Using Online Instruction and Virtual Laboratories to Teach Hemostasis in a Medical Laboratory Science Program

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ABSTRACT

Hemostasis laboratory testing methods have changed significantly over the past decades, from totally manual, to fully automated methodologies. Most medical laboratory educators prefer to use manual or semi–automated methods to teach hemostasis so that students can "see" what is occurring during the testing method, but many semi-automated instruments are no longer commercially available or are not cost-effective for education programs. In consideration of these factors and due to programmatic expansion to a coordinate campus, the CLS program explored new ways to teach hemostasis methods equitably and affordably across two distant locations. Working with an instructional design team versed in online education, five virtual hemostasis laboratory exercises were created that mimic the manual methodologies. Web-based didactic instruction was also developed to teach the testing theory and pathophysiology related to patient results. The efficacy of the virtual instruction was evaluated through assessment of student performance on exam questions, professional certification scores for the platelet/hemostasis sub-category, student satisfaction surveys, and evaluation of student performance during their clinical experience. Results showed that students in the virtual delivery format performed significantly better on exam questions compared to the traditional delivery method group, but there was no significant difference in their performance on the professional certification exam. Both student and preceptor feedback have been positive on the value of the exercises for students' understanding of hemostasis.

ABBREVIATIONS

CLS-Clinical Laboratory Science or Clinical Laboratory Scientist, MLS-Medical Laboratory Science or Medical Laboratory Scientist, BOC-Board of Certification exam, GPA-Grade Point Average, PT-Prothrombin Time, APTT-Activated Partial Thromboplastin Time, TT-Thrombin Time, PC-Personal Computer with Microsoft Operating System, MAC-Macintosh-based computer with Apple Operating System, DSL-Digital Subscriber Line Internet connection

INDEX TERMS

Hemostasis, virtual laboratory instruction, online education

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INTRODUCTION

As with all methodologies within the medical laboratory, hemostasis testing has evolved considerably over the past 50 years. Testing methods in this discipline have changed from the original coagulation tilt-tube methods to semi-automated methods (e.g. Fibrometers), and now to fully automated methodologies. Many semi-automated coagulation instruments are no longer in production and the expense of current fully automated instrumentation is beyond the reach of many educational programs, yet fundamental principles and methodologies have remained moderately static during these same years.

In student laboratories (i.e. chemistry, hematology, microbiology & transfusion medicine), on-campus instruction involves manual or semi-automated methods, while the clinical site provides experience with large automated instrument testing. For all subject areas, it is essential that students understand what happens inside instrumentation as they move from campus, to their clinical experiences, and eventually into the workplace. Knowledge of methodologies is essential for student competency and allows students to detect potential errors, troubleshoot instrument malfunctions, validate instrument performance, and eventually evaluate and interpret patient results.

Because the majority of hemostasis testing in medical laboratories is currently performed on fully automated instrumentation, coagulation tilt-tube testing is no longer performed and, as a result, students no longer needed to develop any proficiency in performing this method. Nevertheless, visualization of this basic method has instructional value for understanding the underlying principles of analysis. A mechanism to teach the fundamentals of hemostasis pathophysiology along with diagnostic testing theory was pursued without a wet laboratory while using a technique that allows the student to directly visualize the reactions detected using current instrumentation. This approached also provided the consistency and equity of instruction essential for the program and necessary for accreditation in light of multiple performance sites.

Several factors influenced the shift to virtual laboratory exercises for hemostasis including:

1) lack of instrumentation, reagents, and supplies for student laboratories within a budget,
2) the need to provide equivalent instruction at two locations 90 miles apart,
3) recognition that current hemostasis practice in most laboratories does not require the psychomotor skills associated with manual or semi-automated coagulation testing, and
4) the manipulative/psychomotor skills required for this testing are taught in other courses in the curriculum.

Efficacy of Online or Web-Based Instruction

Abundant literature exists comparing the traditional face-to-face delivery format of educational lessons with those of blended or online delivery formats showing either no significant differences in student learning outcomes or if significance is found, the online students typically perform better than students in traditional delivery formats.[1,2,3] However, investigation of the same literature presented limited studies using actual measurements of student outcomes on the efficacy of online or blended delivery formats for college science courses in particular. There were even fewer studies comparing student outcomes for laboratory courses, upper division courses, or those in a health profession where high levels of competency and critical thinking efficacy outcomes are required.[1] Sadoski and Colenda reported on the expansion of a medical school curriculum to a distant location using a number of electronic delivery formats.[4] However their study compared the same electronic delivery at two locations without a traditional delivery control group. The literature review initially provided very little in the way of a template or best-practices to follow for the development of this course. However, current literature did show that laboratory simulation or virtual exercises had been successfully developed for some introductory college science courses, supporting the premise of this project.[5,6]

