135	45	90	60	30	0	40	0	0	30	30	N/A
Minimum	4	4	0	0	0	0	0	0	0	0	0	23
Maximum	269	269	300	270	135	135	135	21	15	259	260	1846
Standard Deviation	55	53	69	52	26	27	31	4	4	46	42	324

Table 6

Average Hours Spent on Clinical Rotation in MLT Programs

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis	Total
N	42	42	42	42	31	7	7	9	4	18	25	56
Average Hours	109	123	129	119	44	35	32	37	32	39	43	550
Range	301	291	384	408	110	159	119	119	119	119	155	840
Median	96	120	120	116	35	16	16	32	3	24	32	536
Mode	80	96	96	64	32	16	16	1	1	16	32	480
Minimum	35	45	64	40	10	1	1	1	1	1	5	120
Maximum	336	336	448	448	120	160	120	120	120	120	160	960
Standard Deviation	50	50	61	64	24	52	38	36	51	39	35	174

Table 7

Average Hours Spent on Clinical Rotation in University-based MLS Programs

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular Diagnostics	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis	Total
N	32	32	32	32	26	9	6	7	4	13	16	46
Average Hours	125	140	159	127	37	24	62	10	29	31	31	656
Range	140	196	160	152	74	30	170	17	74	44	50	1424
Median	120	120	160	120	40	22	35	8	14	28	34	640
Mode	120	120	160	120	40	20	30	6	N/A	20	40	480
Minimum	60	64	80	48	6	10	30	3	6	16	6	240
Maximum	200	260	240	200	80	40	200	20	80	60	56	1664
Standard Deviation	37	47	46	41	17	10	62	6	30	14	12	230

Table 8

Average Hours Spent on Clinical Rotation in Hospital-based MLS Programs

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular Diagnostics	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis	Total
N	32	32	32	32	31	23	21	13	9	21	28	39
Average Hours	168	177	221	180	60	55	51	20	27	70	55	904
Hours	277	288	294	334	230	247	242	98	96	247	160	1484
Median	160	164	205	172	40	32	33	8	16	48	50	840
Mode	160	160	160	120	40	40	40	8	8	120	80	600
Minimum	48	32	96	50	20	3	8	2	4	3	10	180
Maximum	325	320	390	384	250	250	250	100	100	250	170	1664
Standard Deviation	70	64	70	72	49	61	53	25	29	56	33	354

Table 9

Average Percentage Decrease in Clinical Rotation Time Across All Program Types

Discipline	Hematology	Blood Bank	Microbiology	Chemistry	Urinalysis	Molecular Diagnostics	Laboratory Operations	POC Testing	STAT Testing	Immunology	Hemostasis
N	48	45	59	53	25	9	5	4	1	27	26
Average	28%	28%	29%	30%	29%	23%	38%	28%	50%	37%	33%
Minimum	8%	8%	8%	2%	5%	5%	10%	20%	50%	10%	5%
Maximum	64%	57%	70%	64%	73%	50%	100%	50%	50%	100%	100%
Range	56%	49%	62%	62%	68%	45%	90%	30%	0%	90%	95%
Standard Deviation	14%	13%	14%	13%	19%	15%	34%	13%	0%	24%	23%

Note. Participants were asked about changes over the last ten years, from 2013-2023

Chapter 3: Clinical Staff Perceptions of Clinical Rotations in Medical Laboratory Science Education

Abstract

Shortages in medical laboratory scientists and medical laboratory technicians have made it difficult to staff medical laboratories across the United States. A large bottleneck that exists in medical laboratory education is the requirement for students to perform a clinical rotation to complete their education. Clinical rotations in medical laboratory science vary greatly from one program to the next, with major differences that will impact the experiences students have at each site. The size of the laboratory, geographic location, testing services offered, number of staff members, attitudes towards students, and program structure are all common differences between facilities that will change the value of the clinical experience for the student. To determine how differences in facilities and opinions influence the training experience, a survey was created and sent to laboratorians across the United States asking for participation from those who work directly with students performing clinical rotations in their laboratories. The survey acquired 155 responses from individuals representing different sizes of laboratories, job titles, geographic locations, and ages, which were then used to evaluate the perceptions of clinical staff working with students. While most laboratory staff maintain a positive view when working with students, the increased testing demands, decreases in staff, and centralization of core departments make it difficult for many laboratories to work with students. Hosting students on clinical rotations is often seen as a necessary burden by laboratory staff, but this burden could be reduced if more consideration were given to the role of the clinical rotation and what is needed to achieve that goal.

Abbreviations

National Accrediting Agency for Clinical Laboratory Science (NAACLS), Program Directors (PDs), Medical Laboratory Science (MLS), Medical Laboratory Technician (MLT), American Society for Clinical Pathology (ASCP), Board of Certification (BOC), Clinical Laboratory Improvement Amendments (CLIA)

Keywords

Medical Laboratory Education, National Accrediting Agency for Clinical Laboratory Science, Clinical Rotations, Medical Laboratory Science, Changes in Clinical Rotations, Medical Laboratory Technician, Clinical Laboratory Science

Introduction

Medical laboratory scientists (MLS) and medical laboratory technicians (MLT) are important members of the healthcare team and play a crucial role in diagnostic medicine (ASCLS, 2012). Laboratory professionals are often an unknown part of the healthcare team, but they are responsible for an estimated 70% of medical diagnoses through their work (Leber et al., 2022). Nearly all samples collected from patients in hospitals or clinics are sent to the laboratory to look for abnormalities. It is a crucial role that requires years of education and training to safely practice within the profession, but staff shortages across the profession have made it difficult for laboratory administrators to find qualified personnel (Lawson & Ledesma, 2018). Laboratories have been understaffed for decades, and the problem continues to worsen (ASCLS, 2017). Burnout was cited as a major problem facing clinical laboratories even before the COVID pandemic increased the burden on laboratory professionals (Nowrouzi-Kia et al., 2022). The profession needs help but can only address the shortage by graduating more students from MLS or MLT programs (ASCLS, 2018).

To become certified as an MLS or MLT, students must complete a program that is accredited by the National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) and pass the American Society for Clinical Pathology (ASCP) Board of Certification (BOC) exam (ASCP, 2024). NAACLS is the main credentialing body for medical laboratory education programs and there can be significant differences from one MLT/MLS program to the next. One requirement of NAACLS that applies to all MLS or MLT programs is that students be given an opportunity for clinical experiences as part of their medical laboratory education (NAACLS, 2021). This statement is the basis for the clinical rotation required in most MLS and MLT programs. However, each program and their clinical affiliates are given the freedom to design this clinical rotation individually.

Clinical rotations typically require students to rotate through hematology, chemistry, blood banking, microbiology, immunology, urinalysis, and molecular diagnostics departments before the clinical rotation is complete. Students rotating through a laboratory on clinical rotation may be an added burden in laboratories already understaffed and experiencing burnout, furthering dissatisfaction with MLS/MLT working conditions (Nowrouzi-Kia et al., 2022). The clinical rotation is often seen as a necessary burden by most working in the laboratory because they understand the need to train and recruit new students if the profession is going to stabilize staffing issues. Though laboratorians are willing to put in the extra work to train students while understaffed, many have indicated these constraints impact the clinical experiences they can offer the students.

While most program directors see clinical rotations as a necessary part of medical laboratory education, currently, very little is understood about how differences in clinical rotations impact the education of MLS students (Beazer, 2024). Differences in clinical rotation experiences act as a bottleneck for matriculation, making this a topic of interest for program directors who are trying to graduate more medical laboratory professionals (Beazer, 2024). While program directors of medical laboratory education programs find significant value in clinical rotations and generally support keeping them the same, it is important to understand the perceived value from the standpoint of those who work directly with students during these rotations. This study attempts to reveal the differences between clinical sites, the differences in opinions, and the perceived benefits and drawbacks of clinical rotations from the perspective of clinical educators working with students. It is hypothesized that there are significant differences in the education received at each site, and the perceived value and purpose of the clinical rotation varies among clinical educators. In this dissertation, medical laboratory scientists from across the country were asked about their perceptions of clinical rotations, the purpose of these rotations, and what can be done to improve them.

Clinical laboratories across the United States are as varied as the hospitals they support. Some laboratories operate in completely rural areas as part of individually-run hospitals, and other laboratories may reside in the middle of urban centers, supporting multiple facilities as part of a larger health system. Thus, opinions about clinical rotations may differ based upon the size of the laboratory, and whether the facility is in a rural or urban location. This research project separates the opinions of the clinical sites by facility demographics, establishes demographics of participants, then seeks the opinions of participants about clinical rotations in their laboratories.

This research shows the statistical differences in opinions between program directors and clinical educators on the role of clinical rotations, underpinning the respective roles of each program.

To complete this study, a literature review was performed across Proquest, Google Scholar, Onesearch, CINAHL, and PubMed. No articles were found relating to perceptions from clinical educators, or about clinical rotations, although one article looked at differences in education with reduced time on rotation (Callahan, 2019). This research fills a void in our understanding of the clinical rotation as part of clinical laboratory education, providing valuable data for clinical educators across the United States.

Methods

A descriptive, cross-sectional study design was used to assess the value of clinical rotations from the perspective of the hospitals and clinics. A summative survey was developed to ask quantitative questions assessing the perception of clinical educators on their role in medical laboratory education, and their perceptions about the impact of the length of time students spend on clinical rotations (Appendix D). Considerable variability exists across MLS and MLT preceptor sites, but some consistency exists, justifying a medium effect size for the survey research. A power of 95 percent was used for this research and requires 134 participants for a medium effect size with a set alpha level of 0.05 (Cohen, 1988).

Research Instrument

The survey was developed using the Qualtrics survey platform, which allows tracking of multiple links across the different recruiting mediums and generates a mobile-friendly version. The survey instrument was first reviewed for face validity by the dissertation committee of this research project. After project approval from the dissertation committee, the survey instrument was tested by an expert panel of 10 professionals, each with experience in medical laboratory education. The expert panel was asked to respond to the questions as accurately as possible for their facility, or those they have worked with prior. Respondents were then asked specific questions (see Appendix C) developed by Cobern and Adams (2020) to consider after completion of the survey (Cobern & Adams, 2020).

The completion of the survey by the expert panel duplicated the internal validity from the dissertation committee and established the external validity of the survey instrument (Andrade, 2018). Chronbach's alpha coefficient was computed in SPSS to determine the reliability of the survey questions, with a value of 0.810 from the expert panel responses, showing a high degree of reliability across the survey (Tavakol & Dennick, 2011). Additional adjustments were made to the surveys based upon recommendations from the expert panel.

Questions assessed the experience of the participant and the number of MLS education programs they work with. After establishing the background of the clinical educator and the facility they work in, the survey asked for perceptions of clinical rotations and the length of time students should spend on their clinical rotations. Refer to appendix D for all survey questions and response options.

Ethical Considerations

The researcher has dual affiliations at Weber State University as faculty, and through University of South Dakota (USD) as a student, requiring IRB approval from both institutions. IRB approval was first sought from the USD, where the dissertation coursework was being completed, and serves as the primary IRB. Exempt IRB approval was granted from both institutions.

Research Participants and Sampling Procedures

Educational coordinators and clinical preceptors employed by hospitals and clinics were the target population for this study. The education coordinator title is not an important aspect because laboratory administrators or bench technologists may also be serving in this capacity as part of their work requirements and may use different titles to describe the work. With the variability of titles and roles of clinical laboratory educators, this dissertation research targeted those who work in a clinical laboratory setting and routinely work with students on their rotations. There were no exclusionary criteria for clinical educators to take this survey if they met the aforementioned parameters of the target population.

The researcher serves as the program director for the Weber State University (WSU) Medical Laboratory Science program, providing direct access to many clinical sites. None of the clinical sites are exclusive to WSU, meaning they may have students from other schools performing clinical rotations with different time requirements and expectations. These clinical educators have direct experience teaching students from programs across the country, with first-hand accounts of the benefits and drawbacks of the variation of clinical rotations among MLS and MLT programs. All affiliates were included as a blind carbon copy email to preserve anonymity of the requests and responses. Biases toward or against WSU MLS program were considered in using this recruiting method, however, our affiliates are not exclusive and many work with other programs, providing a valuable perspective for comparison between educational methods.

Additional recruiting sites included the LISTSERV hosted by the American Society for Clinical Laboratory Science (ASCLS), and the Medical Laboratory Scientist Facebook group.

The ASCLS LISTSERV hosts both educational threads and clinical threads sent out daily to individuals with interest in those topics. The MLS Facebook group is a private group with over 48,000 members (Facebook, 2023). Not everyone in the Facebook group met the inclusion criteria, and language on the post emphasized that participants need to be working directly with students on clinical laboratory rotations to participate. Independent links were developed to track the targeted participation of WSU affiliates and the ASCLS LISTERV versus the Facebook group. Tracking the two groups shows different participation rates and was a measure to evaluate potential bias and quality of responses from one group versus the other.

Results

There were 155 total individuals who began the survey, 6 did not answer any questions after agreeing to the survey terms, and the survey was ended for 11 individuals who answered that they do not work with students on clinical rotations. Nearly 30% of respondents participated via the Facebook link. The main difference between the participants from Facebook and those from email and LISTSERV was the years of experience and their position in the laboratory. Those that completed the survey from the Facebook link averaged 15 years working in the laboratory, 11 years working with students, and 4 years in a supervisory position. The respondents from direct emails and the LISTSERV averaged 19 years in the clinical laboratory, with 12 years teaching students, and nearly 10 years of supervisory experience. Along with experience, the primary job responsibilities were more advanced among those from the direct emails and LISTSERV than it was for the Facebook responses, with 80% working in a supervisory role while only 44% of the Facebook participants had supervisory responsibilities. Responses are differentiated based upon job title when necessary for this research, which eliminates the need to differentiate the responses from Facebook. All respondents were reported in aggregate regardless of the medium through which they came to participate in the survey.

Participant Demographics

After eliminating incomplete responses, there were 134 respondents left who had worked with students on clinical rotations. Of the remaining participants, 61 indicated they oversaw students on rotation with little direct work with the students, 24 oversaw the students on rotation while also working directly with them, and 49 work on discipline-specific benches and have direct teaching responsibilities of the students.

The roles of clinical educators were varied, and twenty of the respondents reported having multiple responsibilities in their facility. Most respondents worked in an administrative capacity, with 44 reporting as supervisors, 17 as lab managers, and 18 as laboratory directors. Many added the role of education coordinator in addition to their other roles in the laboratory with 18 total people in that position, and only 5 of those having this position as their sole responsibility. Thirty participants listed medical laboratory scientist as their primary role, only 4 listed medical laboratory technician as their primary role.

The average age of respondents was 45 years, with a range of 51 years. Most participants earned their laboratory credentials through a four-year college/university (107 responses), and most participants also reported a bachelor's degree as their highest level of education completed (82 responses). After the bachelor's degree, the next highest level reported was a master's degree (44 responses), then associate degree (3 responses), and doctorate (2 responses). Only 16% of participants were male, and 84% identified as female. Participant demographics are summarized in tables 10 and 11.

Facility Demographics

Out of the 134 respondents, 117 worked in hospital laboratories, 7 worked in a reference lab, and another 7 worked in clinic labs. The size of the hospital labs ranged from 11 beds to 2700 beds, with an average of 418 beds, and a median of 319 beds. Hospitals were categorized as small (0-150 beds), medium (151-450 beds), or large (451-2700 beds) in evaluating the data from the survey (Tian, 2016). Participants were asked if their hospital or clinic was part of a larger hospital system, and 69% were part of a larger hospital system, while 31% were not. Twenty of the respondents worked at facilities that also housed a hospital-based MLS program on site, while 109 did not have a program.

Most respondents indicated that their facility takes both MLT and MLS level students on clinical rotations, with 90 facilities (70%) that host both types of students each year. Twenty-eight (22%) of the respondents host only MLS level students, and 11 (8%) will host only MLT level students. The total number of responses accounts for 745 clinical rotations for MLS level students and 573 MLT level students each year. The clinical sites average 6 students per year at both the MLS and MLT level, with a median of 4 students for both levels. Participants were asked about the number of students performing categorical training at their facilities; however, many respondents answered the same numbers across each of the major categorical disciplines that were equivalent to the number of students in their MLS or MLT programs. These responses indicated confusion and there were not many participants answering these questions, so these data have been excluded from these analyses.

Participants were asked how many different MLT, MLS, or categorical programs/schools their facility works with to provide students with a clinical rotation. The majority only work with

1 MLS (44%) or MLT (48%) program, and the distribution of responses can be seen in Figure 6. Most responses also indicated they do not have students from online didactic programs rotating through their laboratory. Thirty-two percent of facilities do not work with students from online programs at the MLS level, and 16 percent at the MLT level. Of those that do work with students from online programs, they made up less than 5% of their total students in their rotations. Respondents were asked to evaluate whether their facility has the capacity to accept more students on clinical rotation, 19% can take more students, 74% cannot take any more students, and 7% indicated they have capacity for more students but will not take any more.

Several factors influence the clinical experience provided to students on clinical rotation, and participants were asked about the geographic location of their facility, changes made to their laboratory services offered, and the experiences available for students. A United States Census lookup sheet was provided to participants to determine whether their facility was “Mostly Urban”, “Mostly Rural”, or “Completely Rural” (United States Census Bureau, 2022). Using census parameters, 71% were in “Mostly Urban” areas, 21% were “Mostly Rural”, and 8% of laboratories were in “Completely Rural” areas. Additionally, the location of the facility may dictate the hiring and training requirements based upon the state the facility operates within, so participants were asked if they operate in a state that requires licensure, and if there is a minimum amount of time required for students on clinical rotation. Florida, Georgia, and Tennessee were the states most reported with licensure and a minimum amount of time required. Collectively, 85 participants reported that they do not work within a licensure state, 21 participants were in states with licensure and time requirements for rotations, 7 reported operating in a state with licensure but no time requirement, and 17 did not know if there was licensure or minimum hours required for students in their state.

Facilities vary in what services are offered and the changes made that will have an impact on the experiences of students. Participants were asked if they had made specific changes to their programs that would impact the students on rotation, and the percentages of facilities experiencing common changes to laboratory rotations can be found in Figure 7. Large hospitals had higher percentages of changes across most parameters, including centralization of testing and cuts to staffing. In large hospitals, 61% reported their facilities had experienced an increase in testing, while the small and medium hospitals were roughly 20% lower in this statistic.

The number of people in the immediate geographic location influences the breadth and amount of testing that can be performed in the facility, making it an important variable impacting the clinical rotations students perform there. The changes to clinical sites were evaluated against the urban or rural parameters the participants responded to earlier in the survey, responses were then evaluated for differences based upon their geographic locations. The most common changes were experienced to a similar extent across the Mostly Urban, Mostly Rural, and Completely Rural groups. Increased testing and decreased staffing were experienced by all locations, with each reporting between 38%-50% for both parameters. Laboratories moving microbiology to a centralized location was another change reported, though this was a change that impacted the completely rural and mostly urban areas more than it impacted the mostly rural sites. All changes sorted by rurality are shown in figure 8.

An aspect that varies from one location to the next is the requirement for students to draw blood. Participants were asked if students perform phlebotomy as part of their clinical rotation, and the degree of freedom the students are given when drawing. Across all laboratories surveyed, 42% do not let students perform phlebotomy in their facility, while 58% allow students to draw blood. Of the facilities that do allow students to draw blood, nearly 50% always require supervision, and 21% progress to letting their students draw unsupervised. Phlebotomy as a part of the student clinical experience is more prevalent when looking at rurality of the facility and can be seen in figure 9. This supports what is often seen clinically, as rural hospital laboratory workers are more involved with blood collection than the larger urban laboratories.

The final question about facilities was the procedures for clinical rotations, and asked who decides how much time the students spend in the laboratory as part of their clinical rotation. Laboratories may have organized clinicals in place that students are required to move through before they complete their clinical rotation, and different programs must conform to their rotation requirements. Only 8% of programs had structured requirements for every student rotating through their lab, and another 7% indicated they were hospital-based MLS programs, setting their own times. However, most clinical sites indicated that they schedule the time that the MLS or MLT program requires the students to be there, with 82% operating their rotations this way.

Facility Perceptions of Clinical Rotations

Survey participants indicated the number of students their laboratories host have increased over the last ten years, with 36% saying their laboratory increased the number of students they are able to take, and 19% saying they decreased how many students they could take. Even though over half of respondents had seen changes, 46% percent of respondents said their laboratories had not changed in the number of students they are able to host for clinical rotations. Many laboratories are reporting an increase or same number of clinical rotation placements, yet program directors still report that they have struggled finding these rotations for students. This could be a contradiction between what program directors are seeing in contrast to the clinical sites, or it may highlight that even with the efforts of clinical sites to take more students, it is not enough to keep up with the needs of laboratory education programs.

