

# Addressing Student Confidence in Clinical Laboratory Practice and Communications: A Simulation-Based Approach

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## ABSTRACT

Simulation in medical education is well documented as an effective educational approach for increasing student engagement and expanding understanding of professional practice. For medical laboratory science (MLS) students, simulation-based laboratories offer a structured opportunity to engage with the preanalytical, analytical, and postanalytical phases of laboratory testing prior to entering clinical rotations. This study evaluates the impact of a novel clinical laboratory simulation experience, *Designing and Operating a Clinical Laboratory*, on MLS student confidence and comprehension of clinical laboratory operations and communications. Impact of the simulation was assessed by evaluating student confidence in performing key functions required of medical laboratory professionals. Participants completed a pre- and postsimulation questionnaire consisting of Likert-scale items and open-ended questions. Our findings demonstrate consistent increases in confidence across multiple phases of laboratory testing following participation in the simulation. Additionally, participants were asked to rate the effectiveness of the simulation, with responses indicating high levels of satisfaction in, and perceived value of, the exercise. Finally, we describe the design, development, and facilitation of this educational simulation to support replication and further research in this important field of study.

**ABBREVIATIONS:** ALT - alanine aminotransferase, AMR - analytical measurement range, CLS - clinical laboratory science, MLS - medical laboratory science, SBT - simulation-based training, SOP - standard operating procedure, TAT - turnaround time, UNC - University of North Carolina, UNC-IRB - UNC institutional review board.

**INDEX TERMS:** simulation training, medical laboratory sciences, medical education, professional practice.

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## INTRODUCTION

Simulation training has been widely recognized for its positive impact on the professional development of students in medical education programs.<sup>1</sup> Benefits of simulation-based training (SBT) include increase in learner confidence, interprofessional awareness, and improvement when performing occupational and other task-based practices.<sup>2–4</sup> Medical laboratory science (MLS) students also benefit from SBT in both laboratory-focused and interprofessional practice.<sup>5–7</sup>

A need for increased and robust reporting on SBT in medical laboratory education has been identified in the literature.<sup>8</sup> In response, a framework informed by the International Nursing Association for Clinical Simulation and Learning Standard of Best Practice was proposed to support medical laboratory educators in the development, implementation, evaluation, and documentation of MLS simulations.<sup>8,9</sup> Guided by this framework, we aim to contribute to this important area of scholarship by reporting on the design, execution, and outcomes of our novel simulation-based student exercise, *Designing and Operating a Clinical Laboratory*.

## METHODS AND MATERIALS

### General Course and Simulation Development

In the spring of 2023, clinical laboratory science (CLS) faculty at the University of North Carolina (UNC) began exploring the development of a simulation exercise for the required course, Clinical Chemistry Laboratory. Rooted in our collective 15+ years of experience working as medical laboratory scientists in core laboratory settings, we aimed to develop a laboratory experience that would reasonably simulate a generalist laboratory while working within the manual testing capacities of our student laboratory space. Our focus was to create a standardized introduction to clinical workflow, laboratory communications, and management of collection and specimen issues while providing an opportunity for students to work collaboratively in a supervised environment, all prior to beginning their clinical rotations.

Assays were selected from previous student laboratory exercises and included testing in areas of transfusion medicine, urinalysis, hematology, and general chemistry. In alignment with the National Accrediting Agency for Clinical

Laboratory Science guidelines for incorporating preanalytical, analytical, and postanalytical testing phases in CLS curriculum, objectives were developed to address laboratory design, operations, and key functions performed by medical laboratory scientists in a clinical environment.<sup>10</sup>

The 2-day simulation, *Designing and Operating a Clinical Laboratory*, took place at the end of the Spring 2024 semester, following the completion of 7 clinical chemistry laboratory exercises. The 7 exercises covered method validation topics including linearity, sensitivity, interference, bias, and method comparison. Multiple manual chemistry assays were used to explore these topics throughout the semester, including total protein, glucose oxidase, and enzymatic alanine aminotransferase (ALT). In addition to examining testing methods, the students also determined unknown patient values, all using prequoted specimens.