As with differences in the quality of face-to-face instruction, there are differences in the quality of online education that may impact student learning outcomes. Traditional lecture formats now compete with a wide variety of distractions offered by wireless technology. Providing lecture slides with an audio voice-over via a course management system provides no higher level of student engagement than traditional face to face lecture. A poorly designed course will not provide the appropriate learning experiences whether it is delivered face-to-face, in a hybrid format, or through the Internet. Student engagement regardless of delivery format has consistently been a positive factor for student learning.[1,7,8,9]

While moving toward the use of more online or hybrid instruction in higher education, it is important to recognize that not all course content is optimally delivered online just because the technology is available. Individual educational goals should first be assessed to see which mode of instructional delivery and instructional design will provide an optimal learning experience for the student, allowing them to reach the desired outcomes.[9,10] The instructional materials provided, student activities, and assessments in the course must then align with the course goals. In a competency-based allied health educational program such as CLS, students must be provided the opportunities to build both didactic and psychomotor skills as well as critical analysis and problem solving. The goal was to create an online course and virtual laboratory that would be able to deliver the same aligned experiences as the traditional classroom or laboratory to the students through a non-physical presence.

MATERIALS AND METHODS

Developing the Virtual Laboratory Exercises

The target for the online course project was five hemostasis laboratory exercises traditionally taught using a water bath and tilt-tubes or with Fibrometer instruments along with the corresponding face-to-face didactic lectures. Before proceeding on this project, it was essential to determine whether these course units could be presented in a constructive format through online delivery. CLS Program faculty worked with a team versed in online education module development including an instructional designer, videographer, and an Adobe® Flash programmer to develop a virtual laboratory session for each of the existing traditional laboratory exercises and corresponding lectures. Instructional designers were able to help align the course materials in a sequence directed toward the desired student outcomes. For this particular project, some rearranging of the content was required, but no material was added or deleted from the original course. The lecture and laboratory lessons were divided into the following virtual lecture/laboratory modules:

1. Prothrombin Time (PT)
2. Activated Partial Thromboplastin Time (APTT)
3. Thrombin Time (TT)
4. Factor V Assay
5. APTT Inhibitor/Inactivator Assay

Instead of simply watching a video of someone performing the testing, these modules required student interaction. In each of the simulated exercises, the students went through the entire traditional process including reconstituting and mixing reagents, confirming water bath temperatures, gathering all testing supplies, etc. The student had to select the reagents using a computer mouse, mix the reagents, check water bath temperatures and set up each test tube. The student then performed the clotting test online by starting a stopwatch when reagent was added, watching a video of a clot forming using the tube-tilt method and clicking the stopwatch again when the video showed clot formation. In the current application, students downloaded and filled-in a worksheet for each exercise. Results were submitted through the online course management system for scoring.

Students were allowed to practice as many times as they wished before testing their specimens and submitting their results. Even after their results had been submitted students could return to the modules for review and preparation for exams. This feature of extended practice was not available to students in the traditional delivery format due to need for supervised laboratory time and the cost of reagents.

Comparison of Traditional and Virtual Delivery Student Outcomes

The efficacy of this new delivery format was investigated by evaluating the performance of 272 students in a university-based 2+2 MLS program over six years. A total of 101 students received hemostasis instruction via the traditional face-to-face lecture and laboratory format (years 2006-2008) while 171 students received instruction via online lectures and virtual laboratory format (years 2009–2011). A single instructor, with over 40 years of teaching and bench experience in hemostasis and specialty hematology laboratories, was the course director for all years and delivery modes.

Exam questions during this six year time period were evaluated for their appropriate use in the study. Many of the exam questions were discarded because they had not been used for all six years of the study period. Other questions were modified over time either because of 1) unacceptable difficulty index; 2) an occasional negative discrimination index; or 3) modification based on a particular content emphasis that year.[11] Over the six-year span of instruction, only 13 questions were unchanged and consistently used on the hemostasis exam without any modifications (Table 1). Student performance on these questions was compared between those who received their instruction via the traditional face-to-face method and the students who participated in the virtual delivery format. In addition, student scores on the Board of Certification (BOC) exam for the platelets and hemostasis sub-category were compared by instructional delivery format and cohort year.[12] To confirm that student groups were of equivalent academic ability a comparison was made of student grade point averages (GPA) during the CLS Program.