The perceptions and attitudes towards students on clinical rotation can make a big difference in the experience the student will have while performing their internship. Respondents were asked to summarize the collective feeling of their laboratory about mentoring students on clinical rotations, through selection of 11 provided responses. These responses were a variety of positive and negative perceptions common in the workplace, describing the feelings of those working with students, and multiple options could be selected. The most common response among all programs was that they saw the clinical rotation as a great recruiting tool for their laboratory, and the second most common was that it was fun to pass along their knowledge to the students. Rounding out the top 3 responses was a negative response, that their laboratory does not have enough staff to help train students. All responses to perceptions of laboratory staff towards students on clinical rotation are shown in figure 10. With the ability for respondents to select multiple options, there were varieties of answers that ranged from completely positive to completely negative. Responses were individually logged for each answer the participant gave on this question as: Positive, Mostly Positive, Mixed, Mostly Negative, and Negative. If responses to the question were over 67% negative or positive, then it was logged as mostly positive, or mostly negative. For the responses to be purely positive or negative, then their selections could not have one response to the contrary. Across all facilities responding, there were 35 positive responses, 11 mostly positive, 50 mixed responses, 9 mostly negative, and 4 negative responses. Responses to this question vary depending on the job title of the participant, the size of the facility, and the geographic location, with each of these variables further broken down to evaluate the perception of laboratory staff working with students on clinical rotations.

Job title is an important variable since the roles in the laboratory could have an impact on their ability to observe the perceptions of others in their laboratory. Some employees may hide their true feelings about working with students for fear of it impacting their job or finances. Laboratory managers and directors were lumped together as laboratory administrators and were more direct in their view of how the laboratory viewed clinical rotations. Laboratory administrators had only one response out of 23 that presented mixed opinions, 17 that were positive or mostly positive, 4 that were mostly negative, and 1 that was negative. Laboratory supervisors, which are a step below the laboratory administration, had 13 positive responses, 9 mostly positive, 8 mixed, and 4 mostly negative responses. Of the 9 people who identified "education coordinator" as their main responsibility, they had 4 positive responses and 5 mixed responses, with no negative comments. Medical laboratory scientists and technicians were the last job category selected and the responses showed more negativity than the other laboratory positions. Out of 31 MLS/MLT responses, 11 were positive, 4 were mostly positive, 11 were mixed, and 5 had negative responses to what they see in their laboratory about the perceptions of working with students.

Hospital size is a variable that needed to be identified because a larger hospital is correlated to the size of the laboratory and the amount of staff available. More staff may mean more help with training students, but it can also result in more diverse opinions about students rotating through their laboratory. Selecting the hospital size as a variable resulted in 23 responses from small hospitals, 48 from medium hospitals, and 40 responses from large hospitals. Figure

11 shows the perceptions of students on clinical rotation for the different sizes of hospitals and laboratories, and there is a trend that follows this variable. As the laboratories get bigger, the perceptions of students on clinical rotations moves more negative.

Rural laboratories face different problems than urban laboratories, most notably the difference in recruiting new laboratory scientists to areas that are more geographically isolated. The difficulty in recruiting new laboratory scientists is an important reason to evaluate how rurality impacts perceptions of clinical rotations. There were substantially more clinical sites in mostly urban areas than there were in rural areas. There were 113 laboratories that selected their geographic locations and answered the perceptions from their clinical laboratory. There were 84 responses from “Mostly Urban” sites, 24 responses from “Mostly Rural” sites, and 10 responses from “Completely Rural" sites. Figure 12 shows the proportion of positive and negative responses based upon the rurality of the site. Similar to the other variables for perceptions of the laboratory, the negative responses never outweigh the positive responses. However, the “Rural” and “Mostly Rural” sites were more positive about students on clinical rotations than is seen in the “Mostly Urban” sites.

The last question for collective facility perceptions asked about laboratory policies for hiring new graduates, and the role the clinical rotation plays in training new employees. If the clinical rotation is viewed as an important aspect of medical laboratory education, then facilities should take this into consideration when hiring recent graduates. Participants were asked if their laboratory adjusts the training time for new hires who graduated from programs with longer clinical rotations versus those with shorter clinical rotations. Respondents had two options, they could select that their facility does adjust the time of clinical rotations, or that their facility does not take the clinical rotation into consideration when training new employees. Of all participants, 41% stated that their facility will adjust the amount of training based on the program they came from, while 59% do not let the clinical rotation performed by the student influence their training protocols (see figure 13).

Participant Perceptions of Clinical Rotations

After answering questions about clinical rotations on behalf of their healthcare facility, participants were asked to provide their personal opinions of clinical rotations. The first question asked if working with students and educating future laboratorians was something they enjoyed about their job. The majority of respondents enjoy educating students as part of their job with 48% responding “Definitely Yes”, and 27% responding “Yes”. Twenty-four percent of participants “Sometimes” enjoy educating students, and only 1% responded that they do not enjoy educating students. No significant differences were seen with rurality, hospital size, or age, but there was a small difference seen when selecting for job title. All nine education coordinators responded “Definitely Yes” to enjoying working with students. Responses from lab directors and lab managers also leaned heavily in the positive responses, which can be seen in figure 14. While Supervisors and MLS/MLT remained positive, there were fewer positive responses seen from these groups in comparison to the lab managers and directors.

Participants were asked to rank from 1-10 the importance of five different options as to what the main role of clinical rotations are (see figure 15). Across all responses, participants saw “Applying the theory, techniques, and skills learned during didactic education in the clinical” as the most important reason for clinical rotations, scoring an 8.3 out of 10. The second most common response was to “Introduce the student to the workflow of the laboratory” with 8.2 out of 10. The next three in order of score were “Provide student interactions with other laboratorians and hospital/clinic staff” (7.1/10), “Train them the same as a new employee to prepare them to work independently” (6.5/10), and “Be the primary source of education in the laboratory education program” (4.8/10). Opinions about the role of clinical rotations varied slightly among the size of the hospital, with small hospitals placing a greater emphasis on training students the same as they would employees (7.68/10), otherwise results stayed consistent across all variables.

According to survey respondents, the main role of the clinical rotation is to apply the skills the students have learned in their didactic education, and get the workflow of the laboratory. The next question builds upon that premise and asked respondents how to handle a student who is working and proficient in a specific area of the laboratory, and whether they should be required to perform the clinical rotation in that specific area. The most common answer was that the hours should be waived since the student is already certified and proficient in that area, with 32% of participants selecting this as their solution. The remaining responses can be seen in figure 16. There were four participants that selected “Other” and gave additional feedback that the student should still do the same amount of time but should spend it in other departments in which they are not proficient.

Participants were asked if technology should be used to reduce the amount of time students spend in the laboratory on clinical rotations/internships, and examples were given of artificial intelligence, virtual reality, or remote teaching via Zoom. Participants responded, with 52% selecting “No”, 38% selecting “Maybe”, and only 10% selecting “Yes”. While 38% of the responses indicate an openness to embracing technology to help with students on clinical rotations, the majority of respondents do not want technology to take hours from traditional clinical rotations.

The length of clinical rotations is central to this research, and participants were asked if they see a clear difference in the quality of new employees from programs with longer clinical rotations versus those with shorter clinical rotations. An example was given of a year-long rotation versus a two-week rotation, two extremes of what is typically used. The majority of respondents reported seeing a major difference in employees who come from the two different programs, with 47% choosing this option. Thirty-six percent said they do not see a difference, and 18% said it was a minor difference between these populations. Laboratory managers, directors, and supervisors more frequently saw this as a major difference than education coordinators and MLS/MLT respondents, who more selected that they do not see a difference in the groups.

Having established that most participants saw a major difference in new employees that were hired from longer clinical rotations versus shorter clinical rotations, then what is the perfect length of time for a clinical rotation? Participants were asked what the perfect length of time (in weeks) would be for MLS, MLT, and categorical clinical rotations. The answers to this question exemplified the range of opinions on the matter (see figure 17). On average, respondents felt 25 weeks was the best amount of time for clinical rotations at the MLS level, 24 weeks at the MLT level, and 14 weeks at the categorical level. The highest amount that could be selected was 104 weeks, and would be the equivalent of a two-year rotation. Three participants selected 104 weeks at the MLS level, and two selected it at the MLT level. The shortest rotation length selected was 1 week for MLS and 2 weeks for MLT clinical rotations, with a range of 103 weeks and 102 weeks, respectively. The standard deviation was 21 weeks for both MLS and MLT programs, showing great variability among participants. The average of 25 weeks for the MLS level and 24 weeks for the MLT level are close to the 6-month range for clinical rotations. However, the median for the MLS level was 20 weeks, and 17.5 weeks for the MLT level, indicating skew at the top end of the range. Figure 17 shows the perceived ideal weeks of clinical rotations for each level of education.

Knowing the ideal time that respondents wish to have students on clinical rotations, the last question asked them about the time students are spending in their laboratory, and if it should be adjusted. Sixty-three percent of respondents felt students were spending an adequate amount of time in their laboratory for their educational needs. Twenty-eight percent of respondents felt that students needed more time on clinical rotations, with 46% of those specifying that their laboratory cannot accommodate the students for more time. Only 11% of respondents said that students need to spend less time on clinical rotations based on what they have seen in their own laboratories.

Discussion

Laboratories of all different sizes and capabilities serve as clinical rotation sites for MLS and MLT students finishing their degrees. Each laboratory can be completely different in the services offered and their capacity for students on rotation, a continually evolving reality. The top three responses to the questions about changes to laboratories in the last 15 years were: increased testing, decreased staffing, and moved microbiology to a central location for multiple hospitals. Two of those responses indicate that the laboratories are expected to do more with less, all while still accepting students for clinical rotations. The third response about the centralization of microbiology shows how much these clinical rotations are starting to shift, with 41% reporting that their microbiology department has been moved off site. Microbiology is still considered one of the core topics of MLS and MLT education, and students need to have time rotating in this area (American Society for Clinical Pathology, 2023). This means that there are diminished rotations at the original site that may forgo the typical plate reading and testing done, or that more students will be rotating through the centralized locations, putting a heavier burden on that site. The same issues exist for Blood Bank, though only 9% of laboratories reported centralization of this testing. Phlebotomy is another example of the differences in clinical rotations among students with only 58% of clinical sites training students how to draw blood. Phlebotomy is a critical skill for some employers, yet is not considered a core proficiency of medical laboratory education.

There are no specific standards for what the clinical rotation should consist of, making each clinical site unique, and the experiences the students have there may not be comparable to their peers at other institutions. The rurality of the facility, size of the hospital, number of lab workers, attitudes of the trainers, organization of the training, and time spent on rotation are all factors that will change the experience the student has at that facility. The variability across rotations is not a bad thing, though it needs to be understood that a student who performs a rotation at one clinical site may then be hired on at another clinical site and still not know how they perform the testing, because their training was different.

If clinical rotations can vary so much from one facility to the next, then the purpose of the clinical rotation needs to be explored in medical laboratory education. When participants were asked about the primary role of the clinical rotation, their top two answers were to apply the theory, techniques, and skills learned during didactic education, and introduce the student to the workflow of the laboratory. The second to last response (Figure 15) about the role of rotations was to train the student the same as a new employee, meaning many laboratories do not see this as an important role in training students. This was highlighted in another question when participants were asked if their facility would adjust the training time for a new employee based upon the length of time they spent on clinical rotation in their laboratory education program, and 59% stated that their facility does not consider the clinical rotation when training new graduates (Figure 13). The majority of facilities disregard the time a student spends on clinical rotation when they are training them to work in their facility, this is something every program director needs to stop and consider.

When asked about the perception of clinical rotations from their laboratories, 39% of respondents said that students were helpful on the bench. NAACLS has strict rules about the clinical rotations not being used for non-compulsory service work, meaning students should be there to learn, and if they are being used to fill in for staff then it is against the NAACLS standards (NAACLS, 2024). While the responses stating that students were helpful on the bench do not necessarily mean this is happening across all who responded to this option, it is a reason some laboratories like to have students on longer clinical rotations. One participant added to their response, “Since Covid, we have struggled to find staff. Students are a plus, they help fill a spot but I feel that we don’t spend as much time teaching. With extra workload, it is stressful trying to find time to work with students.” This was one participant directly stating that they are using students to fill in their staffing shortages and are not spending much time training them. Along with this comment, there were others stating that they simply do not have the time to work with the students they host on rotation, so they often sit on the side waiting until there is enough free time for somebody to show them something.

Though some laboratories harbor negative perceptions of clinical rotations, the majority of laboratories have positive experiences and see the clinical rotation as a crucial portion of laboratory education. Participants stressed the importance of the clinical rotation, but 74% stated they do not have the capacity to take any more students, and an additional 7% stated they have capacity but will not take any more students. There is finite space available for students to perform clinical rotations, yet laboratory education programs must find a way to increase graduates to try and alleviate the shortages seen in clinical laboratories.

A question that would have been important to include in the survey is if their laboratory hires new employees who have not gone through a laboratory education program, instead relying on minimums required by CLIA regulations for clinical laboratories (Centers for Medicare and Medicaid Services, 2017). Much importance is placed on the role of clinical rotations, however, there are many laboratories hiring individuals who have neither done a clinical rotation, nor learned core didactic concepts of medical laboratory science. The shortage of qualified MLS/MLT staff has pushed laboratory leadership to hire those without backgrounds in medical laboratory science and train them on the job for the roles they will take in the laboratory. The education is crucial, but seems easy enough to brush aside when hiring practices become difficult.

Medical laboratory education programs shoulder a fair amount of the blame for the shortage of medical laboratory scientists; there has not been enough students to keep up with demand. While input from clinical sites is a major driver in decisions made about clinical rotations, the amount of time the students spend on clinical rotation is largely determined by the laboratory education program, with 82% of clinical sites stating they schedule the student for the time the program requires. The clinical sites carry the burden of the decisions made in the educational programs, and their time and resources should be further considered when evaluating the minimum requirements for the rotation. The clinical rotation needs may vary from one program to the next, and from one clinical facility to the next, but it needs to be regularly evaluated by programs. If something can be taught through online lectures before the student has to step foot in the laboratory, then it can reduce the burden on the clinical staff to teach it at the same time as they are showing it. Most see the role of the clinical rotation as connecting the didactic to the laboratory side and giving exposure to the workflow of the laboratory, more than that is beyond their role.

Clinical rotations are a crucial service to the profession that take a lot of time and effort to provide, and come at a cost to the laboratory. Laboratory administration and laboratory education administration should ask themselves what they see as the role of the clinical rotation, and whether or not they are achieving that goal. Laboratory educators need to find ways to be more efficient with the time the students are spending on clinical rotation, and plan accordingly for the rotation activities that can only be performed on-site. The field should consider moving to a competency-based rotation rather than a time-based rotation, allowing the student and clinical site to be as efficient as possible with the time they are there. Clinical rotations act as a bottleneck to getting more qualified laboratorians working, and the longer the profession struggles to produce enough qualified workers, the more likely it is that employers will hire those without adequate training. There needs to be some agreement on the role of the clinical rotation and more efficient use of this time, or else it will continue to act as a barrier to graduating more qualified medical laboratory scientists.

Conclusion

Laboratory directors make most of the decisions regarding the details of the clinical rotations for their medical laboratory science programs. However, it is also important to understand the perspectives of those who work closely with the students on rotation because they understand the difficulties and needs of these students better than any other. This survey asked for the direct opinions of those working at hospitals and clinics with students on rotations, finding important differences in opinion based upon variability in the hospital and the participant. Most laboratories see the clinical rotation as a burden they must shoulder, but they also see it for the good it brings to the profession and the potential recruits it brings to their laboratory. Key responses experienced by many respondents were that laboratory consolidation of microbiology and blood bank, combined with increased testing demands, have made laboratory rotations difficult to come by for additional students. It is difficult to grow our profession by the numbers needed if we cannot add more students to clinical rotations, as most participants indicated they cannot support additional students. Program directors need to get creative in the ways to budget the time they require for students on rotation. There are many ways to ease the burden on clinical sites, and these options need to be further explored if laboratory education programs are to increase the number of graduates to keep up with demand. Working with clinical sites to be efficient in the delivery of the clinical rotation will ensure more clinical spots for students, ultimately improving the quality of the students and the safety of the patients they will work with as medical laboratory scientists.

Table 10

Demographics of Education Coordinator Survey Respondents

Gender	N	**Percentage**
Female	113	84.3%
Male	21	15.7%
Experience with Students		
In charge of the students but perform minimal direct teaching	61	45.5%
Discipline specific bench working directly with the students	49	36.6%
In charge of the students AND do most of the direct teaching on their rotation	24	17.9%
Education Attained		
Associates	3	2.3%
Bachelors	82	62.6%
Masters	44	33.6%
Doctorate	2	1.5%
Type of Program Laboratory Credentials Earned Through		
Four-year College/University	107	81.7%
Non-degree Granting Proprietary Program	5	3.8%
Two-year College/University	15	11.5%
Independent Laboratory	1	0.7%
Other	3	2.3%
Primary Role in the Laboratory		
Lab Director	18	14.0%
Lab Manager	17	13.2%
Supervisor	44	34.1%
Education Coordinator	9	7.0%
Medical Laboratory Scientist	35	27.1%
Medical Laboratory Technician	4	3.1%

Note. The "Other" responses consisted of two who indicated they had post-baccalaureate on the job training, and another who clarified that they do not have traditional laboratory credentials.

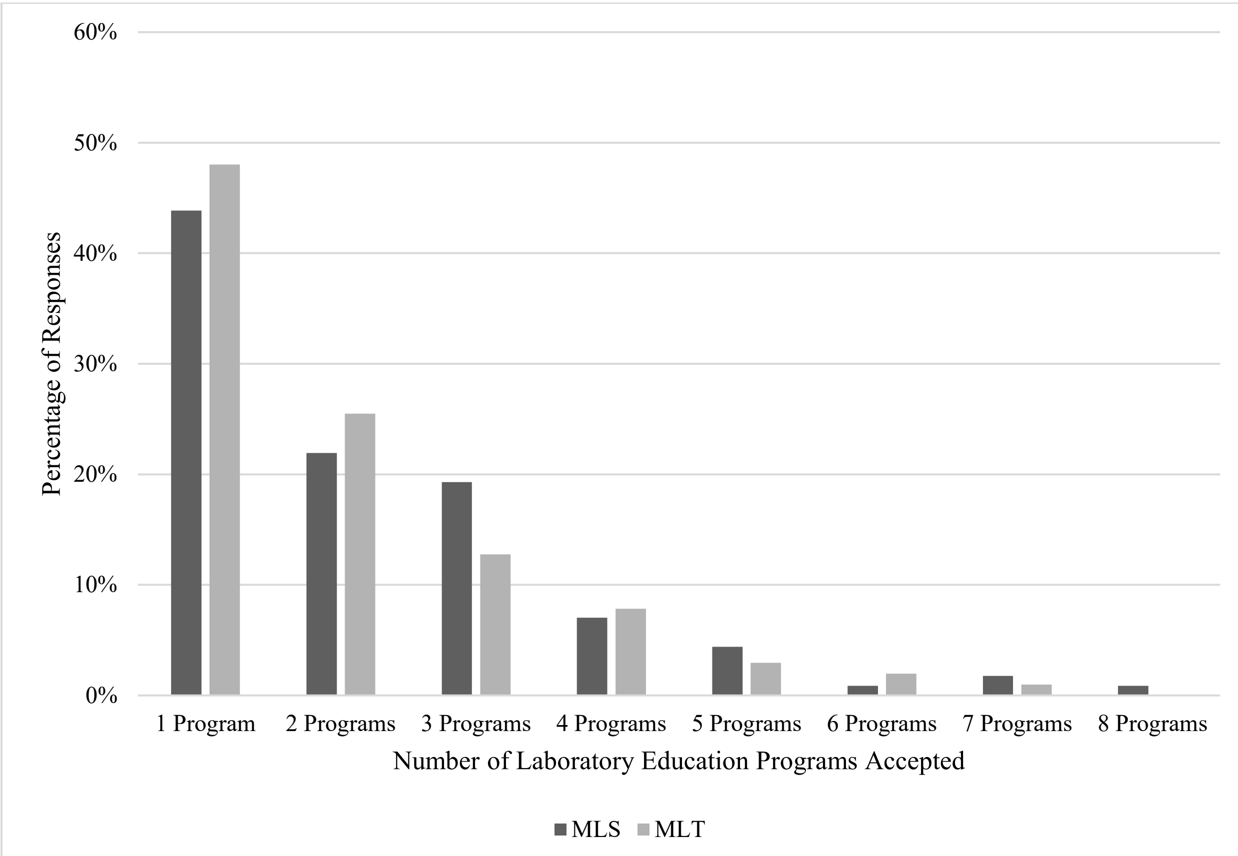
Table 11

Age and Years of Service for Education Coordinator Survey Respondents

Respondent Age (n=134)	**Years**
Mean	44.6
St. Dev.	12.5
Minimum	23
Maximum	74
Years in the Clinical Laboratory (n=134)	
Mean	17.8
St. Dev.	12.6
Minimum	0
Maximum	50
Years in a Laboratory Supervisor Role (n=134)	
Mean	8.2
St. Dev.	9.9
Minimum	0
Maximum	44
Years Working with Students on Clinical Rotation (n=134)	
Mean	11.9
St. Dev.	10.2
Minimum	1
Maximum	47