### Simulation Setup and Schedule

At the start of each simulation day, students attended a presimulation briefing (faculty led) covering the simulation in general and the objectives for the simulation (Table 1). Additional briefing topics covered the parameters of the simulation, including influences on laboratory design, personnel requirements, specimen handling, procedures, and documentation. A timeline for the simulation activity is presented in Table 2. The students also received an additional set of documents required for the simulation activities of the day (Table 3). Additional labels provided to students identified specimen processing and specimen storage locations (Table 4).

**Table 1.** Learning objectives for *Designing and Operating a Clinical Laboratory*

#	Learning Objective	Learning Domain (Blooms)
1.	Identify and implement strategies for developing efficient laboratory workplace design.	Cognitive, psychomotor
2.	Develop an employee schedule to meet the needs of laboratory operations.	Cognitive, affective
3.	Develop and demonstrate communication skills required to perform collaborative laboratory operations.	Affective, cognitive
4.	Recognize the role of, and perform, various laboratory bench operations, including specimen processing, specimen analysis, result reporting, and specimen storage.	Psychomotor, cognitive
5.	Perform, assess, and monitor quality control analysis required for patient testing.	Psychomotor, cognitive
6.	Assess the quality and suitability of specimens based on knowledge of analyte characteristics, known interferences, and procedural information.	Cognitive, psychomotor
7.	Take appropriate action when patient specimens are unsuitable for analysis (eg, collection error, specimen interference).	Cognitive, affective, psychomotor
8.	Take appropriate action to obtain accurate results when patient values exceed linearity (eg, perform dilutions).	Cognitive, psychomotor
9.	Take appropriate action when reporting critical values (eg, communicate results to provider and document communication).	Cognitive, affective, psychomotor
10.	Monitor and respond to TAT requirements for each analyte.	Cognitive, psychomotor
11.	Use the preanalytical and postanalytical checklist to prepare for analysis and report results.	Cognitive, psychomotor

### Specimen Preparation

Students received specimens and test orders for 5 patients. A combination of deidentified patient specimens provided by our primary clinical affiliate and faculty-developed specimens were used in the simulation. Students performed approximately 35 assays, including quality control, duplicate testing, and dilutions. Collectively, the delivered specimens included results that were greater than the analytical measurement range (AMR) of an assay, collection errors, and critical values, all of which required student intervention and communication with a clinician. For the purposes of this simulation, CLS faculty assumed the role of a clinician receiving and documenting laboratory communications. A list of assays, assay frequency, and specimen preparation is presented in Table 5.

### Study Population

Twenty-one students participated in the simulation exercise and completed the presimulation survey. Twenty students completed the postsimulation survey. Participants were all CLS students in the CLS division within the Department of Health Sciences at the UNC-Chapel Hill School of Medicine. All participants were in their second semester of UNC-CLS courses and had completed all required laboratory exercises in the required course, Clinical Chemistry Laboratory.

Participation in the simulation was a required activity for all students enrolled in the course. Participation in the evaluation of the activity was anonymous and voluntary. Students were invited to participate in the simulation evaluation (pre- and postsurvey) during 2 separate