Table 1. Student Performance on Course Exam Questions

Question	Question Subject	Average Percent Correct (SE) Traditional	Virtual
1	Prothrombin times purpose	73.5 (3.4)	74.9 (4.8)
2	Use of Thromboplastin	84.0 (5.2)	96.1 (2.6)
3	Phospholipid function	87.1 (2.6)	99.4 (0.6)
4	Calcium function	74.3 (8.8)	92.6 (1.5)
5	Non-activated PTT	91.6 (5.8)	89.0 (2.1)
6	Thrombin time	90.5 (3.2)	91.8 (2.3)
7	Factor VIII deficiency	88.9 (5.6)	95.2 (0.9)
8	Inhibitor/Inactivator study Case Study 1	84.4 (1.7)	84.3 (4.6)
9	An abnormal APTT correction	89.7 (2.5)	87.9 (2.9)
10	Inhibitor/Inactivator Case Study 2	80.6 (3.2)	76.3 (4.1)
11	Heparin Concentration Calculation	76.1 (3.9)	91.1 (1.1)
12	Factor Assay Interpretation	86.2 (4.4)	95.3 (3.1)
13	Factor Assay Procedure	78.1 (1.6)	87.6 (4.8)
	Overall*	83.5 (1.7)	89.4 (2.1)

* Significant p=.019

Clinical preceptor evaluations of student performance, collected as part of the routine evaluations during the clinical experience, were compared for students in the traditional vs. virtual group. Preceptors were not informed in advance of the change in curriculum delivery format to prevent bias in their evaluation ratings. The clinical evaluation form was open ended and asked questions about students' level of content preparation and ability to interpret results. Finally, students in the virtual group were asked to complete an optional survey exploring their satisfaction with the virtual laboratory units, ease of access and navigation, as well as soliciting suggestions for improvement of content and delivery.

RESULTS

Analysis of Student Performance Outcomes

Student results were compared based on their course delivery format, using the "percent correct" on the exam test questions and performance on the Board of Certification (BOC) sub-discipline as the dependent student outcomes. A comparison of GPA by student cohort year ($F_{(1,5)}$=.666; p=.649) and by delivery format ($t_{(204)}$=-1.562; p=.120) found no significant differences indicating there was no need to control for student GPA in the analysis of student outcomes.

The results for individual questions were mixed between the groups. The virtual delivery students performed better than traditional delivery students on some questions, at the same level on some questions, or poorer on other questions. A t test was performed to compare the total number of test items correct on the hemostasis exams and to compare student performance on the related sub-discipline on the BOC exam. Student cohort scores on the BOC showed no significant differences between the course delivery formats ($t_{(1,4)}$=7.329; p=.054) while a significant difference was found for student performance on the on-campus test questions ($t_{(1,4)}$=14.664; p=.019). Further review showed that the overall mean percent correct on the exam questions was higher for the virtual delivery student group (M=89.4%) compared to the traditional delivery student group (M=83.5%) (Figure 1).

Clinical preceptor evaluations of student performance during their clinical experience also showed no appreciable differences between the traditional and virtual groups of students. Rating of students' preparation for their clinical experience in hematology (which included hemostasis) and their performance on the bench remained at a satisfactory/competent or exceeds expectation levels.

Analysis of Survey Results

Sixty five of the 171 students (38%) in the virtual delivery group completed the optional survey. Four students experienced some technical difficulties such as slow loading or screen freezes, but these students were connected to the Internet via phone modem. None of the students connected by cable modem or via digital subscriber line (DSL) reported having any loading or connection problems.

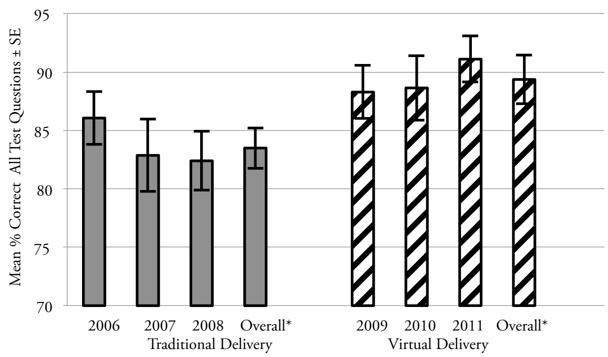

Figure 1. Average student scores on campus exam questions by cohort year. Years 2006 – 2008 students were instructed with face-to-face lectures and hands-on laboratory exercises. Years 2009-2011 received instruction through online lecture presentations and virtual laboratory exercises. Overall performance by delivery method was significantly different (* $t_{(1,4)}$=14.664; p=.019).