Figure 6

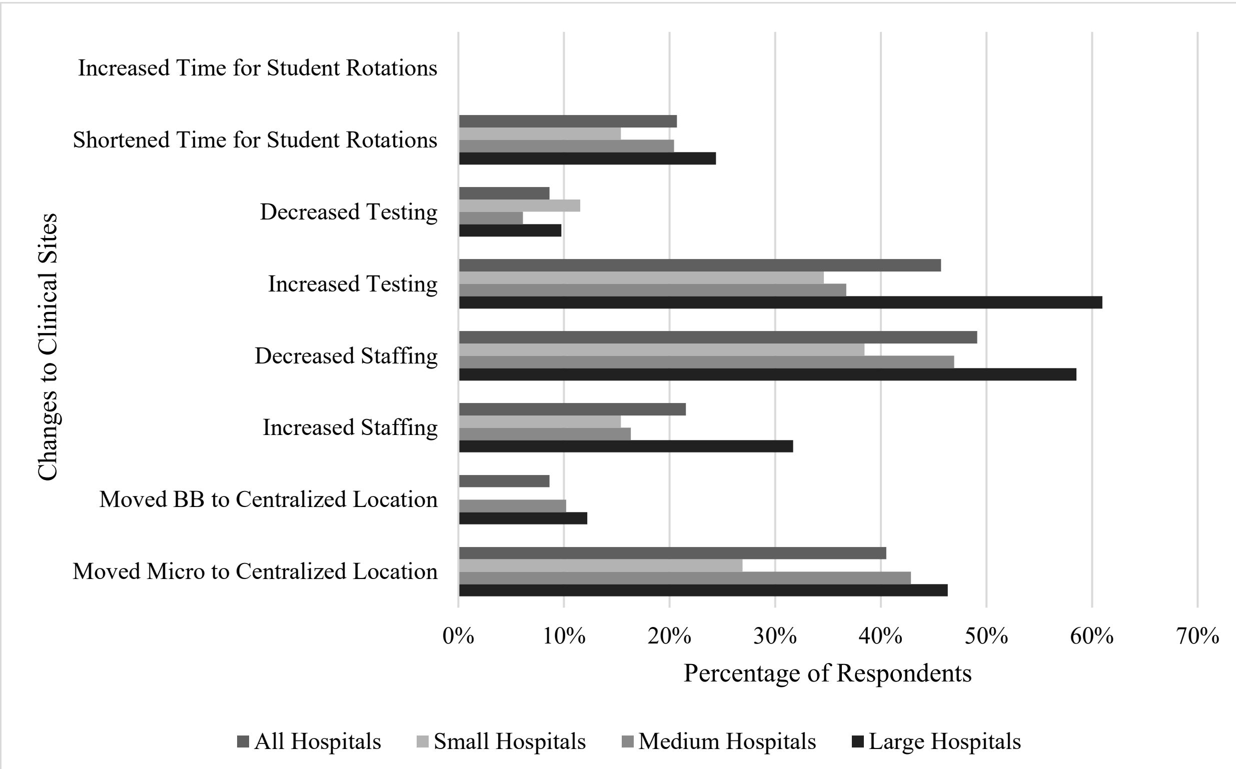
Number of MLS/MLT Educational Programs Clinical Sites Work with to Provide a Clinical Experience (n=129)



Note. Participants were asked how many different MLT or MLS programs/schools their facility works with to provide students with a clinical rotation. There were 129 responses total most respondents indicated that their facility takes both MLT and MLS level students on clinical rotations, with 90 facilities (70%) that will host both types of students each year. Twenty-eight (22%) of the respondents will only host MLS level students, and 11 (8%) will only host MLT level students. The total responses for MLS rotations is n=114, and the total responses for MLT rotations is n=102.

Figure 7

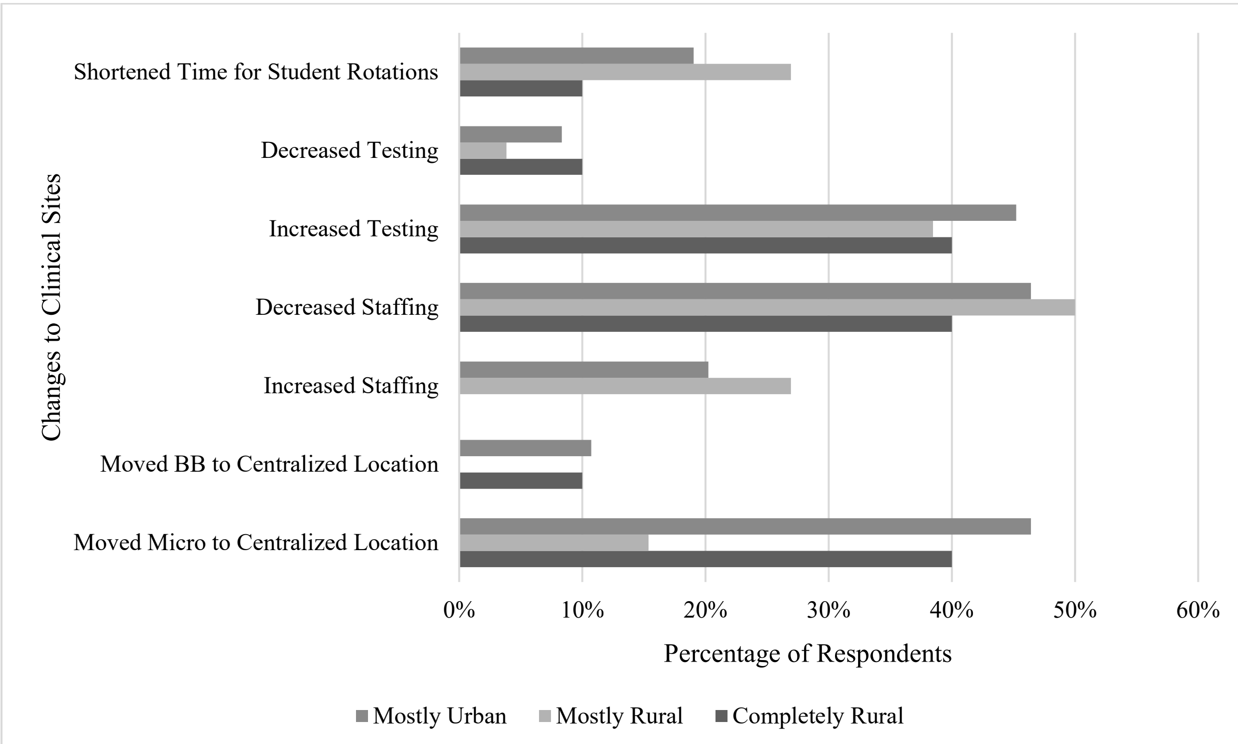
Percent Changes to Clinical Sites Impacting Student Rotations by Hospital Size (N=116)



Note. Participants could select all that apply. Of the 116 participants, 73 selected more than one option. Ten participants selected "other", of which four indicated that no changes had been made, and four others had made changes to the number of students they could accept on clinical rotations. The number of respondents by hospital size are: small hospitals (n=26), medium hospitals (n=49), large hospitals (n=41).

Figure 8

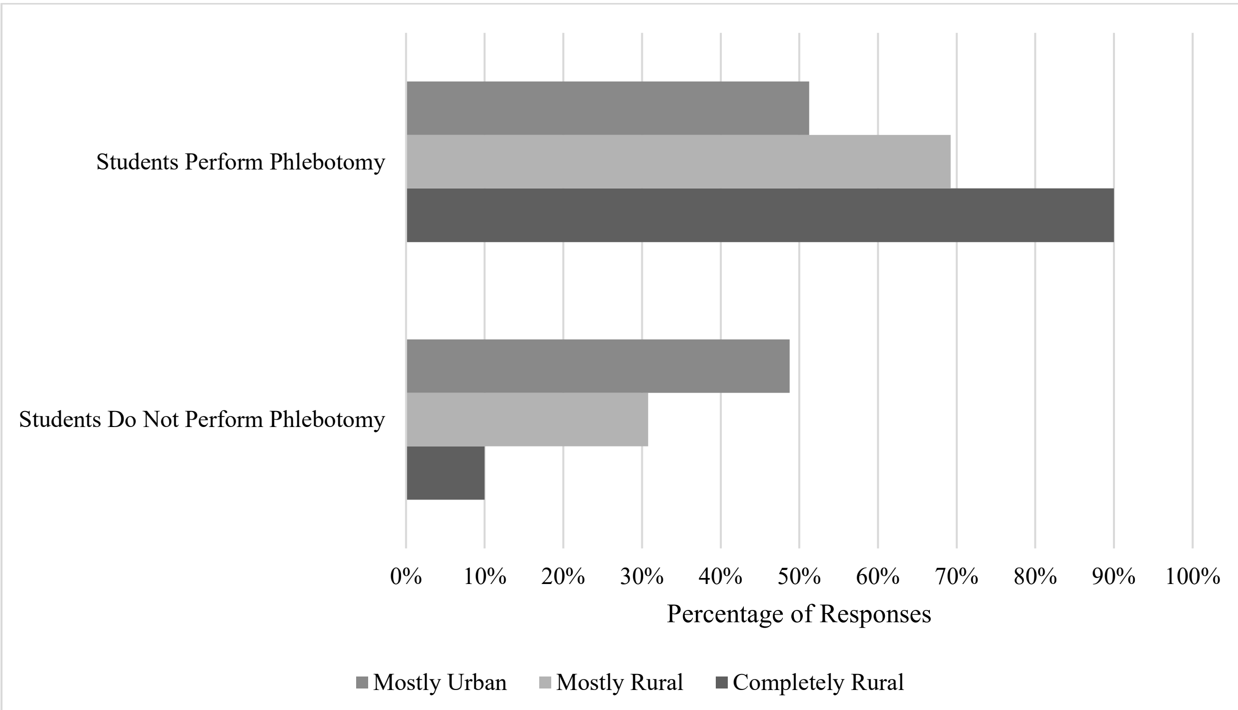
Percent Changes to Clinical Sites That Impact Student Rotations by Rurality (N=120)



Note. Participants could select all that apply. Of the 120 respondents, 76 selected more than one option. Nine participants selected “other”, of which three indicated that no changes had been made, and four others had made changes to the number of students they could accept on clinical rotations. The number of respondents by rurality are: completely rural (n=10), mostly rural (n=26), mostly urban (n=84).

Figure 9

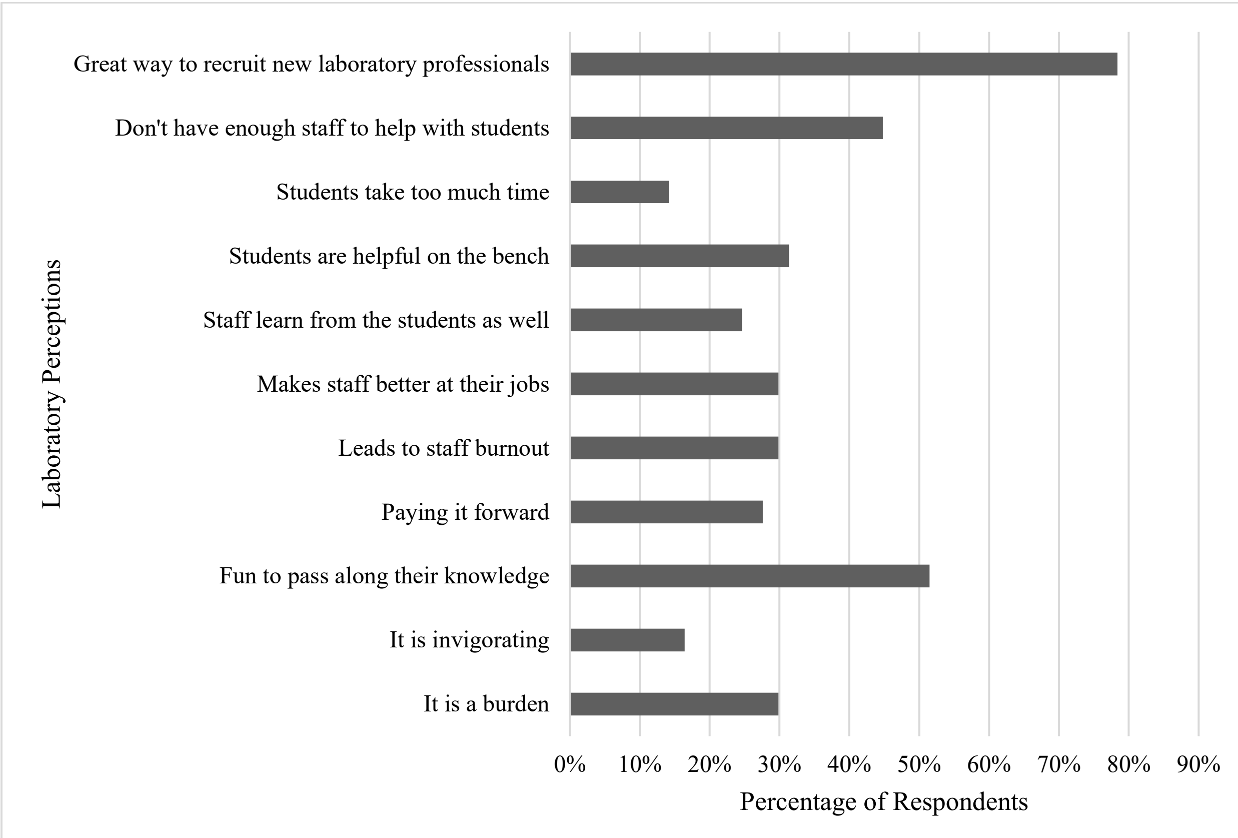
Percent of Clinical Sites Allowing Students to Draw Blood by Rurality (N=116)



Note. There were 116 total responses. The number of respondents by to student blood collection by rurality are: completely rural (n=10), mostly rural (n=26), mostly urban (n=80).

Figure 10

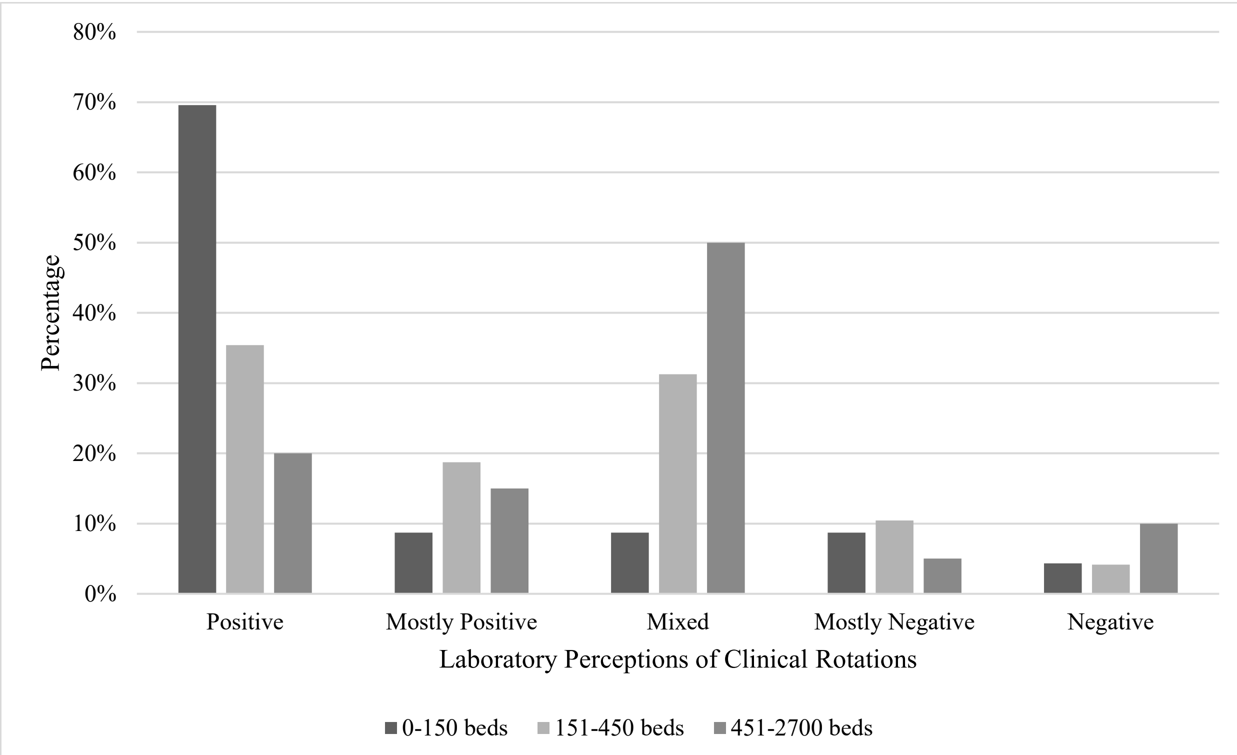
Laboratory Perceptions of Students on Clinical Rotation (N=124)



Note. Respondents were asked to summarize the collective feeling of their laboratory about mentoring students on clinical rotations, and could select all that apply. From the 124 participants, 114 selected more than one option, and 101 selected three or more options. Eight participants selected “other”, of which three further clarified that it is important for recruiting to the profession and to their own laboratories, and 3 others talked about the difficulty of working with students that are not interested in the information, like pre-med students or those that do not like specific areas of the laboratory.

Figure 11.

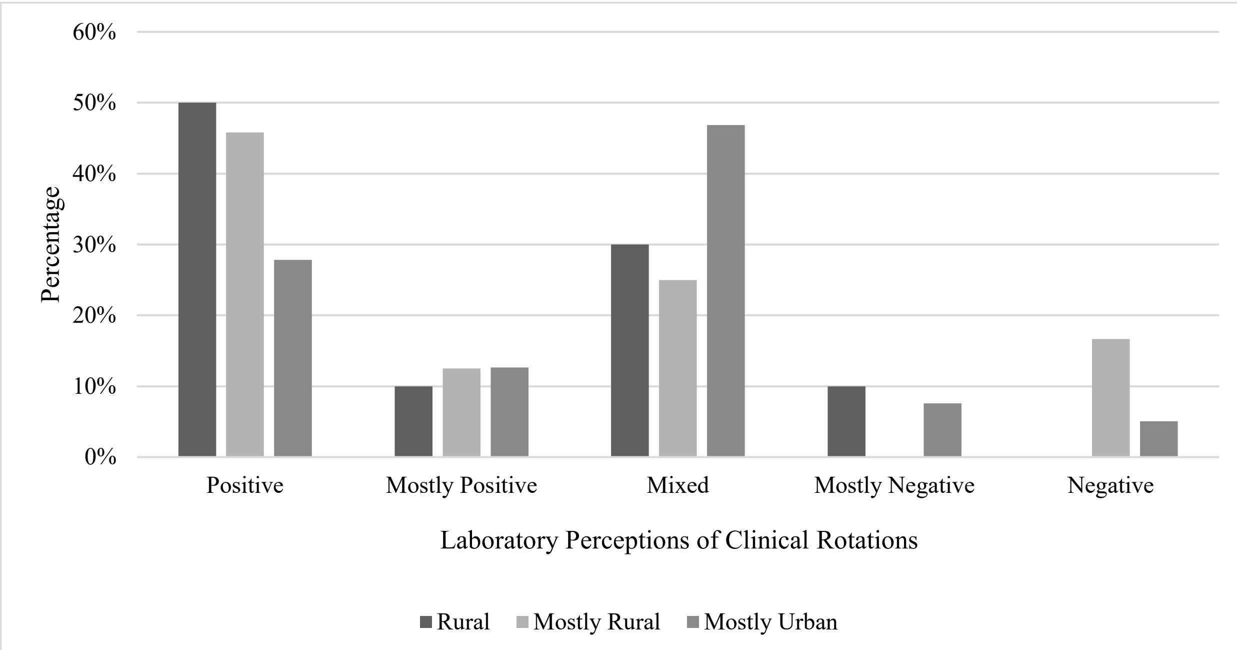
Laboratory Perception of Clinical Rotations by Hospital Size (N=111)



Note. Respondents were asked to summarize the collective feeling of their laboratory about mentoring students on clinical rotations, and could select all that apply. Responses were individually logged for each answer the participant gave on this question as: Positive, Mostly Positive, Mixed, Mostly Negative, and Negative. If responses to the question were over 67% negative or positive, then it was logged as mostly positive, or mostly negative. For the responses to be purely positive or negative, then their selections could not have one response to the contrary. There were 111 total responses. The number of respondents by hospital size are: small hospitals (n=23), medium hospitals (n=48), large hospitals (n=40).