**Table 2.** Timeline of simulation activity

Day	Activity	Details
<b>Day 1: designing a clinical laboratory</b>	8:30 a.m. Presimulation survey	Conducted in a separate lecture classroom
	12:00 p.m. Faculty-led briefing	Introduction to laboratory design Define simulation parameters <ul style="list-style-type: none"> <li>• Personnel requirements</li> <li>• Position descriptions</li> <li>• Test menu/analytical benches</li> <li>• Physician space</li> </ul>
	12:30 p.m.–3:00 p.m. Designing a clinical laboratory (student led)	Determine laboratory positions <ul style="list-style-type: none"> <li>• analytical bench assignments</li> <li>• employee schedule</li> <li>• laboratory layout/design</li> </ul> Review SOPs for each bench <ul style="list-style-type: none"> <li>• Identify/request required instrumentation</li> </ul> Complete individual checklists Store documents <ul style="list-style-type: none"> <li>• bench assignments/schedule, design, checklists</li> </ul>
<b>Day 2: operating a clinical laboratory</b>	12:00 p.m. Faculty-led briefing	Review SOPs: specimen receipt/accessioning, handling, TATs, rejection, interference, reporting, critical values, cancellations, data/specimen storage. Distribute laboratory documents (Table 3).
	12:30 p.m.–3:00 p.m. Operating a clinical laboratory (facilitated simulation)	<ul style="list-style-type: none"> <li>• Specimen processing: order review, confirm proper collection/handling, aliquots, store primary specimen, deliver aliquots to appropriate bench.</li> <li>• Analytical benches: manage TATs, evaluate specimen integrity, perform quality control, follow analytical and result reporting procedures.</li> <li>• Documentation and storage: patient orders, patient specimens, analytical worksheets, patient reports.</li> </ul>
<b>Day 14</b>	3:30 p.m. Faculty-led debriefing	Group discussion on roles, responsibilities, experiences, impressions of simulation.
	8:30 a.m. Postsimulation survey	Conducted in a separate lecture classroom.

**Table 3.** Issued documents required for *Designing and Operating a Clinical Laboratory*

Issued	Document	Description
<b>Day 1</b>	SOP	Includes description of simulation, objectives, position descriptions, procedure for all simulation benches.
	Position and bench assignments worksheet	List of students and analytical benches. Bench assignments documented by student-elected supervisors.
	Day 1 checklist	Completed and submitted to supervisors by all participants.
<b>Day 2</b>	Patient order sheet	Patient order form (delivered during simulation with specimens).
	Specimen receipt worksheet	Specimen accession/processing document.
	Specimen rejected worksheet	Specimen accession/processing document.
	Analytical bench worksheet(s)	Separate quality control and patient worksheets for each analytical bench.
	Patient report worksheet	Patient final results worksheet for each analytical bench.

morning lectures. A facilitator read a preapproved recruitment script, providing the description of the simulation and study design, and then displayed a QR code and web address linked to the survey. Students were informed

of the voluntary and anonymous nature of the study and were then invited to use a mobile device or laptop to access the web-based (Qualtrics) survey instrument. In order to ensure anonymity, all students were allowed to

**Table 4.** Bench labels for specimen processing/specimen storage

Label	Purpose
1. Specimen delivery	Drop off location for incoming specimens.
2. Urinalysis collection cup	Storage location for aliquoted urine specimens.
3. Rejected specimens	Storage of specimens rejected for collection errors.
4. To centrifuge	Placement of primary specimen requiring centrifugation with labeled aliquot tubes.
5. Spun	Aliquoted specimen delivery, postcentrifugation.
6. Completed specimens	Completed specimens with released results. Canceled specimens because of specimen integrity issues.

**Table 5.** Patient test orders, frequency, and specimen type

Order Type	Frequency	Patients	Specimen Type
Glucose (GLUC/FGLUC)	3	A, B, E	Faculty developed
Alanine aminotransferase (ALT)	3	C (redraw), D	Faculty developed
Total protein (TP)	3	A, C (redraw), D	Faculty developed
Urinalysis (UMAC)	4	A, B, D, E	Faculty developed
Hematocrit (HCT)	3	C, D, E	Deidentified patient
ABO type	3	C, D, E	Expired donor red cell/faculty-developed plasma

access their electronic devices, regardless of survey participation, for 15 minutes, which corresponded to the time that was allotted for survey participation. The study was deemed exempt by the UNC Institutional Review Board (UNC-IRB).

### Study Design/Evaluation Tools

This study used a pre- and postintervention design strategy to assess confidence levels both before and after participating in the simulation exercise. Using a Likert scale for ranking, students were asked to assess confidence levels in areas of laboratory performance and communication. The postsimulation survey included an additional set of questions assessing the student's evaluation of the simulation experience. In addition, 2 free-text response questions were included in the postsimulation survey as a method to collect qualitative feedback. Survey questions reflected the simulation objectives and covered preanalytical, analytical, and postanalytical areas of laboratory practice (Table 6).