Eighty nine percent of the students used a PC based computer while the remaining 11% used a MAC based computer. Forty-five percent of students used Internet Explorer, 20% Mozilla, 4.5% Safari, and 1.5% Google Chrome as their Internet browser. None of these differences resulted in any access problems or utilization issues.

The vast majority of students (97%) felt that the virtual delivery was effective, provided confidence in understanding, and was easy to navigate. Students stated that they liked the ability to work with the modules at any time of day or night (48%) as well as the ability to repeat the modules multiple times (16%). They felt the ability to repeat the units along with the interactive nature helped build confidence in their understanding of the content and testing method (16%). They also felt that the online modules were straight-forward and concise and helped them focus on the content and purpose of the lesson.

DISCUSSION

With the evolution of htesting toward fully automated methods and the lack of affordable commercial instrumentation, the program faced the need to adapt its method of teaching in this discipline. Adding to the situation, a coordinate campus site was opened for the CLS Program requiring delivery of the same course content at a distant location 90 miles away. One of the options was to convert the hemostasis unit to a set of online lecture and virtual laboratory modules. CLS faculty worked with an instructional design team, versed in online education, to create five virtual hemostasis laboratory exercises that mimicked the manual methodologies along with web-based didactic instruction. The instruction design team was a critical factor contributing to the success of the virtual laboratory exercises providing a strategic design for student-focused delivery of course materials. Instructional designers guided faculty in converting the course to an online format, ensuring that the course materials aligned with the unit goals and objectives and in turn, the activities and assessments. Although a long-term traditional delivery format course had been in place prior to initiating this project, it took about four months to design the virtual course. Much of this additional time was spent developing more detailed explanations within course materials. Because the instructor is not physically present to answer student questions as they arise in the online course, instructors had to integrate anticipated questions into the course materials and environment for optimal student support.

One of the unanticipated problems came from the students' inability to access some of the course materials through different Internet connections. Most image and video files were too large for phone modem access, causing access problems for some students. A temporary solution was to direct students to on-campus computer labs for course material access. It became evident that in addition to specifying the minimum technical requirements for student computers, it was necessary to specify how they should best access the Internet. During the last year of the study and for the future, students entering the CLS program were required to have access to either cable or DSL connections to the Internet. Internet access speed could be a concern for future expansions to more rural coordinate campuses until adequate high speed Internet infrastructure is developed at those locations.

Complete course conversion to a digital simulation format is rarely contemplated years in advance. One of the things that limited the ability to provide a more intense review of student and program outcomes was the number of questions that could be included in the study analysis. The hemostasis final exam questions varied considerably over the six year span of the study prohibiting longitudinal comparisons for the study groups. Although the questions are similar from year to year, the instructors purposely modify the exam to minimize opportunities for cheating. Only 13 of the original exam questions stayed exactly the same over the entire study period and therefore had complete performance data for all six years. The small number of questions could have limited the sensitivity of the analysis. Because BOC platelet/hemostasis sub-category data was not available for individual students, the study had to rely on aggregate data, rather than on individual matched datasets. A more comprehensive approach to data collection and storage has been implemented so that future studies will not suffer the same limitations.

This study examined student performance on exam questions before and after changing the course delivery method from a traditional classroom to a virtual classroom. Test question analysis showed that the students in the virtual delivery format group performed significantly better than the traditional delivery format group on course exams but there was no difference in their performance on the BOC. However, because the campus exam questions represented only a small portion of the course questions, the significance may not be entirely valid. Since there was no significant difference in the BOC scores, the project was considered successful for accredited program evaluation. Because the CLS Program may expand to other coordinate campuses, also at some distance from the main campus, this study was a critical accomplishment. Students in this study enjoyed the flexibility of learning the course material on their own time and the flexibility of repeating exercises to build understanding.

SUMMARY

Many universities and health science programs in particular have embraced the development of online education and virtual laboratory experiences to enhance student learning and expand access.[1,7] In this study, a set of virtual lecture and laboratory exercises were developed to replace traditional wet laboratories and face-to-face lectures. Although literature has shown that students in online instructional delivery formats reach equivalent outcomes to students in traditional delivery formats, it was essential that as an accredited MLS 2+2 program, the efficacy of this new delivery format be evaluated for the student and program outcomes. The success of this project encourages the exploration of other areas of laboratory science education that could be converted or enhanced through application of digital learning models.

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