Figure 12

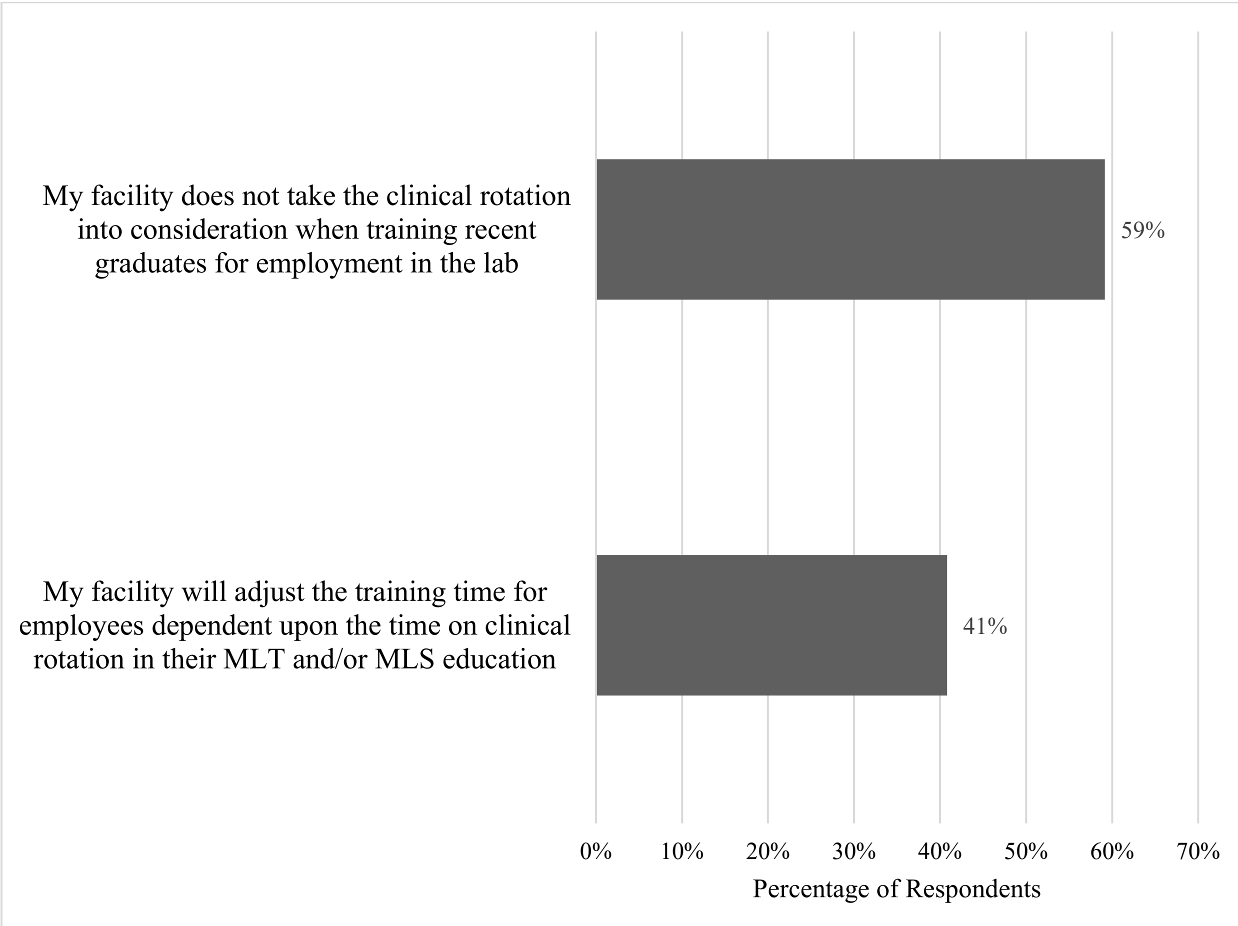
Laboratory Perception of Clinical Rotations by Rurality (N=113)



Note. Respondents were asked to summarize the collective feeling of their laboratory about mentoring students on clinical rotations, and could select all that apply. Responses were individually logged for each answer the participant gave on this question as: Positive, Mostly Positive, Mixed, Mostly Negative, and Negative. If responses to the question were over 67% negative or positive, then it was logged as mostly positive, or mostly negative. For the responses to be purely positive or negative, then their selections could not have one response to the contrary. There were 113 total responses. The number of respondents to perceptions of clinical rotations by rurality are: completely rural (n=10), mostly rural (n=24), mostly urban (n=79).

Figure 13

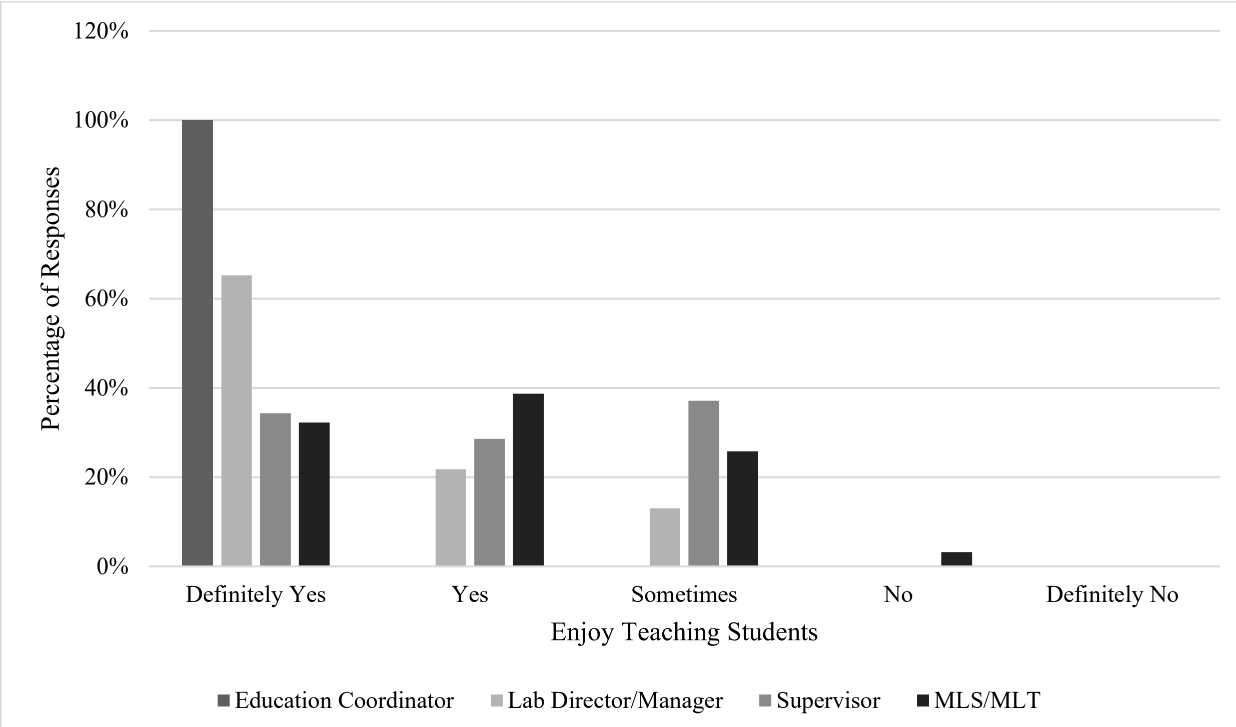
Consideration of Training Time Spent on Clinical Rotation in Hiring of Graduates (N=120)



Note. Participants were asked if their laboratory adjusts the training time for new hires who graduated from programs with longer clinical rotations versus those with shorter clinical rotations. Respondents had two options displayed above.

Figure 14

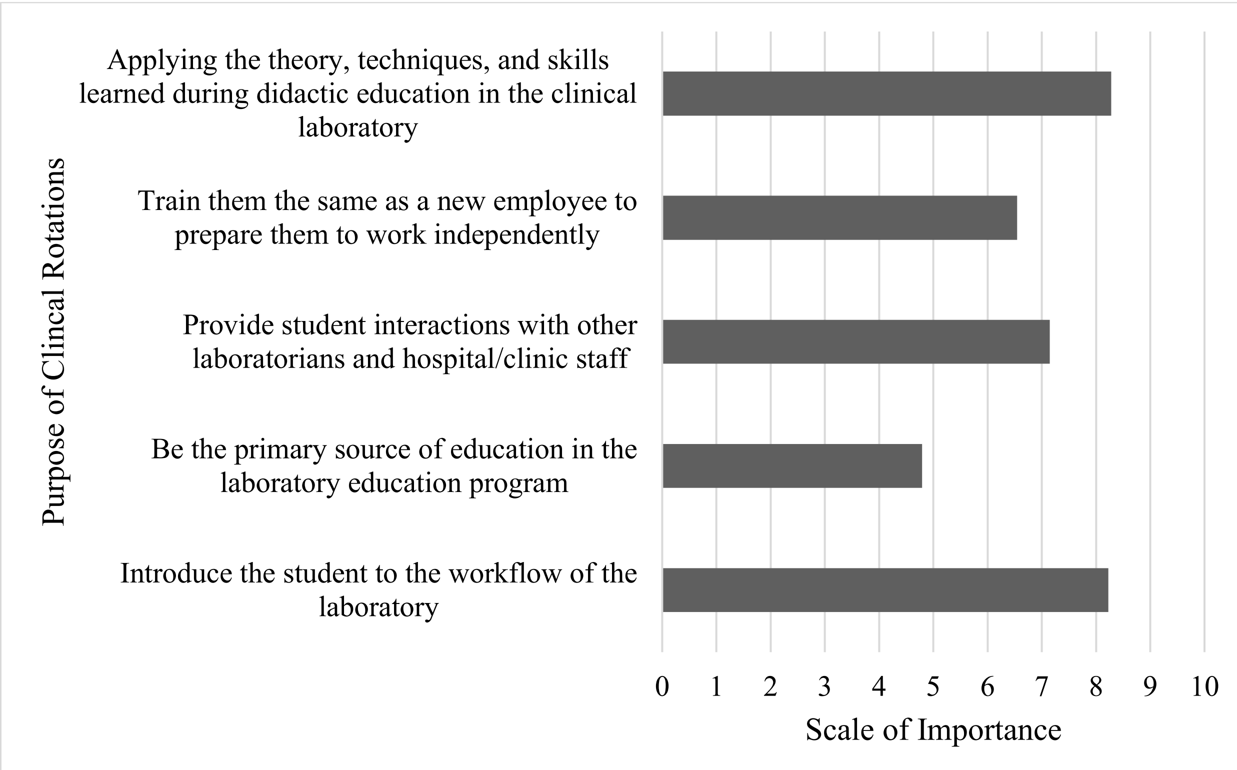
Joy of Teaching Students by Job Title (N=98)



Note. Participants were asked if working with students and educating future laboratorians was something they enjoyed about their job. Separated by job title, there were 98 total responses. The number of respondents by job title are: Education Coordinator (n=9), Lab Director/Manager (n=23), Supervisor (n=35), and MLS/MLT (n=31).

Figure 15

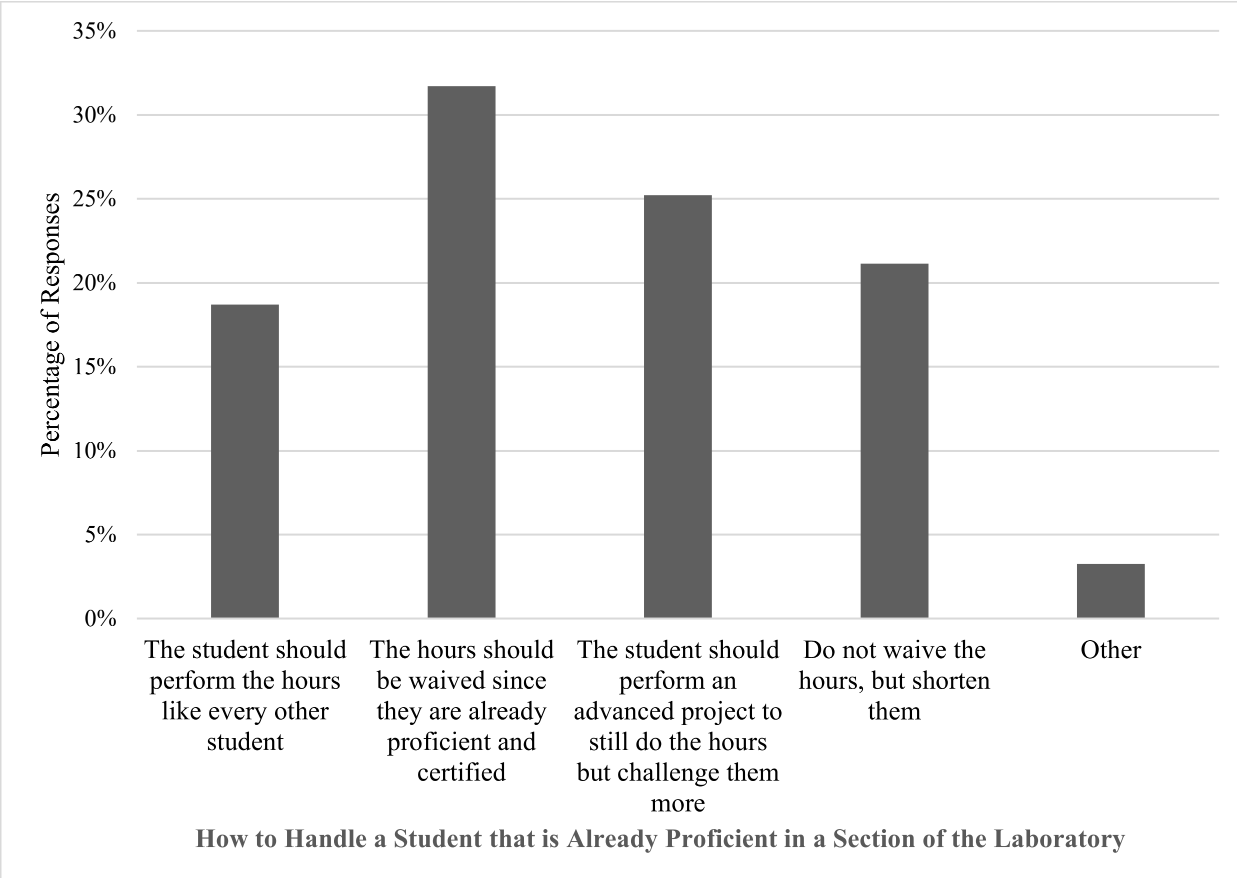
Perceived Purpose of Clinical Rotations from Clinical Educators (N=134)



Note. All respondents were asked to rank from 1-10 the importance of five given options as to what the main role of clinical rotations are. One is the least important, ten is the most important.

Figure 16

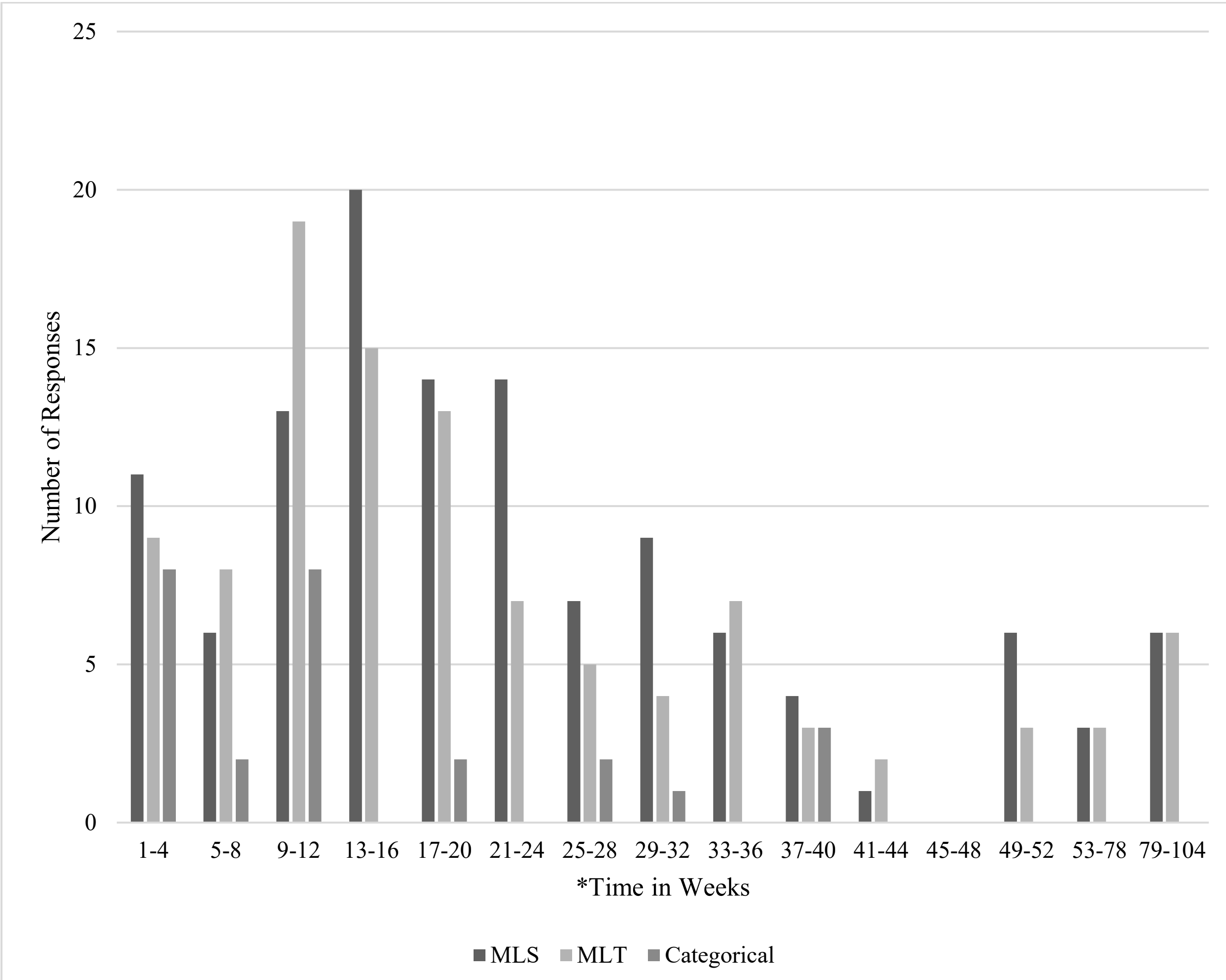
Proficiency Versus Time on Rotation (N=123)



Note. There were 123 total responses with four respondents selecting "other". Two of the respondents that selected "other" thought the time could still be used in other areas of the laboratory, giving students more time to focus on the areas they are not proficient, and one respondent thought the decision on shortening the rotation should be left up to the student.

Figure 17

Perceived Ideal Time Spent on Clinical Rotation in Weeks by Number of Responses (N=122)



Note. There were 122 total responses. This figure shows the total number of responses for each block of time in weeks. The number of respondents by program type are: MLS (n=120), MLT (n=104), and categorical (n=26). *Hours on rotation are reported throughout this study, this question required a larger scale and was asked in number of weeks.