## RESULTS

Student responses before and after simulation were anonymous and unpaired. Confidence levels were measured using a Likert scale and analyzed by comparing mean confidence ratings before and after the simulation. To evaluate the significance of the observed changes, a one-sided Mann-Whitney U-test was performed using SAS version 9.4.<sup>11</sup>

Following participation in the simulation, students reported a significant increase in confidence levels on 13 of the 15 items assessing their confidence in performing certain clinical tasks and procedures required of medical laboratory scientists (minimum *P* value <.05). Confidence level comparisons and statistical significance are presented by testing phase: preanalytical (Figure 1), analytical (Figure 2), and postanalytical (Figure 3).

The most pronounced increases in confidence level means, with highly significant shifts in reported confidence (*P* < .0001), were observed in items related to identifying collection errors, performing testing within the stated turnaround time (TAT), identifying specimen issues requiring recollection, and knowing which specimens required aliquoting (*P* = .0002). Students also reported significant increases in confidence across all items assessing interprofessional interactions, including communicating tests requiring cancellation and critical values (*P* < .05). In the 2 areas that did not show significant increases in confidence—identifying results greater than AMR and preparing a dilution—students reported high presimulation levels of confidence. These topic areas are covered extensively throughout the course and are a primary focus of quizzes and examinations, which likely explains the preexisting high level of confidence.

In addition to quantitative responses, students provided enthusiastic free-text comments highlighting the simulation as fun, engaging, and educational. One student stated, "It was really helpful in understanding how a lab communicates and how workflow runs on a day-to-day basis in the lab." Feedback also included constructive suggestions regarding the simulation's workflow, with several

**Table 6.** Pre- and postsimulation survey questions

**For the following questions, use the confidence scale (below) to rate your confidence level in performing the following laboratory practices: (1) not confident at all, (2) slightly confident, (3) somewhat confident, (4) confident, (5) very confident**

1.	Confirming proper specimen collection (including collection time, container, and patient requirements)
2.	Identifying when to cancel a specimen due to a collection error
3.	Determining which samples require centrifugation or aliquoting
4.	Aliquoting samples for multiple benches
5.	Performing and assessing quality control results
6.	Performing analytical testing within the published turn-around-time
7.	Identifying results above AMR
8.	Performing dilutions on patient specimens
9.	Identifying samples that require cancellation for possible sample interferences (hemolysis, bilirubin, lipemia)
10.	Identifying samples issues that require a new sample to be collected before analysis
11.	Identifying a critical value

**For the following questions, use the following confidence scale (below) to rate your confidence level when delivering the following laboratory communications: (1) not confident at all, (2) slightly confident, (3) somewhat confident, (4) confident, (5) very confident**

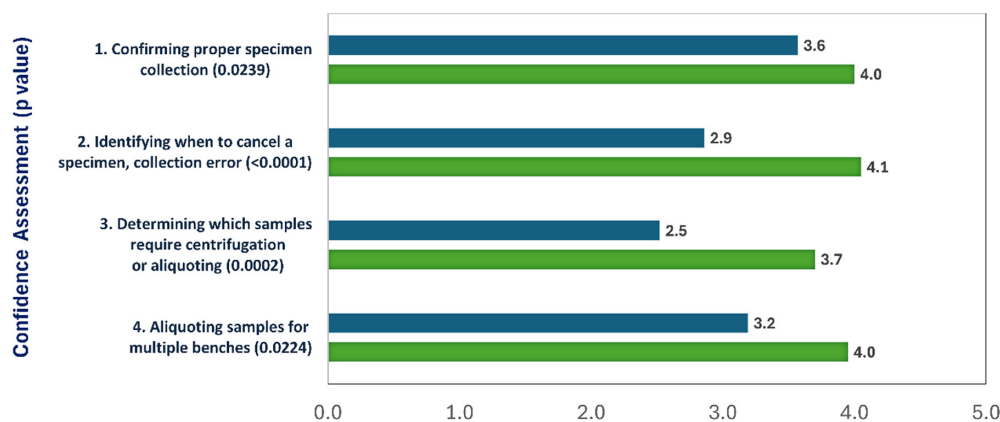
1.	Notifying care team of a canceled specimen order due to a tube collection error
2.	Notifying care team of a patient sample exhibiting sample interference
3.	Notifying care team of a canceled order and request a new sample for collection/analysis
4.	Notifying care team of a critical value

**Additional postsimulation survey questions**

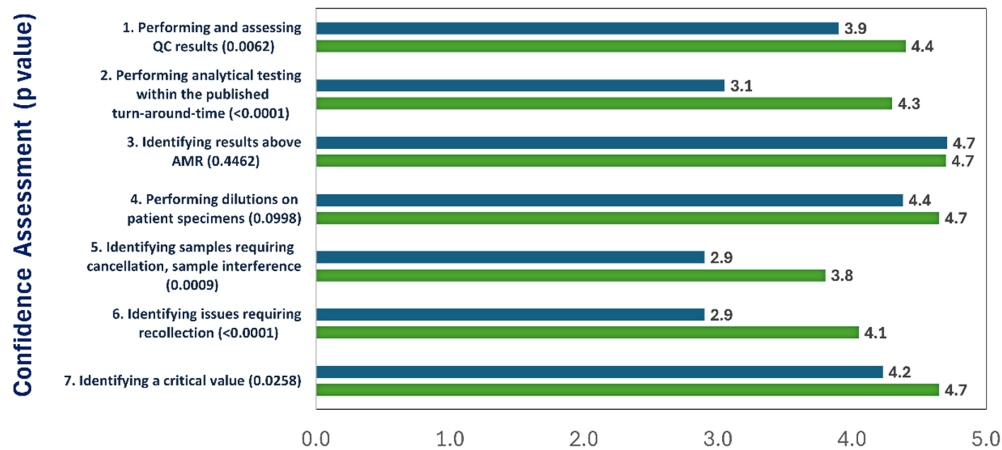
1.	This exercise increased my understanding of specimen processing
2.	This exercise increased my understanding of laboratory workflow
3.	This exercise encouraged group collaboration
4.	I enjoyed participating in this exercise

**Open-ended post-simulation survey items**

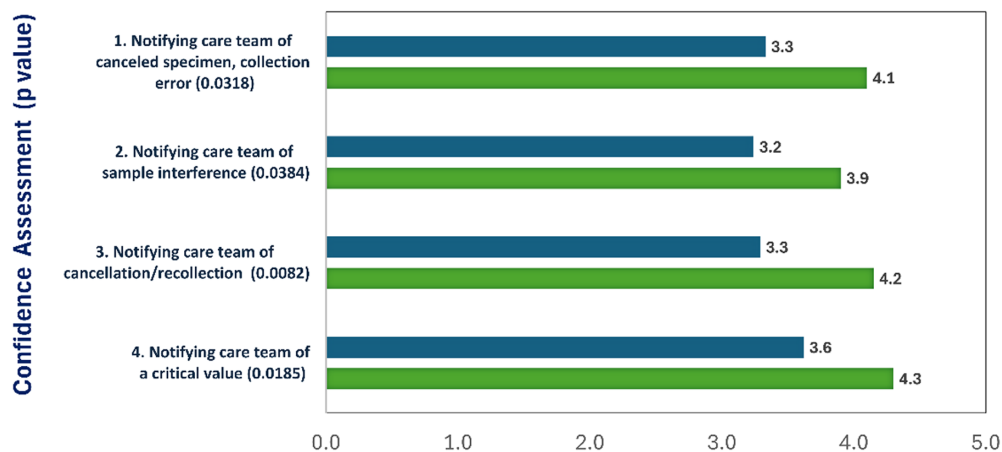
1.	In your opinion, what were the strengths of this exercise?
2.	In your opinion, how could this exercise be improved?