Chapter 4: Evaluating the Relationship of Medical Laboratory Education Outcomes to Student Time in Clinical Rotation and Didactic Education

Abstract

Medical laboratory scientists and technicians are vital healthcare professionals who use complex methods and instrumentation to aid in the diagnosis, monitoring, or prevention of numerous diseases. It can take years of training to qualify for the MLS or MLT certification exams that are required by many healthcare facilities for their employees. The training of laboratory professionals is detailed and specific for diseases and diagnostics that are crucial to accurately perform the tests that will impact patient care. Shortages in qualified medical laboratory professionals have persisted for decades, resulting in laboratory and hospital administration to hire non-credentialed individuals who lack the proper laboratory training. One major reason for the shortage of qualified medical laboratory personnel is that laboratory education programs are not graduating enough students to keep up with demand. Most laboratory directors have indicated that clinical rotation availability has been a hindrance to their programs accepting more students in their laboratory education program. While the opportunity for clinical rotations is a requirement from NAACLS, the main credentialing body for medical laboratory education, there are no specific requirements for the time spent on rotation. Clinical rotations may have different purposes for the hundreds of medical laboratory education programs, but this research focuses on their impact on key quality outcomes of individual programs. Certification pass rates were evaluated through regression analysis looking for a relationship with student time spent on didactic education, student time spent on clinical rotation, and the number of graduates from each program. A relationship exists with time spent on clinical rotation and certification pass rates for hospital-based MLS programs, with no relationship observed between clinical rotation time and certification pass rates in university-based MLS programs. There was no observed relationship between certification pass rates and student time on didactic education across all program types (MLT, hospital-based MLS, and university-based MLS). Hospital-based MLS programs had a weak relationship with the number of graduates and certification pass rates that was not seen in the other program types. The weak relationship between the tested variables did not rise to statistical relevance, indicating there may be other explanations for variance in certification pass rates in laboratory education programs or there was not enough power to detect differences.

Abbreviations

National Accrediting Agency for Clinical Laboratory Science (NAACLS), Board of Certification (BOC), Medical Laboratory Science (MLS), Medical Laboratory Technician (MLT), American Society for Clinical Pathology (ASCP)

Keywords

Medical Laboratory Education, National Accrediting Agency for Clinical Laboratory Science, Clinical Rotations, Medical Laboratory Science, Hospital-Based Programs, University-Based Programs, Minimum Time Requirement

Introduction

Medical laboratory scientists are responsible for complex testing that is critical to medical diagnostics, and the healthcare system (Leber et al., 2022). Laboratory professionals spend years learning details of clinical chemistry, microbiology, hematology, coagulopathies, immunohematology, and many other specialized testing diagnostics to care for patients accurately and efficiently (Bureau of Labor Statistics, 2021). However, shortages of medical laboratory professionals have caused strains in hospital laboratories and clinics across the country, forcing laboratory administration to hire individuals who lack the proper training to safely perform testing (Lawson & Ledesma, 2018). The shortage of qualified medical laboratory scientists is not a new phenomenon and has persisted for years despite efforts to mitigate the issues (ASCLS, 2018; ASCP, n.d.). The longer the staffing shortages are allowed to persist, the more it allows for the normalization in hiring of non-medical laboratory trained personnel (Lawson & Ledesma, 2018). Many solutions have been pursued to alleviate the shortage, often centered around improving visibility, increasing wages, or recruiting more to the profession (ASCLS, 2018). Medical laboratory education programs are often discussed because of the need to produce more educated laboratory professionals; however, the solutions often focus on recruiting more to the programs or opening more schools (ASCLS, 2017). An area that needs more attention in medical laboratory education is the constriction caused by clinical rotations in medical laboratory education, preventing programs from accepting more MLS or MLT students. Clinical rotations act as a major bottleneck to bringing more students into medical laboratory education programs, with 57% of program directors indicating that the clinical rotation prevents them from accepting more students (Beazer, Landscape, 2024; Scott, 2015).

The National Accrediting Agency for Clinical Laboratory Sciences (NAACLS), which serves as the primary accrediting body for medical laboratory education programs, requires students have "the opportunity to participate in applied clinical experiences" (NAACLS, 2021). NAACLS does not set minimum amounts of time required on clinical rotation or what should be performed, other than stating "the activities assigned to students in the clinical setting are educational" (NAACLS, 2021). The standards must be vague because MLS and MLT programs are structured differently across the country, with substantial differences between hospital-based programs and university-based programs.

Adjusting the length of the rotation can have an impact on the perception of the program because the majority of clinical laboratorians who work with students see clinical rotations as an indicator of the quality of the instruction the student has received throughout their education (Beazer, Perceptions, 2024). While more time on clinical rotation may be a benefit to students, it is difficult to measure because programs are not required to divulge the amount of time necessary for students to complete their degrees. The perceived correlation between time spent on clinical rotation and the quality of the clinical laboratory education is the aim of this research. The corresponding research question is: Do programs with longer clinical rotations than their peer institutions see higher quality-related outcomes than those with shorter clinical rotations?

Medical laboratory professionals are required to be certified to work in most hospitals and clinical laboratories, and a student can become certified by passing the American Society for Clinical Pathology (ASCP) Board of Certification (BOC) (ASCP, 2024). There are two levels of examinations for laboratory professionals, (1) the Medical Laboratory Technician (MLT) exam is administered to students after completing a NAACLS-accredited program and an associate's degree, and (2) the Medical Laboratory Scientist (MLS) exam requires completion of a NAACLS-accredited MLS program and a baccalaureate degree to sit for the exam (ASCP, 2024). Both exams are difficult adaptive tests that challenge students in all facets of clinical testing, with the MLS exam covering more information than the MLT exam (ASCP, 2024). The BOC certification rates serve as a benchmark for the quality of the education offered by the institution, and NAACLS requires that each program publishes certification pass rates, graduation rates, and post-graduation placement rates for prospective students to make informed decisions based upon these program outcomes (NAACLS, 2024). The outcomes, including certification pass rates, are published for at least three previous years, providing an average for each program (NAACLS, 2021).

When looking at the differences between programs, there are a number of variables that stand out as likely influences on program outcomes. Most hospital-based programs operate exclusively on, or have the option of, a 4+1 format where students must have a baccalaureate degree before beginning their program. In contrast, the majority of university-based programs operate on a 3+1 format where the laboratory curriculum is integrated with required general education courses (Beazer, Landscape, 2024). Hospital-based programs also average about 11 graduates per year in comparison to the 26 per year in university-based programs (Beazer, Landscape, 2024). Program requirements, number of faculty, and incoming student GPA are all factors that would likely have an impact on the outcomes of individual programs. While there are a number of influences on the success of students in a program, this research did not seek to answer each of those individual variables, and was specifically looking at the value of clinical rotations on program outcomes, adding context where possible for the observed results.

Since the BOC pass rates are a benchmark that NAACLS holds schools accountable to, it was used as a benchmark to evaluate the curriculum and clinical rotations. Didactic education and clinical rotations are the two main interactions laboratory education programs have with their students. A relationship between the time spent on clinical rotation and BOC pass rates may serve as justification for longer clinical rotations. This research also looked for non-linear relationships to determine if there is a curvilinear correlation between the data, indicating a level of diminishing returns. Clinical rotations have served as a bottleneck to developing more qualified medical laboratory scientists and technicians, and determining the value of the clinical rotation is an important step in evaluating what the profession can do to alleviate the persistent shortage.

A literature search was performed across Proquest, Google Scholar, Onesearch, CINAHL, and PubMed. Articles were found that discussed the clinical rotation compared to outcomes in specific programs, but no articles were found that evaluated program outcomes across multiple laboratory education programs. More specifically, no information could be found that asked program directors about their specific educational variables, and related those to outcomes across all MLT and MLS programs. This research is unique in its approach and provides valuable information for those that work with medical laboratory students, both in the laboratory and in didactic education.

Methods

This study utilized a cross-sectional research perspective looking for a statistically significant difference between the BOC pass rates among programs with long clinical rotations versus those with short clinical rotations. The null hypothesis is that there is no statistically significant relationship between the time spent on clinical rotation, or didactic education, and certification pass rates. The alternative hypothesis is that time spent on clinical rotation or didactic education leads to a significant change in certification pass rates. This study builds upon prior research performed in chapter two of this dissertation research where the average length of time was reported by MLS/MLT program directors through a survey that was developed and validated by the investigator using Qualtrics, which established the length of time each program spends on clinical rotation and on didactic education (Beazer, Landscape, 2024). From the Qualtrics survey, the average time spent on clinical rotation was determined for all laboratory education programs before breaking it down into categories of MLT programs, hospital-based MLS programs, and university-based MLS programs. Of the 469 possible program directors that were recruited to the survey, 159 completed the survey for a response rate of 34% of all NAACLS-accredited MLS and MLT programs (Beazer, Landscape, 2024).

NAACLS-accredited programs are required to post the last three years of program outcomes on their website which covers certification pass rates, graduation rates, and employment placement rates. Links are posted on the NAACLS website for all accredited programs. Every MLS and MLT program website was reviewed and their certification rates, graduation rates, and placement rates were recorded for each program in an excel spreadsheet. Additionally, many programs provided absolute counts for graduates and certification attempts, these data were recorded when provided to add additional context. The program directors who completed the Qualtrics survey reported the amount of time they require their students to perform clinical rotations and the time their students spend in didactic education. The data reported from Qualtrics was combined with the information reported by each individual program on their website, providing the time students spend on major functions in the program with the overall outcomes that are seen. The data was imported into SPSS statistical software and evaluated for linearity and outliers before performing a regression on certification pass rates compared to hours spent on clinical rotation and hours spent on didactic education (IBM Corp, 2021).

To test whether a regression analysis was appropriate for use with these data, standard assumptions were evaluated through a series of tests (Laerd Statistics, 2015). A scatterplot was developed comparing the dependent variable of certification pass rates to three separate independent variables of clinical rotation hours, didactic education hours, and the absolute count of graduating students. The data was stratified by the percentages of pass rates into eight tiered groups that ranged from 100% pass rates to 41% pass rates. Ordinal dummy values were assigned to each group of BOC pass rates as shown in Table 12. Additionally, the data were evaluated by MLT programs, university-based MLS programs, and hospital-based MLS programs. Visual inspection of all scatterplots indicated a linear relationship between the variables, and independence of variables is inherent in the study design since they are published values unique to each individual program. Homoscedasticity was evaluated by visual inspection of a plot of standardized residuals versus standardized predicted values, which was acceptable for the linear regression (Laerd Statistics, 2015).

There were three initial outliers flagged through the SPSS statistical software, all values in the low range of pass rates of 41%, 50%, and 50.33%. After removing these values, three more flagged on the low end with values of 54%, 57%, and 59% pass rates (Laerd Statistics, 2015; Osborne and Overlay, 2004). After the second round of outlier removal, there were no more outliers identified in the data outside of three standard deviations (IBM Corp, 2021). Two of the outliers were MLT programs, and four were university-based MLS programs. The decision was made to include most of the outliers because these are values that are reported to NAACLS and are verified by the individual programs (Laerd Statistics, 2015). Only one outlier was permanently removed because it was a new program with only one year reported thus far, increasing the chance of error. Both sets of data are reported in the results section with the outliers included, and omitted, for each of the variables. Hospital-based MLS programs did not contain any outliers, and for this reason only one set of data will be presented for these programs.

Assumptions of normality were assessed using histograms and P-P charts shown in figures 18, 19, 20, and 21. Visual inspection of all charts showed a normal distribution of the data, which improved through the stratification of the pass rates into the same eight-tiered groups (Laerd Statistics, 2015). Regression analysis was performed to compare provided independent variables with certification pass rates. The adjusted R square is reported for each regression performed to represent the proportion of variation explained by the model. Using the adjusted R squared accounts more for positive bias and is more representative of a value expected in the population (Laerd Statistics, 2015). All regression and ANOVA results are found in Table 13.

Results

Outcomes of All MLS and MLT Programs

As a broad view of NAACLS-reported outcomes among the main categories of laboratory education programs, the certification, graduation, and placement rates were evaluated for MLT programs, university-based MLS programs, and hospital-based MLS programs. Figure 22 shows each of the individual parameters by program type. There is a negligible difference among the placement rates among all 479 programs, and there is a small dip in the number of graduates in MLT programs versus MLS programs, where 93% of students who start MLT programs will finish compared to the 97%-99% that finish MLS programs. The largest difference among all programs is the certification pass rates. Hospital-based programs and university-based programs take the Medical Laboratory Scientist exam through ASCP, and hospital-based programs had a 92% average pass rate while the university-based programs had an 84% pass rate, showing an 8% difference between the two types of programs. MLT programs take the Medical Laboratory Technician exam through ASCP, and averaged an 88% pass rate on the associate-level MLT certification exam.

Didactic Education vs Certification Rates

The total amount of didactic hours reported by program directors were compared to certification pass rates. Across all programs, there was no difference between the time a student spends on didactic education and the certification test scores. The ANOVA results were $F(1,111)=.123$, $p=.726$; with a p-value greater than .05, we fail to reject the null hypothesis and the variance in pass rates may be attributed to other factors than time on didactic education. Minimal differences were seen between groups through all regressions run on the time in didactic education, with stratification, outliers, and the type of program showing no differences in the data.

Clinical Rotations vs Certification Rates

The total amount of time students spend on clinical rotations was the next variable to be tested in comparison to ASCP BOC pass rates. Data from the survey of program directors showed clear differences in the amount of time spent on clinical rotation among MLT, university-based MLS, and hospital-based MLS. Medical Laboratory Technician programs require an average of 550 total hours, university-based MLS programs require 656 hours, and hospital-based MLS programs require 904 hours of clinical rotations to be performed to earn their degree (Beazer, Landscape, 2024). It would be expected that these large differences would make a major impact on the certification pass rates of the individual programs.

The regression analysis showed a difference between groups for all program types, with an adjusted R^2 of .059 with the outliers included, and .094 with the outliers removed, contributing 5.9% and 9.4% of the variance seen. With the outliers removed, the results of the ANOVA were $F(1,113)=12.773$, $p<.0001$. The results of the linear regression show there is a difference between time spent on clinical rotation and certification pass rates across all programs, and the null hypothesis is rejected. Stratification across all program types improved for data run with outliers included, increasing the variance by 2.2%, but had a minimal impact when the outliers were removed.

The prior comparison of certification pass rates showed they were 8% higher among hospital-based MLS programs, and hospital-based programs also require 248 more clinical rotation hours than university-based MLS programs. These two statistics seemed to indicate a connection between clinical hours and certification pass rates at the MLS level. The adjusted R^2 of hospital-based program clinical rotation hours compared to their certification pass rates was .132, or 13.2%. There were no outliers within the hospital-based MLS programs, but stratification of the data was also performed. Stratified data decreased the overall correlation from 13.2% to 10.7%. The ANOVA analysis resulted in $F(1,32)=6.004$, $p=.02$, with a p-value less than .05, resulting in the rejection of the null hypothesis. These results show a relationship between the time spent on clinical rotations and certification pass rates in hospital-based MLS programs.

University-based MLS programs have lower clinical hours required than the hospital-based programs, and also saw some of the lowest pass rates of the three program types. Regression analysis showed there was no difference between university-based MLS programs and the amount of time their students spend on clinical rotations. Four outliers identified in prior analysis were removed and the regression was run again, with no change in the adjusted R^2. Analysis with stratification on data with outliers and without outliers made no difference in the results.

Medical Laboratory Technician programs require the least amount of clinical rotation hours of the three program types, however, this program type is only an associate level of education compared to the baccalaureate level required by MLS programs. The initial regression performed included the two outliers identified in this data set, and showed no difference between groups in the certification pass rates of MLT programs and the time they spend on clinical rotations. Removal of the outliers showed a slight improvement in the data, with an adjusted R^2 of .011, or a 1.1% variance. Stratification of the data with outliers included improved to an adjusted R^2 of .010, and stratification of outliers removed improved to .016, for a 1% and 1.6% variance of the time on clinical rotation compared to certification pass rates. The overall result at the MLT level with outliers removed resulted in an ANOVA of $F(1,47)=1.538$, $p=.221$. With the p-value greater than .05, we fail to reject the null hypothesis, and cannot identify a relationship between student time on clinical rotation and certification pass rates at the MLT level.

After assessing all program types, then breaking them down into their individual categories, it appeared the relationship between certification pass rates to time students spend on clinical rotation was bolstered by the hospital-based MLS programs. The MLT programs showed minor variance that was not statistically significant, and university-based programs had zero variance, indicating the 9.4% of variation from time spent on clinical rotations may be attributed to the influence the hospital-based programs had on the data set.

Total Graduates vs Certification Rates

In evaluation of the data, it also became clear that there was a difference in the values from hospital-based MLS programs and university-based MLS programs in more ways than just clinical rotation hours. Hospital-based MLS programs graduate and enroll less than half of the average amount of students that graduate from university-based programs, making it another variable to evaluate against the certification pass rates.

Across all programs the adjusted R^2 of number of graduates compared to certification pass rates was .053, accounting for 5.3% of the variation seen in certification rates. Inclusion of outliers gave a slightly higher value of .059, and stratification resulted in an adjusted R^2 of .059 with outliers removed and .081 with outliers included. The ANOVA results of the non-stratified data with outliers removed was $F(1,60)=4.44$, $p=.039$. Collectively, this is a statistically significant result and shows the number of students in the program is related to the certification pass rates. Separating by program type, the MLT level showed violations of mandatory assumptions for use in a regression analysis through heteroscedasticity and non-normal distribution (Laerd Statistics, 2015).

The differences at the MLS level programs were of interest and the homoscedasticity and normal distribution were demonstrated through P-P charts, histograms, and scatterplots. University-based programs showed no relationship with the number of students who graduate from their programs and the certification pass rates. It appeared there was a small difference in hospital-based programs between their graduate numbers and their certification rates, with an adjusted R^2 of .066. The difference in groups increased slightly when looking at the stratified data, moving to an adjusted R^2 of .070. However, ANOVA analysis showed $F(1,28)=3.054$,

$p=.091$, indicating a failure to reject the null hypothesis. Presumptively, there may be a weak relationship present that does not arise to statistical significance because of the low sample size and power when breaking the groups into smaller portions.

Discussion

Clinical rotations are a contentious topic in medical laboratory science education with varied perceptions and motives for the role they play in the education of new laboratorians (Beazer, Perceptions, 2024). Many of these perceptions are opinions because there is no research that has evaluated clinical rotations across all programs and show the correlation to the outcomes of these programs. This research reached 34% of medical laboratory education programs to compare their certification outcomes with the time students spend on didactic education, clinical rotation, and the number of graduates.

It was hypothesized there would not be a statistically significant relationship between the time spent on clinical rotation and the certification pass rates of programs. The hypothesis was rejected as there was a statistically significant result between the clinical rotations and pass rates. This research showed that 9.4% of certification pass rates are tied to the time that medical laboratory science students spend on clinical rotation. The overall variance was likely bolstered by the 13.2% that clinical rotations contribute to hospital-based MLS pass rates. Conversely, the university-based MLS programs showed relationship between the time spent on rotation and the certification pass rates. The MLT programs were also low, showing around 1% variance, but did not rise to statistical significance.

The number of graduates was the only other variable that had an impact on the certification pass rates, and this was only statistically significant when evaluated across all programs. The number of graduates showed no relationship to the certification pass rates in university-based MLS programs, and while it appeared that the number of graduates influenced the hospital-based certification pass rates, the value did not have statistical significance. The variable with the least impact on certification rates was the amount of time that programs spend on didactic education, there was no difference between groups in the time students spend on didactic education and the certification pass rates of the individual programs.

Other Factors for Consideration

The results of this study show that certification pass rates are dependent on many more variables than the three major ones that were the focus of this research. The quality of the instructors, quality of the lessons, engagement from faculty, ratios of students to teachers, time since completing courses, admissions standards, grade point average of incoming students, amount of simulation, structure of the program, and the teaching environment are all factors that will influence the outcomes of the program (Thomas, 2021). It also needs to be acknowledged that laboratory education programs are training students for more than passing the certification exam. It is expected that students will graduate from a program with an understanding of how the laboratory functions and able to perform many of the clinical tasks that are difficult to teach outside of the clinical laboratory. There is not a single right way to teach the students the skills they need to learn, and some programs are heavy in simulation and didactic coursework while others are built almost exclusively on clinical rotations. NAACLS does not make regulations about how programs are put together if they are operating at a high standard and meet certain quality benchmarks (NAACLS, 2021).

This research showed that hospital-based programs have a higher average performance on the certification exams than the university-based MLS programs. What this research does not look at is the incoming GPA of the admitted students and the degrees they enter the program with. Prior research has attributed 22% of certification pass rates to the incoming GPA of admitted students (Conway-Klaassen, 2016). Most hospital-based programs operate with a 4+1 format where students must have a baccalaureate degree before beginning their program. Having already attained a degree in higher education means the students can focus exclusively on the laboratory education aspects, condensing the education into one to two years instead of spreading it out over a four-year period. Studies have shown that taking the certification exams in closer proximity to the laboratory education gives the students a higher chance of passing (Conway-Klaassen, 2016). Around 25% of hospital-based programs exclusively offer a 4+1 program, compared to 14% of university-based programs. Thirty-five percent of hospital-based programs give the option of 4+1 or 3+1, while only 4% of university-based programs offer both, bringing the total number of 4+1 to 60% for hospital-based programs and 18% for university-based programs.