**Figure 1.** Preanalytical processes: evaluating clinical confidence pre- and postsimulation. Survey questions are shown on the y-axis. Mean values for presimulation (n = 21) are shown in blue, and the postsimulation (n = 20) survey results are in green. Mann–Whitney U-derived P values included on y-axis. CIs: (1) not confident at all, (2) slightly confident; (3) somewhat confident; (4) confident; and (5) very confident.



**Figure 2.** Analytical processes: evaluating clinical confidence pre- and postsimulation. Survey questions are shown on the y-axis. Mean values for presimulation ( $n = 21$ ) are shown in blue, and the postsimulation ( $n = 20$ ) survey results in green. Mann-Whitney U-derived  $P$  values included on y-axis. CIs: (1) not confident at all, (2) slightly confident, (3) somewhat confident, (4) confident, (5) very confident.



**Figure 3.** Post-analytical Processes: Evaluating Clinical Confidence Pre- and Post-simulation. Survey questions are shown on the y axis. Mean values for pre-simulation ( $n = 21$ ) are shown in blue and the post-simulation ( $n = 20$ ) survey results in green. Mann-Whitney U derived  $p$  values included on y axis. Confidence Intervals: (1) Not confident at all (2) Slightly confident (3) Somewhat confident (4) Confident (5) Very Confident.

students expressing interest in more patient specimens and additional opportunities for investigation and problem-solving (Table 7). The majority of participants expressed strong agreement with statements identifying the positive value of the simulation experience (Table 8).

## DISCUSSION

Prior to introducing the simulation, the clinical chemistry laboratory course emphasized individual understanding, execution, and evaluation of clinical assays. Given the importance of mastering these foundational concepts and skills, students generally work independently at their personal analytical bench throughout the semester. The addition of the simulation marked a shift in this approach, offering students the opportunity to engage collaboratively

across all phases of laboratory testing while navigating the complexities of clinical workflow and interprofessional interaction. Importantly, the activity took place before students began their clinical rotations, providing an earlier and structured opportunity for exposure to the movement, pacing, and energy required of a medical laboratory scientist in a clinical laboratory setting. The students responded to the simulation with enthusiasm and excitement, which was notable given that it occurred at the end of 2 demanding semesters of MLS coursework.

Preparing for the simulation was a substantial logistical challenge. Developed and facilitated by the 2 authors, it required considerable time to determine facilitation strategies, create a detailed standard operating procedure (SOP) manual for student use, and document internal procedures for specimen preparation. Planning began a year

**Table 7.** Responses to open-ended questions (postsimulation)**In your opinion, what were the strengths of this exercise?**

*It was a great simulation that provided insight into the flow of a clinical laboratory and demonstrated how multiple tests can be performed from patient samples. I think it also gave a many of us a better appreciation of specimen processing*

*It was fun and let me actively learn instead of just reading or hearing about it*

*It was really helpful in understanding how a lab communicates and how workflow runs on a day to day basis in the lab.*

*Being able to simulate a lab was helpful for teaching us sample processing as well as learning communication strategies with our peers. I think it was a good simulation to have before running through clinicals at an actual lab*

*The ability to work as a team and go through the period of waiting for samples while simultaneously running quality control helped to better prepare us for the real lab setting.*

*Number of assays and stats along with group work*

*This exercise was a really great example of work flow and how different benches work together in the lab.*

*It was too short*

*Allows for us to work together toward a common result*

*Engaging and fun*

*It included very real factors of working in a clinical lab like having to work with people in various roles, having to communicate information to providers, evaluating samples and analyzing them within a given time.*

*Well organized, really fun, mimicked a real lab very nicely.*

*Team work and the procedures used to execute each test*

*I thought this exercise was AWESOME! I had so much fun getting to work with my peers in a professional sense, and really enjoyed the experience!*

**In your opinion, how could this exercise be improved?**

*I think it would be a neat idea to have a couple of people be able to "work" as generalists and be able to bounce between benches if need be. I think that would limit how many people are idle at a given moment and would add another level of complexity and appreciation*

*A few more pts for the tests that take less time so one group doesn't feel like everyone is waiting on them*

*I feel like I didn't get to see as much of the specimen processing side as I would've hoped for. If I were to redo it, I think the specimen processing bench would be most beneficial for learning purposes.*

*It would be nice to have a back button on here, I think I missed a question because I got confused. Other than that, everything seemed very well organized. It would have been helpful to have some sort of sheet for keeping track of turn around times as a supervisor though.*

*Maybe more spread out samples/more samples for groups with quicker tests. The ALT took a bit longer, but other groups finished quite quickly. It may be beneficial to add a few more tests/patients (if possible of course) to each bench for the exercise.*

*Adding more samples for some benches so that everyone isn't waiting on one bench to be done and all finish around the same time.*

*Get rid of ALT*

*More samples with problems such as hemolysis or critical values*

*Too much downtime after completing assays*

*Include more samples for benches whose tests run faster and less for the ALT bench. Maybe allow students to cycle through different roles so everyone can experience specimen processing or being a lead MLS.*

*More samples*

*If a shorter assay could replace ALT, I think that would help with down time throughout other benches.*

in advance, with most of the work concentrated in the 4 months preceding implementation.

Patient cases were developed based on the manual assays students had already performed during their 2 semesters of coursework. This allowed for the design of focused and effective examples of common clinical scenarios, such as a patient with an elevated blood glucose

level and corresponding glucose and ketones in urine. While developing patient and specimen scenarios, several procedural challenges emerged. For example, determining how the students would document specimen receipt, results from analytical testing, and required communications led to the development of supporting materials, including patient order forms, specimen receipt logs,

**Table 8.** Participant evaluation of simulation experience

Statement	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
1. This exercise increased my understanding of specimen processing.	0	0	0	45	55
2. This exercise increased my understanding of laboratory workflow.	0	0	0	35	65
3. This exercise encouraged group collaboration.	0	0	5	10	85
4. I enjoyed participating in this exercise.	0	0	0	20	80

testing logs, and a spreadsheet for recording laboratory results. Ensuring proper use of these materials required the development of daily prebriefing sessions to orient students to the simulation operations and train them on documentation expectations. During the simulation activity, one faculty member was then designated as the point of contact for documentation questions and served as a patient care team representative, receiving patient results, documenting communications related to specimen cancellation, and confirming and recording the communication of critical values.

Specimen preparation for the chemistry assays also posed a unique challenge. We aimed to simulate the experience of receiving an unspun serum separator tube while maintaining control over the expected patient values. To achieve this, faculty delivered unspun specimen collection tubes filled with expired donor blood to the simulation lab, and students then prepared labeled aliquot tubes for testing across multiple analytical benches. The faculty member then served as a liaison during this process, transporting the unspun tubes to the student laboratory centrifuge located in an adjacent lab. The original patient collection tubes were then set aside for the remainder of the simulation, and a previously prepared aliquot containing a faculty-developed serum specimen was returned approximately 10 minutes later to students for distribution and testing within the simulation. We used a variety of control materials and calibrators to create the specimens.

Although the simulation required considerable preparation time and was constrained by the manual testing options available in our student laboratory, it provided a realistic and immersive experience that reinforced both technical competency and the value of teamwork and communication required in clinical laboratory practice. Overall, we believe that *Designing and Operating a Clinical Laboratory* provides an approachable and adaptable framework for CLS programs seeking to integrate simulations into their curriculum.

### Limitations

The small sample size is a limitation of this study. Furthermore, the evaluation focused primarily on student

confidence in clinical settings and did not assess gains in cognitive knowledge. In addition, the impact of specific simulation design components, such as decisions related to staffing and bench layout, was not directly measured. Future studies could explore how these elements contribute to participants' operational awareness and understanding of clinical laboratory practice. Finally, the impact of the simulation on student preparedness during clinical rotations has yet to be evaluated. Future studies will be important to determine whether the increased confidence observed after the simulation translates into enhanced readiness for clinical practice.

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