Many of the hospital-based MLS programs advertise the max number of students they can accept and advertise their program as “competitive” admissions. This shows in the average number of students graduating from hospital-based programs in comparison to university-based programs, where hospital-based programs average 10.8 students compared to the 25.8 in university-based programs (Beazer, Landscape, 2024). Those that see strong application numbers can also be more selective in the students they accept, choosing to take students with a higher GPA or a baccalaureate degree. Programs that are less competitive cannot be as selective and may end up with students who meet their qualifications without exceeding them. Students with a higher incoming GPA have a greater chance of passing their certification exams (Thomas, 2021).

Implications for the Medical Laboratory Profession

The issues with finding clinical rotation spots for students will likely become more difficult in the coming years with hospital and laboratory consolidation that has taken place over the last 10 years (Schwartz et al., 2020). According to clinical affiliates responsible for hosting students on clinical rotations, 38% of clinical laboratories that participated in the survey had seen their microbiology departments moved to a centralized location for multiple hospitals, and 8% had this happen to their blood bank department (Beazer, Perceptions, 2024). Forty-three percent of participants reported increases in testing, while 46% reported decreases in staffing, accounting for two of the most reported changes their laboratories had experienced over the last ten years. Additionally, 36% of participants in this survey said their facility had increased the number of students they were able to host on clinical rotations over the last ten years (Beazer, Perceptions, 2024). When viewed collectively, this data paints a picture of increasing efficiency and less time to work with students on clinical rotation, adding context to the difficulty many program directors have in finding clinical rotation spots for their students (Beazer, Landscape, 2024).

With the increasing difficulty of finding clinical rotation spots for most program directors, and the direct impact this is having on graduating more MLS or MLT students, the clinical rotation should be more scrutinized. Clinical rotations have existed as long as the profession has been around but there have been substantial changes to the rotations and to laboratories over the last few decades. Technology has improved to the point that students could step into a virtual reality laboratory from the confines of their own home and get a similar experience to what is done clinically (Scott, 2015). Many laboratory education programs will also simulate a working laboratory to give their students a similar experience to the clinical rotation while not taking up clinical rotation spots in real laboratories. These programs have designed learning activities that guide the student through the didactic material, then introduce them to the testing in carefully designed clinical exercises (A. Wilson, 2019; Honeycutt, 2019). Tele-teach is another way that students can "enter" the laboratory through Zoom, Microsoft Teams, or other software that allows multiple students to video chat and interact virtually with each other and the clinical instructor as they connect the didactic education material to the laboratory testing. Utilizing tele-teach, students can move through the laboratory with an instructor while they interact with samples for their shift, or that have been set up for the educational needs of the students. Clinical rotations are a finite resource for most laboratory education programs, and there are more opportunities than ever before to achieve educational goals more efficiently.

The data has shown a relationship between certification scores to time spent on clinical rotations, but it is a small percentage attributed to the rotation and could have an equal impact in pursuing other variables in clinical education. Reducing clinical time requirements or moving to a competency-based clinical rotation would be efficient for the clinical site, the educational program, and for the students (Tucker et al., 2018). While clinical rotations in university-based programs may not reach the same level of statistical significance to certification pass rates as they do with hospital-based programs, they are still important to clinical laboratory education, and they need to be treated as the limited commodity they are in order to graduate more students, and alleviate staffing shortages.

Conclusion

The shortage that has persisted for decades across the medical laboratory profession has caused burnout among staff, forcing laboratory administrators to hire individuals who are lacking in basic medical laboratory education. More than half of MLS and MLT programs have indicated that clinical rotations are a limiting factor in accepting more students into their programs. This research showed a relationship between hospital-based MLS programs with certification pass rates when compared to the time students spend on clinical rotation, but there was no difference between means when looking at MLT and university-based MLS programs. Program directors need to ask themselves and their advisory boards what they see as the purpose of the clinical rotation in their program, and find efficiencies to balance student education while minimizing the burden of clinical rotations on the profession. Clinical rotations are a finite resource in educating new laboratorians and inefficient use of rotation time is a burden on the entire profession.

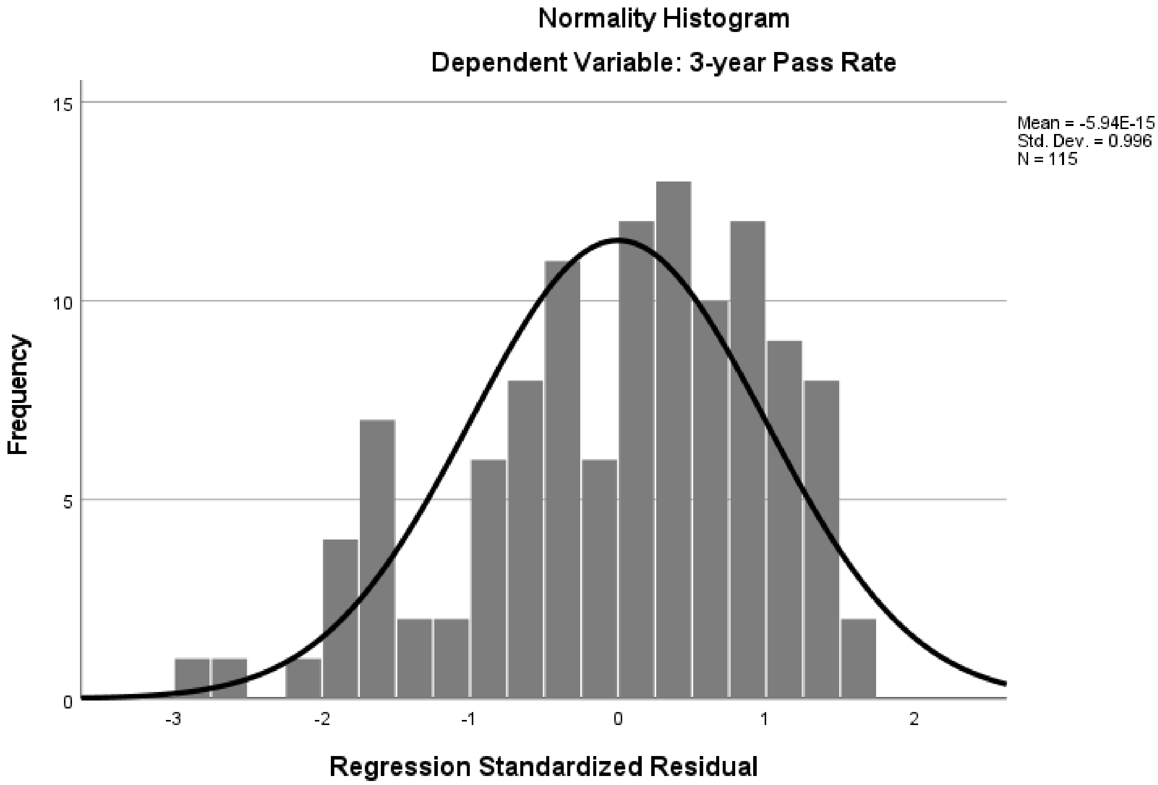
Table 12

Stratification of BOC Pass Rates with the Corresponding Dummy Variable

Certification Pass Rate Range	Dummy Variable
100%	8
95-99.99%	7
90-94.99	6
85-89.99%	5
80-84.99%	4
75-79.99%	3
65-74.99%	2
<65	1

Figure 18

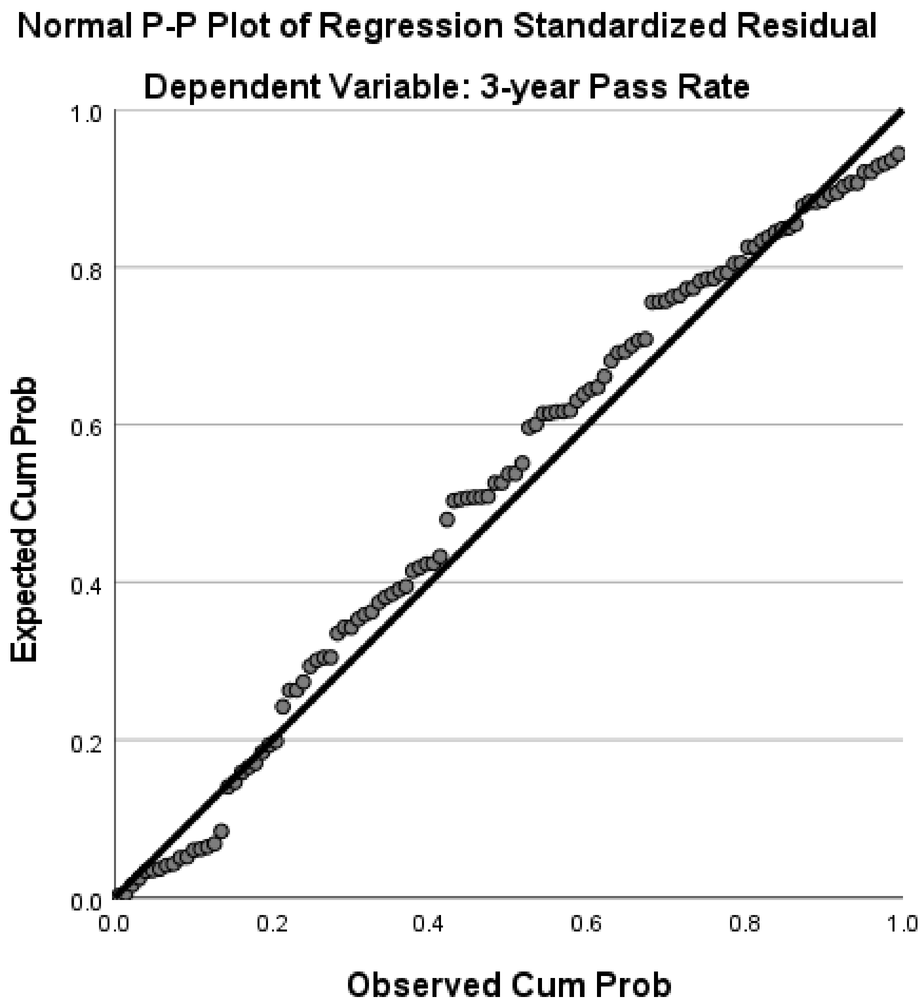
Histogram of Certification Pass Rates vs Clinical Rotation



Note. Histogram showing normal distribution of the data for certification pass rates compared to time on clinical rotation for all programs.

Figure 19

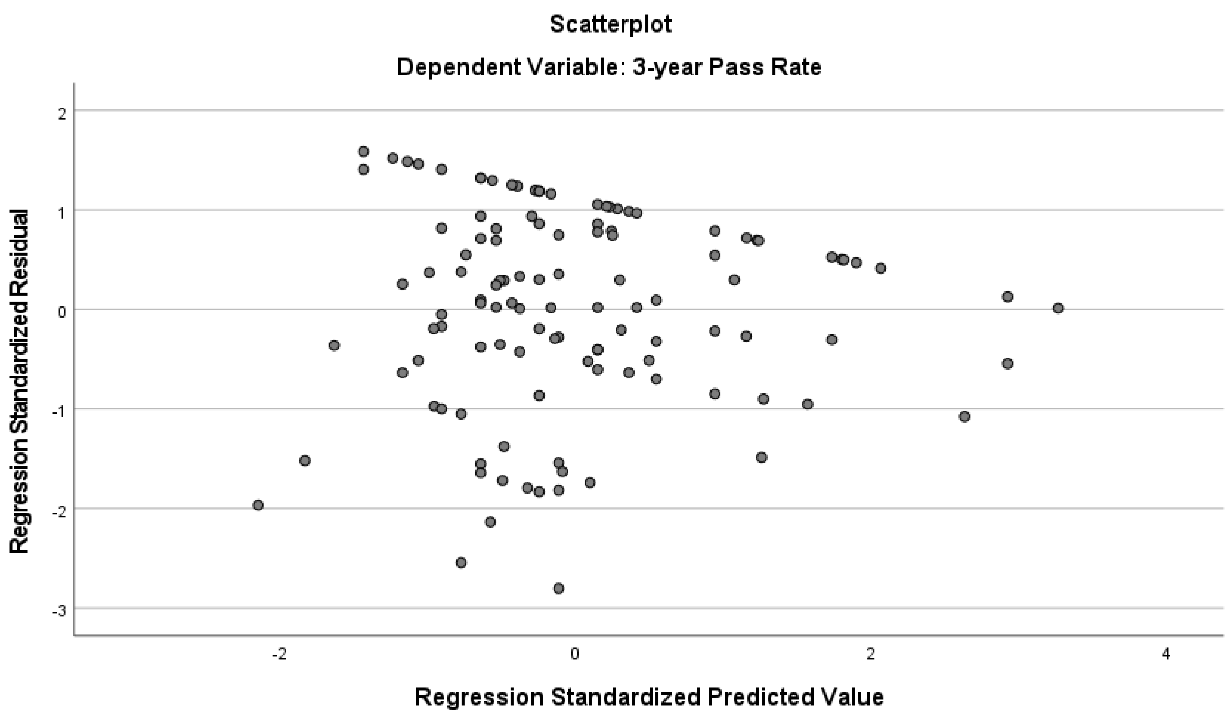
P-P Chart of Pass Rates vs Clinical Rotation



Note. P-P chart of the data for certification pass rates compared to time on clinical rotation for all programs.

Figure 20

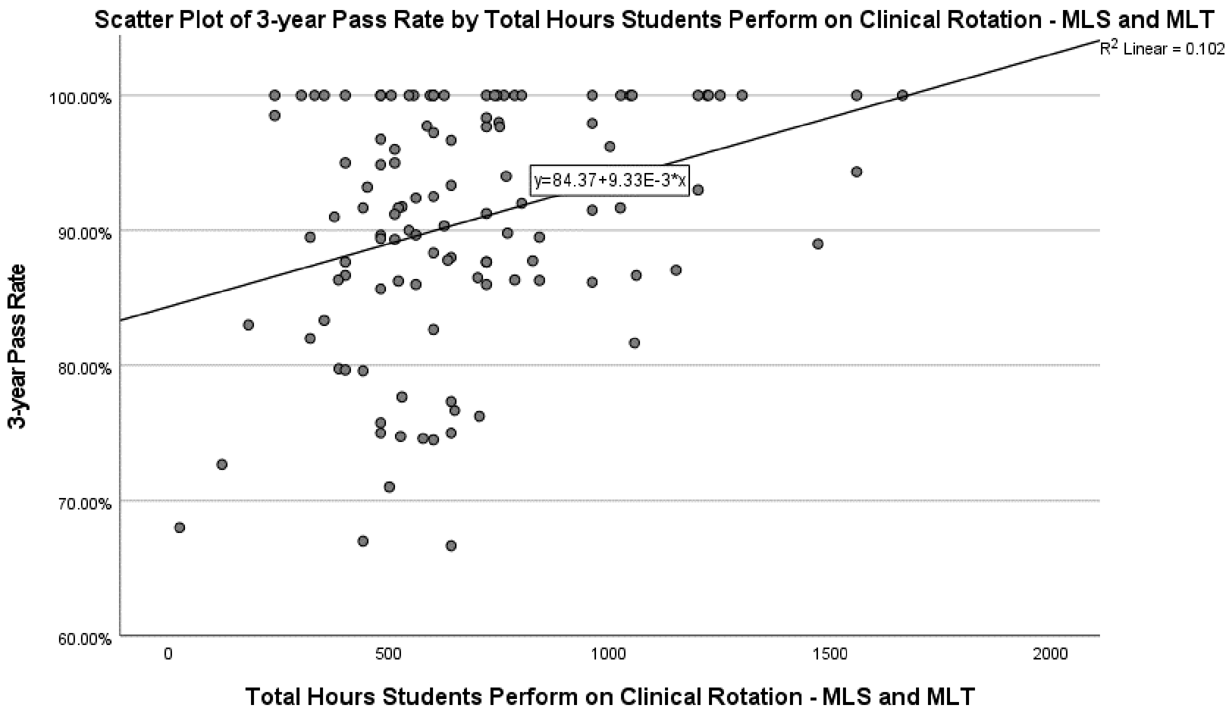
Scatterplot for Pass Rates vs Clinical Rotation



Note. Scatterplot data for certification pass rates compared to time on clinical rotation for all programs.

Figure 21

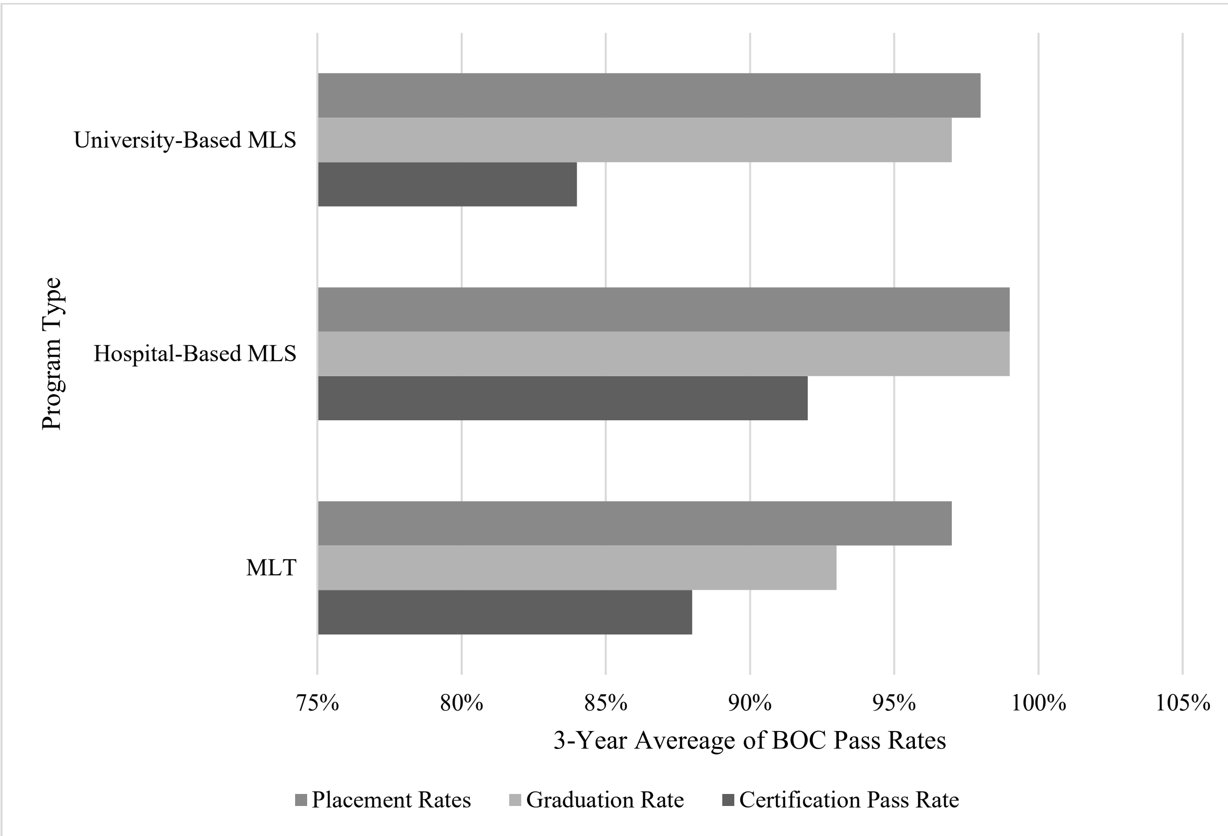
Scatterplot for Pass Rates vs Time on Rotation



Note. Scatterplot data for certification pass rates compared to time on clinical rotation for all programs with fit line.

Figure 22

NAACLS Outcomes for All MLS and MLT Programs



Note. NAACLS outcomes for all 479 MLS and MLT programs across the country.

Table 13

Regression and ANOVA Statistical Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	ANOVA Statistics				
					DF1	DF2	Mean Square	F	Sig.
1	.033a	0.001	-0.008	8.96%	1	111	9.888	0.123	0.726b
2	.258a	0.067	0.059	11.80%	1	119	1181.111	8.482	.004b
3	.319a	0.102	0.094	8.44%	1	113	909.623	12.773	<.001b
4	.298a	0.089	0.081	2.01394	1	119	47.127	11.619	<.001b
5	.397a	0.158	0.132	8.10%	1	32	393.506	6.004	.020b
6	.366a	0.134	0.107	1.6489	1	32	13.496	4.964	.033b
7	.178a	0.032	0.011	10.09%	1	47	156.627	1.538	.221b
8	.262a	0.069	0.053	7.42%	1	60	244.688	4.440	.039b
9	.273a	0.075	0.059	1.60811	1	60	12.533	4.847	.032b
10	.314a	0.098	0.066	8.57%	1	28	224.175	3.054	.091b

Note. Model 1: All Programs a. 3-year Pass Rate b. Time spent on Didactic Education Model 2: All Programs w/outliers a. 3-year Pass Rate b. Clinical rotation hours Model 3: All Programs w/o Outliers a. 3-year Pass Rate b. Clinical rotation hours Model 4: All Programs a. Stratified Pass Rate b. Clinical rotation hours Model 5: Hospital-Based Programs a. 3-year Pass Rate b. Clinical rotation hours Model 6: Hospital-Based Stratified a. Stratified Pass Rate b. Clinical rotation hours Model 7: MLT Program Pass Rates a. 3-year Pass Rate b. Clinical rotation hours Model 8: All Program Pass Rates vs Number of Graduates a. 3-year Pass Rate b. Number of yearly graduates? Model 9: All Programs Stratified Pass Rates vs Number of Graduates w/o outliers a. Stratified Pass Rate b. Number of yearly graduates? Model 10: Hospital-Based MLS Pass Rates vs Number of Graduates a. 3-year Pass Rate b. Number of yearly graduates

Chapter 5: Conclusion

Background

Medical laboratory science was born from multiple scientific advancements in the 19th century that had a profound impact on medicine (Farhud, 2018; Blevins & Bronze, 2010). These discoveries advanced the detection and treatment of numerous diseases over the years with many more continually discovered (Duffy, 2011). Medical laboratory science is the bridge to take these profound scientific discoveries across into medical practice, integrating them into the hospital systems where they can change the lives of those who desperately need them. This is a profession of highly-trained individuals who have been described as the backbone of modern medicine (Preza, 2023).

The struggles to fully staff medical laboratories with qualified medical laboratory scientists is well-documented, and frequently discussed from multiple angles throughout this dissertation research. The shortage of trained medical laboratorians has persisted for decades despite efforts to address some of the major concerns within the profession. One of the more impactful changes happened over a decade ago with the alignment of professional titles, a change that is still not fully implemented across the profession (ASCLS and ASCP BOC, 2020). Marketing and general recruitment have been tried across various professional societies and individual programs, although the impact those efforts have made in advancing the profession as a whole are still unclear. What we do know is that these efforts have fallen short of providing adequate solutions for understaffing. The shortage of medical laboratory scientists has hurt the profession, causing burnout among staff and pushing laboratory personnel to look elsewhere for employment, furthering staffing issues within the profession (Nowrouzi-Kia et al., 2022).

To reduce burnout among their staff, laboratory administrators will look to fill positions in any way possible. The easiest route to fully staffing the laboratory is to hire those who have a baccalaureate degree and the minimum amount of science credits required under the Clinical Laboratory Improvement Amendments (CLIA) (Centers for Medicare and Medicaid Services, 2017). Some accreditors require laboratory-specific credentials but for those that do not, hiring non-laboratory trained staff is an easy solution to fix staffing shortages (College of American Pathologists, 2016). In 2022, the Centers for Medicare and Medicaid Services (CMS) proposed a rule change that allows individuals with a nursing degree to perform and supervise moderate and high-complexity testing, forgoing the minimum amount of science credits as long as they have a nursing degree (Centers for Medicare and Medicaid Services, 2023). The American Hospital Association (AHA) came out against this proposed change with the backing of 5,000 hospitals and the physicians and nurses within their professional organization, supporting the expertise of trained medical laboratory professionals (American Hospital Association, 2022). There is a persistent threat to devalue the role of medical laboratory science education on the healthcare team, pushed on the premise that intervention is needed because staffing shortages are a danger to healthcare (Morris, 2023). The practice of hiring non-laboratory trained staff negates the skills that are unique to this profession and lowers the bar for testing and patient safety. There are many non-laboratory trained individuals who may excel in the laboratory, however, the route to entry in this profession should be standardized without exception, and teach the basic skills needed to safely work in a diagnostic laboratory.

The staffing shortage of medical laboratory professionals is a problem that must be addressed by measures more impactful than rule changes that diminish the education and skills needed to work in this profession. Education is often a focal point in fixing the shortage of medical laboratory scientists because we cannot alleviate shortages in the field without finding ways to properly train new laboratorians. Multiple avenues have been pursued in clinical education to graduate more students, and one area that does not get enough attention is the clinical laboratory rotation, which acts as a barrier to graduating more students.

Chapter Summaries

Decisions in MLS education are made with generalized data because there has been very little information available that establishes what the landscape of MLS education looks like. This dissertation research aimed to explore the current landscape of medical laboratory education with a specific focus on the role of clinical rotations in shaping student outcomes among NAACLS-accredited programs. Integrating the findings from the surveys of program directors and clinical educators, as well as analyzing the relationship among educational variables and certification rates, this research provides valuable insight into current medical laboratory education and offers recommendations for the future of clinical rotations in this profession. Key findings of each chapter are discussed before moving into more specific recommendations, and the limitations of this research.

Chapter two provided a comprehensive overview of the current state of medical laboratory education in the United States. Utilizing a survey of 469 NAACLS-accredited MLS and MLT program directors, 34% completed the questionnaire. The data showed a clear delineation between hospital-based MLS programs, university-based MLS programs, and MLT programs. These differences were highlighted throughout the paper while still showing a collective representation of data from all programs. The results highlighted the variability in time allotted for clinical rotations and didactic education, the program structures, and the number of graduates produced by each type of program. The total amount of hours on didactic education was higher for the university-based programs than it was for hospital-based programs. Conversely, hospital-based programs spent more time on clinical rotation than university-based programs. The total amount of time spent on both combined was similar, highlighting the variability in how programs educate even though they spend a similar amount of time overall. This survey also revealed a downward trend in clinical rotation hours over the past decade with specific laboratory disciplines showing steeper reductions than others.

Chapter three investigated the perceptions of clinical educators regarding the role of clinical rotations in medical laboratory education. A survey sent to clinical educators through Facebook, email, and a professional LISTSERV provided valuable insights to the benefits and challenges of hosting students on clinical rotations. While most participants maintained a positive perspective about working with students, the increased testing demands, decreased staffing levels, and centralization of core testing departments were recognized as barriers to providing optimal clinical experiences. This study also highlighted the differences in perceptions based upon the geographic location, size of the facility, and the primary role of the clinical educator. The phrase “necessary burden” was commonly used to describe clinical rotations. Many respondents felt clinical rotations were necessary for recruiting, and as an obligation to the profession, but recognized the toll it took on their facility and staff to host students. These findings emphasized the importance of considering the unique needs and constraints of the individual facilities when designing and implementing clinical rotations, as well as an understanding that clinical rotations operate differently in every laboratory.

Chapter four investigated the relationship between certification pass rates and the time spent in clinical rotation, didactic education, and the number of graduating students each year. Through a regression analysis of NAACLS-accredited programs from chapter 2, the study found a statistically significant relationship between the certification pass rates and clinical rotation hours in hospital-based MLS programs. However, this relationship was not observed in university-based MLS or MLT programs. Additionally, there was no significant relationship found between time spent in didactic education and certification pass rates across all programs. The results from this chapter showed the hospital-based program scores are influenced by the time they spend on clinical rotation, though it is still a minimal amount attributed to the rotations alone. Other factors have a greater impact on certification pass rates than clinical rotation hours, and these should be more heavily pursued to reduce the "necessary burden" imposed on clinical laboratories.

Integrated Framework

The conceptual framework of this dissertation research, grounded in constructivism, game theory, and general system theory, provides a lens through which to interpret these findings and their implications in medical laboratory education. Game theory highlights the increasingly competitive environment in which laboratory education programs operate, with program directors making decisions that balance the needs of the students, clinical sites, and the viability of their own programs. The increased competition for students combined with the difficulty of securing clinical rotations for students may influence the decisions made about program structure, program availability, and clinical rotation requirements.

Constructivism emphasizes the role of prior knowledge and personal experience in shaping educational outcomes and perceptions of the importance of clinical rotations in medical laboratory education. The diversity among programs exemplified throughout this research shows how students and educators are developed differently across the country, creating experiences that are impactful for them later on when they may be responsible for making decisions that shape the landscape of MLS or MLT education. Chapter two briefly discusses the number of program directors who graduated from the same type of program (hospital-based or university-based) they are now teaching in. Continuing in the same format creates a siloed environment where individuals have difficulty seeing the differences that exist in the profession, preventing them from appreciating the benefits and drawbacks of other types of programs. These constructivist-derived perceptions serve as a reason for over-valuing clinical rotations while simultaneously under-valuing them by others.

General system theory highlights the interconnectedness of numerous stakeholders in medical laboratory education, including professional societies, hospital systems, accrediting bodies, and the individual students. Changes in one part of the system can have a ripple effect through medical laboratory education. Consolidation of microbiology and blood bank departments to centralized locations in larger hospital systems are a prime example, increasing the difficulty for program directors to find clinical rotation spots capable of providing a rounded experience for students. In a similar vein, general system theory shows how a lack of action on a topic can have an impact on others in medical laboratory education. If part of the system is continually short of the requirements needed to optimally function, it will eventually have an impact on the others. The laboratory is an integrated system and the inability to graduate more students is a burden on the rest of the profession, and healthcare as a whole.

Recommendations

In light of these findings and theoretical considerations, several recommendations can be made to address the challenges faced in medical laboratory education, and to ensure the development of a skilled workforce that keeps up with current staffing demands.

Online Learning

Higher education institutions are continually changing, and major shifts are still expected in the coming years (Alexander, 2020). One of the biggest changes in the last 15-20 years has been the internet and the array of opportunities it opens for medical laboratory education. COVID-19 forced many MLS and MLT programs to switch to an online format, which some have continued using, while others reverted back to their original format. Program directors were asked if they had fully online curriculum for their students, with exception of the clinical rotation, and 88% indicated they do not. For a generation that has grown up with access to unlimited educational materials within a few clicks, it raises the expectations for these resources which can benefit students, instructors, and the clinical sites. Creating online materials for laboratory procedures that students are required to review before entering the laboratory would decrease the student time required in the laboratory to observe the testing and can instead be reserved for more hands-on activities.

Simulation

Incorporating simulation into the educational environment can adapt technology or keep it traditional, setting up mock laboratories for students to perform testing and make mistakes in a controlled environment. Simulation activities used by programs can differ in the breadth and depth of the exercises, with some programs going to extensive lengths to give students a "clinical experience" within their facility. Virtual reality programs are continually advancing and have the ability to immerse students in specific laboratory scenarios to give specific educational experiences that students may not even have the opportunity to see in a physical clinical rotation because they are uncommon occurrences. This technology has already been used in medical schools where students are trained in open-heart surgery to prepare them for real-life situations (Mahtab & Egorova, 2022). If this technology is successful in preparing medical students for performing surgery, then it could also be adapted in laboratory education to reduce the time required for students on physical clinical rotations.

Adaptivity

Not all students that are interested in medical laboratory science are able to drop everything they are doing and enroll full-time in programs. Becoming more accessible to varied demographics will help recruit more to the profession. Integration of a 4+1 format is a perfect example of this because these are students who went to school and completed degrees which they may struggle to find employment with. These are students who have the educational credentials to get through a chemistry or biology degree that would make excellent MLS professionals once they have completed the laboratory coursework within a program. Many hospital-based programs offer this path, though it is not used as readily by university-based programs.

Competency-Based Clinicals

Simplifying the clinical rotation should be a goal of every MLS and MLT program, providing clear instructions for what a student should be doing with their time in the laboratory. Developing a competency-based assessment with the specific tasks students should know before finishing their rotation would provide an efficient list for clinical instructors. The competency-based clinical rotation would help laboratories know how much work is expected from each program without going through extraneous information that may not be required by one program versus another.

Variability of the Clinical Rotation

Over half of all program directors have indicated that clinical rotations are a limiting factor in accepting more students into their programs, so it is presumed these programs could potentially add more students if they were not concerned about providing an "opportunity for a clinical experience" to each of those enrolled. Much time and energy has been focused on recruiting more to the profession and increasing visibility when fixing that problem will only exacerbate the shortage of clinical rotation slots. Clinical rotations are not the same across the profession and can even differ within a hospital system. There are numerous different variables that change the experience from one facility to the next, like: testing platforms, patient populations, sizes of facilities, volumes of testing, and attention given to the rotating students. If there is so much variability across laboratories, then what is the purpose of the clinical rotation? This is not a question that can be answered by this research, but it is a question that should be discussed within laboratory education programs and among their advisory boards. There is little doubt that increasing the amount of time on rotation will improve the skills of the student much the same that an employee has opportunities to learn at their job every day, however, the rotation time comes at a cost. Increasing time without specific objectives becomes a burden that is shouldered by understaffed clinical laboratories, as well as the students.

No relationship was revealed between certification scores and the amount of time university-based MLS and MLT programs performed on clinicals. The clinical rotation has a different purpose for programs across the country, yet they are often assumed to be the same. A program that utilizes heavy simulation in their own laboratories may only want to use the clinical rotation to give their students exposure to the workflow and processes of the laboratory. A hospital-based program with very little didactic education offered to the students outside of the laboratory may be poised to use the bench time to teach specific topics that the students need to be successful. Neither one of these approaches is right or wrong, it is just a different means to an end. Clinical rotations may not need to be adjusted across all programs, but it's important to recognize that they might not be essential for every program. Assuming they are necessary for all programs simply because they are crucial for some negates the unique differences of programs and can hinder discussions that could resolve enrollment issues in MLS education.

The shortage of qualified medical laboratory scientists has caused decision makers at the top echelons of government to step in and start making changes to the profession. Nurses do not perform any time on clinical rotations and yet CMS has put forth a rule change to allow those with a nursing degree to perform moderate and complex laboratory testing without having the minimum amount of science credits that were previously required under CLIA, let alone any medical laboratory training. Major changes are being proposed federally while medical laboratory educators argue over the value of clinical rotations.

It is time to get serious about the shortage of qualified medical laboratory scientists, and truly address this problem. Arguably, some programs may operate efficiently without a traditional clinical rotation, incorporating simulation and technology to achieve the same end goal as others. Programs that can demonstrate adequate systems to educate medical laboratory professionals should not be required to have their students perform extraneous clinical rotations, this would free more clinical rotation spots for the programs that truly need it as a part of their core curriculum while reducing the burden on our clinical laboratory partners. The foundational MLS knowledge is what should be prioritized for clinical laboratory students, whether that is learned through clinical rotation, or without it.

Limitations

There are many questions that were asked to better understand the perceptions and demographics of those working in medical laboratory education. However, there were questions that would have added further clarification to the education provided to students and were not part of the surveys. It would have been helpful to ask program directors the amount of time their students spend in simulated laboratories that are meant to mock experiences seen on clinical rotation. Laboratory education programs use simulation to varying degrees, and this information would have been valuable in evaluating against the time students spend on clinical rotation to determine if the time spent in a simulated laboratory is comparable, and whether it has a measurable effect on certification pass rates. Additionally, questions about the minimum time required for students in didactic and clinical education should have been mandatory, with an option to select that minimums do not exist for an individual discipline. Some program directors would answer for minimums in some areas while leaving other disciplines blank, which was interpreted as the program not having minimums in an area, and should be more definitive in question development for future surveys.

Another missed opportunity was to question clinical educators if their laboratory currently hires non-credentialed testing personnel to perform routine testing. There is much discussion in this dissertation research about the issues with hiring laboratory personnel without the proper training, and it would have been useful to request more information in this area. The complexity of testing performed by non-laboratory trained personnel, and the percentage of staff that lack laboratory credentials would have been a great addition to discuss in this paper even though it was outside the immediate scope of this research.

Utilizing a volunteer sampling and questionnaires in this dissertation research was necessary due to the questions asked and the geographic separation between participants. However, these methods increase the possibility of introducing bias. Self-reporting bias was a possibility with the participants completing the questionnaires, and efforts were made through the development of questions and validation of the surveys to mitigate the potential impact on this dissertation research. Future Directions

Future Directions of MLS Education

The results of this dissertation research reveal the landscape of clinical laboratory education and provide key insights into the value of clinical rotations in medical laboratory science. This research is crucial for understanding why programs vary in their clinical rotation time and the intended purpose of these rotations. While this research offers valuable insights into the field, future studies need to paint a clearer picture of current hiring practices in medical laboratories and the extent to which facilities hire non-laboratory trained staff. It is essential to understand how often facilities bypass traditional education to meet staffing needs. Addressing a problem is challenging without fully understanding its pervasiveness.

Understanding the extent of hiring issues is crucial for creating urgency within the profession, though it may not alleviate the bottleneck of clinical rotations in medical laboratory education. The profession can either add more rotation spots in clinical laboratories or reduce the amount of time each student needs to spend on clinical rotation. Most respondents indicated that adding more clinical rotations is not feasible for their laboratory, suggesting that programs need to find ways to reduce the burden on clinical laboratories if the profession hopes to increase the number of graduates.

Efficiency in clinical rotations should be a focus for all program directors, finding innovative ways to teach the curriculum while reducing the time needed in the laboratory. Future research should evaluate programs with high certification pass rates and high graduation rates, emphasizing the unique aspects of programs that efficiently use clinical rotation time. This research highlighted the differences in perceptions of programs with varied lengths of clinical rotations and showed how siloed these perceptions can be due to many program directors working in the same type of program they were educated within. These barriers need to be broken down to develop an understanding that programs can provide high-quality education even if delivered in a different format than traditionally seen in this profession. Harmonization of more direct clinical rotation standards across the profession would strengthen education while recognizing the important differences between programs and should be a focus for future accreditation guidelines.

The future of the medical laboratory profession depends on increasing the number of graduates to keep up with staffing shortages, and this problem can only be addressed if there is agreement within the profession about the severity of the problem and how to tackle it. Many seem resistant to change, but the status quo is insufficient to restore adequate staffing levels. Future research should continue to highlight the bottleneck caused by clinical rotations, seek harmonization of rotation standards, and find creative ways to deliver high-quality education while reducing the burden on already short-staffed laboratories.

Summary

This dissertation research provides valuable insight into the current landscape of medical laboratory education, perceptions from clinical educators, and the relationship between program outcomes and time spent on clinical or didactic curricula. The findings show the complexity of the issues faced by the profession and the need to adopt a multi-faceted approach that addresses the evolving clinical environment, and inconsistent educational standards. Through leveraging the strengths of both hospital-based and university-based programs, adopting innovative educational strategies, and fostering a collaborative environment among educational stakeholders, medical laboratory science can continue to play a vital role in the future of healthcare diagnostics. As the medical laboratory profession navigates the challenges ahead, it is crucial to remain committed to the core values of competence, quality, and patient-centered care that have defined medical laboratory science throughout its history.

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Appendix A: Program Director Clinical Education Survey

Q1
Your Consent Before agreeing to be part of the research, please be sure that you understand what the study is about. You can keep a copy of this informed consent for your records. If you have any questions about the study later, you can contact the study team using the information provided above. If you have read through this informed consent and wish to participate, then please select that option below and the survey will begin. Thank you!

- ○ I have read the informed consent and agree to participate in the study (3)
- ○ I do not wish to participate in the study (4)

Skip To: End of Survey If CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY The University of South Dakota TITLE: Evaluatin... = I do not wish to participate in the study

End of Block: Introduction

Start of Block: Personal Demographics

Q2 What is the highest level of education you have attained?

- ○ Associate's degree (1)
- ○ Bachelors degree (2)
- ○ Masters degree (3)
- ○ Doctorate (4)

Q3 What type of NAACLS-accredited program did you earn your laboratory credentials through?

- ○ Hospital or Medical Center Based (1)
- ○ Two-year College/University (2)
- ○ Four-year College/University (3)
- ○ Non Degree Granting Proprietary School (4)
- ○ Independent Laboratory (5)
- ○ Blood Center (6)
- ○ Military Facility (7)
- ○ Other (8) ____

Q4 What is your age?

	18 26 34 43 51 59 67 75 84 92 100
Age in years ()	

Q5 What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary (3)

End of Block: Personal Demographics

Start of Block: Program Demographics

Q6 Which best characterizes your laboratory education program?

○ Hospital or Medical Center Based (1)

○ Two-year College/University (2)

○ Four-year College/University (3)

○ Non Degree Granting Proprietary School (4)

○ Independent Laboratory (5)

○ Blood Center (6)

○ Military Facility (7)

○ Other (8) ____

Q7 What degrees or certificates does your program offer?

▢ Doctorate in Clinical Laboratory Science (DCLS) (1)

▢ Masters degree in MLS (2)

▢ Bachelor degree (MLS) (3)

▢ Associate degree (MLT) (4)

▢ Categorical training (what disciplines) (5) ____

▢ Other (6) ____

Display This Question:

If What degrees or certificates does your program offer? = Bachelor degree (MLS)

Q7A Which best describes the structure of your MLS program?

○ 2+2 (Students must first complete the MLT before moving on to the MLS) (1)

○ 3+1 (General education with 1-2 years of MLS instruction) (2)

○ 4+1 (Bachelor degree in science related field with accelerated material for MLS in 1-2 years of instruction) (3)

○ Other (4) ____

Q8 Does your program offer a fully online option for the didactic laboratory education? (with exception of the clinical rotation/internship) (ex: all classes can be taken online, the only thing the student must do in person is the clinical rotation/internship)

- ○ Yes (1)
- ○ No (2)
- ○ Not Applicable (3) ____

Q9 How many students graduate from your program each year?

Not Applicable

0 15 30 45 60 75 90 105 120 135 150

Doctorate in Clinical Laboratory Science (DCLS) ()	
Masters degree in MLS ()	
Bachelor degree (MLS) ()	
Associate degree (MLT) ()	
Categorical training ()	

End of Block: Program Demographics

Start of Block: Didactic Education and Clinical Rotation Structure

Q10 For the remaining questions please only answer for one of the following programs. If you have more than one program that you serve as program director for, then choose the program that produces the most graduates each year. Which program will you answer the remaining questions for?

- ○ Medical Laboratory Science (MLS) Program (1)
- ○ Medical Laboratory Technician (MLT) Program (2)

Q11 How many face-to-face teaching hours of didactic education do your students get in your program for each of the following disciplines? (This can be through online videos or in person presentations)

Example: If you have 3 clinical microbiology courses required within your program and each class meets for 3 hours each week in a 15-week semester, you would have 135 hours of clinical microbiology instruction.

	Not Applicable 0 30 60 90 120 150 180 210 240 270 300
Hematology ()	
Immunohematology (Blood Bank) ()	
Microbiology ()	
Chemistry ()	
Urinalysis ()	
Molecular Diagnostics ()	
Administrative/Laboratory Operations ()	
Point of Care Testing ()	
STAT Lab Testing ()	
Immunology ()	
Hemostasis ()	

Q12 How many hours do you require the students perform on clinical rotation for their degree or certificate? (total hours) Leave blank if you do not have the program.

○ Bachelor degree (MLS) (1) ____

○ Associate degree (MLT) (2) ____

Q13 If you require a minimum number of hours for each discipline on clinical rotation, please enter the hours below.

○ Hematology (1) ____

○ Immunohematology (Blood Bank) (2) ____

○ Microbiology (3) ____

○ Chemistry (4) ____

○ Urinalysis (5) ____

○ Molecular Diagnostics (6) ____

○ Administrative/Laboratory Operations (7) ____

○ Point of Care Testing (8) ____

○ STAT Lab Testing (9) ____

○ Immunology (10) ____

○ Hemostasis (13) ____

Q14 Have clinical rotation spots been a limiting factor in accepting more students into your program?

○ Yes (1)

○ No (2)

Q15 In the last ten years, has your program made any adjustments to the length of time required for students on clinical rotations?

- ○ Our program increased the clinical rotation time required (1)
- ○ Our program decreased the clinical rotation time required (2)
- ○ No changes have been made to our clinical rotations in the last ten years (3)

Display This Question:

If In the last ten years, has your program made any adjustments to the length of time required for s... = Our program decreased the clinical rotation time required

Q15A What percentage did you reduce clinical rotation hours by?

Not Applicable

0 10 20 30 40 50 60 70 80 90 100

Hematology ()	
Immunohematology (Blood Bank) ()	
Microbiology ()	
Chemistry ()	
Urinalysis ()	
Molecular Diagnostics ()	
Administrative/Laboratory Operations ()	
Point of Care Testing ()	
STAT Lab Testing ()	
Immunology ()	
Hemostasis ()	

Display This Question:

If In the last ten years, has your program made any adjustments to the length of time required for s... = Our program increased the clinical rotation time required

Q15B What percentage did you increase clinical rotation hours by?

	Not Applicable 0 10 20 30 40 50 60 70 80 90 100
Hematology ()	
Immunohematology (Blood Bank) ()	
Microbiology ()	
Chemistry ()	
Urinalysis ()	
Molecular Diagnostics ()	
Administrative/Laboratory Operations ()	
Point of Care Testing ()	
STAT Lab Testing ()	
Immunology ()	
Hemostasis ()	

Q16 Do you provide the clinical rotation site with expected competencies for the students in each discipline?

○ Yes, we have a specific set of competencies our students must meet while on clinical rotation (1)

○ No, we let the clinical site determine what is needed for each student (2)

○ Not applicable (3) ____

Q17 How important is the clinical rotation/internship in the development of skilled laboratory workers?

○ Very important (4)

○ Important (5)

○ Helpful but not a necessity (6)

○ Not important at all (7)

Q18 Should technology be used to reduce the amount of time students spend in the laboratory on clinical rotations/internships? (AI, virtual reality, teaching remotely via Zoom)

○ Yes (1)

○ Maybe (2)

○ No (3)

Q19 If a student already works and is proficient in a specific section of the laboratory, should they have to perform a clinical rotation/internship in that section, or should their hours be waived for that section? (ex: should a person working as an MLT in hematology be required to complete a clinical rotation in the hematology department to complete their education in an MLS program?)

- ○ The student should perform the hours like every other student (1)
- ○ The hours should be waived since they are already proficient (2)
- ○ The student should perform an advanced project to still do the hours but challenge them more (3)
- ○ Do not waive the hours, but shorten them to only cover areas they are not proficient in (4)
- ○ The hours should only be waived if the student is certified by a credentialing agency to work in that area (5)

Q20 All limiting factors aside, would you increase, decrease, or keep clinical rotation length the same if you were able to immediately make adjustments to your program?

- ○ Shorten the clinical rotation (1)
- ○ Keep the clinical rotation the same (2)
- ○ Extend the time of the clinical rotation (3)

Q21 What is the name of your school/program? (This is needed to correlate to NAACLS data and will not be used for any other purpose. The researcher is the only person who will have access to this data and will only be reported in aggregate to preserve anonymity of the program. If you are uncomfortable answering this question, you may enter "NA".)

____

Q22 Please use the following box for any additional thoughts on clinical rotations for clinical laboratory education, or any clarifying comments for your responses.

____

____

____

End of Block: Didactic Education and Clinical Rotation Structure

Appendix B: Expert Panel Credentials

Expert Panel for Dissertation Surveys

Yasmen Simonian, PhD, MLS (ASCP)^{CM}, FASAHP

- Dean of Weber State University College of Health Professions, former Chair and Director of Weber State University Medical Laboratory Science department, former President of the National Accreditation Agency for Clinical Laboratory Sciences

Mark Spence

- Mark Spence has worked in programmatic accreditation for almost 20 years. He currently serves as the Director of Strategic Initiatives for the National Accrediting Agency for Clinical Laboratory Sciences.

Justin Rhees, M.S., MLS(ASCP)^{CM}, SBB^{CM}

- Justin Rhees served as Program Director of the Medical Laboratory Science Program at the University of Utah from 2014-2018. Prior to that he served as the Associate Program Director from 2011-2014. He is certified as a Medical Laboratory Scientist (MLS) and Specialist in Blood Banking Technology (SBB) through the American Society for Clinical Pathology (ASCP) and has been an educator in the field of immunohematology and transfusion medicine since 2010. He earned his Doctorate of Education (EdD) from A. T. Still University and is an Associate Professor at Weber State University.

Christy Achter, BS, MLS(ASCP)^{CM}

- Christy graduated from Weber State University with a BS in MLS in 2009 and has worked in the laboratory since. Christy also works as part of the MLS Department at WSU mainly with online students pursuing BS MLS degrees, but also arranging clinical rotation assignments for campus MLT/MLS students and as an adjunct instructor for Clinical Chemistry.

Kari Potter, M.S., MLS(ASCP)^{CM}

- Chair and Instructor of Medical Laboratory Science at University of South Dakota. She has fifteen years of experience in the clinical laboratory setting, with over half of those concentrating on clinical education.

Cindi Kranek, BS, MLS(ASCP)^{CM}

- Weber State University MLS Online Coordinator

Stephanie McGee, MBA, MLS(ASCP)^{CM}

- Stephanie is the Microbiology Laboratory Supervisor for Salt Lake Regional Medical Center, and has worked in the health field for 25 years. She has worked in public health as well as several different hospitals as a supervisor, generalist and a microbiology specialist. Stephanie oversees many students' rotations in microbiology.

Sheri Hohmann, MSPH, SM(ASCP)^{CM}

- Sheri is an Assistant Professor in the Medical Laboratory Science Division at the University of Utah, where she teaches Parasitology, Mycology, and Microbiology. Prior to joining the U of U in 2020, Sheri worked for 24 years in the Infectious Disease Division at ARUP Laboratories in various capacities, including bench Technologist in Microbiology, Technical Specialist in Mycology, and Education Coordinator supporting the classic Infectious Disease laboratories. Sheri has interacted with MLS students in each of these roles as clinical instructor, coordinator, and currently as lecturer/course director.

Chere Clawson, BS, MLS(ASCP)^{CM}

- Chere spent 4 years scheduling practical rotations for Weber State University campus students, and managing the online program. Chere spent another 4 years working at Dixie State University running labs for hybrid WSU/DSU program. She has 10 years of clinical laboratory experience, occasionally working with students performing clinical rotations for WSU, BYU and ISU. Chere is currently faculty at WSU, serving as the program's hematology instructor.

Kara Hansen-Suchy, M.Ed, MT(ASCP), SH(ASCP)

- Program Director of Grand Canyon University MLS program, former Faculty and Program Director of University of Washington MLS program.

Appendix C: Survey Validation Questions

The following questions were developed by Cobern and Adams (2020), and were asked of the expert panel for each of the questionnaires used in this dissertation research.

- Having read the items, what do you think this survey is about?
- Do you think subjects in the target population will have difficulties understanding any of these questions?
- Are there items that you suspect most respondents will answer the same way, or will not return a range of responses?
- Are there any changes that you would recommend making that would make items more easily understood?
- In your opinion, is any of the content wrong?
- Did you find any of the questions misleading?
- How much time do you think it would take a person in the target population to thoughtfully complete this survey?

Appendix D: Education Coordinator Survey

Start of Block: Introduction

Q1
CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

Your Consent Before agreeing to be part of the research, please be sure that you understand what the study is about. You can keep a copy of this informed consent for your records. If you have any questions about the study later, you can contact the study team using the information provided above. If you have read through this informed consent and wish to participate, then please select that option below and the survey will begin. Thank you!

- ○ I choose to participate AND I routinely work with students on their clinical rotation/internship (1)
- ○ I choose NOT to participate OR I DO NOT routinely work with students on their clinical rotation/internship (2)

Skip To: End of Survey If CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY The University of South Dakota TITLE: Evaluating... = I choose NOT to participate OR I DO NOT routinely work with students on their clinical rotation/internship

End of Block: Introduction

Start of Block: Participant Demographics

Q2 What is your age?

	18 26 34 43 51 59 67 75 84 92 100
Age in Years ()	

Q3 What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary (3)

Q4 Do you work in a hospital, clinic, reference laboratory, or other healthcare facility that has MLS or MLT students performing clinical rotations/internships?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Do you work in a hospital, clinic, reference laboratory, or other healthcare facility that has ML... = No

---

Q5 Do you directly work with MLT and/or MLS students who are performing clinical rotations/internships at your facility?

- ○ Yes, I am in charge of the students on clinical rotations AND do most of the direct teaching on their rotation. (3)
- ○ Yes, I am in charge of the students on clinical rotations but do not do much of the direct teaching on their rotation. (1)
- ○ Yes, I work a discipline specific bench where I will spend a portion of the rotation working directly with the students. (2)
- ○ No, they rotate through our laboratory, but I have minimal time working directly with them. (4)

Skip To: End of Survey If Do you directly work with MLT and/or MLS students who are performing clinical rotations/internshi... = No, they rotate through our laboratory, but I have minimal time working directly with them.

Q6 What is your role in the laboratory? (select all that apply)

- ▢ Lab Director (1)
- ▢ Lab Manager (2)
- ▢ Education Coordinator (3)
- ▢ Supervisor (4)
- ▢ Medical Laboratory Scientist/Technologist (5)
- ▢ Medical Laboratory Technician (6)
- ▢ Training MLS and MLT Students (7)
- ▢ Other (8) ____

Q7 How long (in years) have you had the following responsibilities?

	0 5 10 15 20 25 30 35 40 45 50
Working in the clinical laboratory ()	
Working with students on clinical rotations ()	
Working in a supervisory role ()	

Q8 What type of NAACLS-accredited program did you earn your laboratory credentials through?

- ○ Two-year College/University (1)
- ○ Four-year College/University (2)
- ○ Non Degree Granting Proprietary School (3)
- ○ Independent Laboratory (4)
- ○ Blood Center (5)
- ○ Military Facility (6)
- ○ Other (7) ____

Q9 What is the highest level of education you have attained?

- ○ High School Diploma/GED (5)
- ○ Associate's degree (2)
- ○ Bachelor's degree (1)
- ○ Master's degree (3)
- ○ Doctorate (4)

End of Block: Participant Demographics

Start of Block: Facility Demographics

Q32 Which best describes your laboratory?

- ○ Reference laboratory (1)
- ○ Hospital laboratory (2)
- ○ Clinic laboratory (3)
- ○ Public Health laboratory (5)
- ○ Other (6) ____

Display This Question:

If Which best describes your laboratory? = Hospital laboratory

Or Which best describes your laboratory? = Clinic laboratory

Q10 How large is your facility by number of patient beds? (Please just enter the estimated number of beds ex: 480)

____

Display This Question:

If Which best describes your laboratory? = Hospital laboratory

Or Which best describes your laboratory? = Clinic laboratory

Q11 Is your hospital part of a larger hospital system?

○ Yes (2)

○ No (1)

Q12 Does your facility operate a hospital-based MLT and/or MLS program where all didactic education is also performed within your facility?

○ Yes (1)

○ No (2)

Q13 How many students does your lab typically take for clinical rotations each year?

Not Applicable

0 10 20 30 40 50 60 70 80 90 100

Medical Laboratory Scientist/Technologist ()	
Medical Laboratory Technician ()	
Microbiology Categorical ()	
Chemistry Categorical ()	
Blood Bank Categorical ()	
Hematology Categorical ()	
Molecular Diagnostics Categorical ()	

Q14 How many different MLT, MLS, or categorical ***programs/schools*** does your facility work with to provide students with a clinical rotation?

Not Applicable

0 2 4 6 8 10 12 14 16 18 20

Number of MLS programs ()	
Number of MLT programs ()	
Number of categorical programs ()	

Q15 Approximately what *percentage* of the students you work with on clinical rotation are from online laboratory education programs? (All of their courses are online except for the clinical aspect.)

	Not Applicable 0 10 20 30 40 50 60 70 80 90 100
Medical Laboratory Science (MLS) ()	
Medical Laboratory Technician (MLT) ()	
Categorical Program ()	

Q16 Do students perform phlebotomy as part of their rotation?

- ○ Yes (1)
- ○ No (2)
- ○ Yes, they progress to draw unsupervised (3)
- ○ Yes, they draw but always supervised by another phlebotomist (4)
- ○ No, they do not draw but they do observe blood draws by experienced phlebotomists (5)

Q17 Is your hospital, clinic, or reference lab in a rural or urban county? (click here for US Census Bureau county lookup)

- ○ Mostly urban (1)
- ○ Mostly rural (2)
- ○ Completely rural (3)

Q18 In the last fifteen years, which of the following changes has your laboratory made that directly impacts the availability of clinical rotation spots.

- ▢ Moved microbiology to a centralized location for multiple hospitals (1)
- ▢ Moved blood bank to a centralized location for multiple hospitals (2)
- ▢ Increased staffing (3)
- ▢ Decreased staffing (4)
- ▢ Increased testing (5)
- ▢ Decreased testing (6)
- ▢ Shortened overall length of time for student rotations (7)
- ▢ Increased overall length of time for student rotations (8)
- ▢ Other (9) ____

Q19 Is your facility located in a state that requires licensure and has a minimum amount of time required for students on clinical rotations/internships?

- ○ Yes, we have licensure and minimum amount of time required (Please add state below) (1) ____
- ○ Yes, we have licensure but no minimum amount of time required (Please add state below) (4) ____
- ○ No (2)
- ○ Do not know (Please add state below) (5)

Q20 Does your laboratory have the capacity (time, space, trainers) to add more students rotating through for clinical rotations/internships?

- ○ Yes (1)
- ○ No (2)
- ○ Have capacity for more students but are not going to take any more (3)

Q21 In the last 10 years, has your facility increased, decreased, or remained the same in the amount of students you are able to take for clinical rotations/internships?

- ○ Increased (1)
- ○ Decreased (2)
- ○ Remained the same (3)

Q22 Which of the following apply to your laboratory's collective perception about mentoring students on their clinical rotations? (select all that apply)

- ▢ It is a burden (1)
- ▢ It is invigorating (2)
- ▢ Fun to pass along their knowledge (3)
- ▢ Paying it forward from the time they spent on their clinical rotations (4)
- ▢ Leads to staff burnout (5)
- ▢ Makes staff better at their jobs (6)
- ▢ Staff learn from the students as well (7)
- ▢ Students are helpful on the bench (8)
- ▢ Students take too much time (9)
- ▢ Don't have enough staff to help with students (10)
- ▢ Great way to recruit new laboratory professionals (11)
- ▢ Other (12) ____

Q23 When setting up rotation times for students from MLT and/or MLS programs, what dictates the amount of time they spend in your laboratory?

- ○ We schedule for the time that the MLS or MLT program requires them to be there. (1)
- ○ We have the same clinical rotation schedule for all students, no matter what program they are coming from. (2)

- There is no scheduled time requirement, once the student has passed all competency requirements, they are done. (3)
- We are a hospital-based MLT/MLS program and we set the time requirement. (4)
- Other (5) ____

Q24 When hiring a recent graduate, does your facility adjust the time of training for those who have been to schools with longer than average clinical rotations vs. schools with short clinical rotations for their students? (For example a year-long rotation versus a two-week rotation)

- My facility will adjust the training time for employees dependent upon the time on clinical rotation in their MLT and/or MLS education (1)
- My facility does not take the clinical rotation into consideration when training recent graduates for employment in the lab (2)

Q25 For the remaining questions, please answer with your personal opinion.

Do you see a clear difference in the quality of the new employees from programs with longer clinical rotations vs schools with shorter clinical rotations? (For example a year-long rotation versus a two-week rotation)

- Major difference (2)
- Minor difference (1)
- Do not see a difference (3)

Q26 Please indicate your opinion on the role of the clinical rotation in the education of the MLS and/or MLT student? (0 being least important, 10 being most important)

0 1 2 3 4 5 6 7 8 9 10

Introduce the student to the workflow of the laboratory ()	
Be the primary source of education in the laboratory education program ()	
Provide student interactions with other laboratorians and hospital/clinic staff ()	
Train them the same as a new employee to prepare them to work independently ()	
Applying the theory, techniques, and skills learned during didactic education in the clinical laboratory ()	

Q27 Judging from the time that students spend in your laboratory, what is your opinion on adjusting the length of time students spend on clinical rotation?

- ○ Students need less time (1)
- ○ Students need more time (2)
- ○ Students need more time, but our lab cannot accommodate them (3)
- ○ Students are spending an adequate amount of time in my laboratory for their educational needs. (4)

Q28 In your opinion, what is the perfect length of time for students from MLS and MLT programs to spend on clinical rotations? (In weeks, assuming a 40-hour work week)

	Not Applicable 0 10 21 31 42 52 62 73 83 94 104
Medical Laboratory Science (MLS) ()	
Medical Laboratory Technician (MLT) ()	
Categorical Program ()	

Q29 Should technology be used to reduce the amount of time students spend in the laboratory on clinical rotations/internships? (AI, virtual reality, teaching remotely via Zoom)

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3) Q30 If a student already works and is proficient in a specific section of the laboratory, should they have to perform a clinical rotation/internship in that section, or should their hours be waived for that section? (ex: should a person working as an MLT in hematology be required to complete a clinical rotation in the hematology department to complete their education in an MLS program?)

- ○ The student should perform the hours like every other student (1)
- ○ The hours should be waived since they are already proficient and certified (2)
- ○ The student should perform an advanced project to still do the hours but challenge them more (3)
- ○ Do not waive the hours, but shorten them (4)
- ○ Other (5) ____

Q33 Is working with students and educating future laboratory professionals something you enjoy about your job?

- ○ Definitely yes (1)
- ○ Yes (2)
- ○ Sometimes (3)
- ○ No (4)
- ○ Definitely not (5)

Q31 Please include any additional comments or thoughts on clinical rotations in the medical laboratory science profession.

____

____

____

____