Novel Module Improves Interdisciplinary Learning of Glomerular Filtration

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Abstract – **In order to improve understanding of capillary filtration, a fundamental biomedical concept, a module that presents capillary filtration in the context of glomerular filtration has been developed and incorporated into the curriculum of the Harvard-MIT Division of Health Sciences and Technology renal pathophysiology course. The module replaces traditional instruction, with two interactive online exercises that present core content and provide real time formative assessment to students. A novel Java simulation of glomerular filtration that permits manipulation of independent variables while displaying the dependent variables is projected during the lecture. Knowledge based outcomes demonstrate that students who used the module have improved mastery of the three learning objectives compared to those taught using traditional techniques. Recently, we have analyzed the patterns of incorrect responses in the tutorials and developed specific feedback for common mistakes, which the majority of students found to be helpful.**

Index Terms – Online, module, capillary filtration, simulation

INTRODUCTION

The concepts underlying capillary filtration are fundamental topics in physiology courses taught to medical students and undergraduate and graduate biomedical engineering students. Students report anecdotally that this material is difficult to master. Furthermore, overall exam performance does not correlate with performance on questions regarding capillary filtration. A module that presents capillary filtration in the context of glomerular filtration has been developed and incorporated into the curriculum of the Harvard-MIT Division of Health Sciences and Technology renal pathophysiology course.

Module design is based on the learning and teaching principles outlined in *How People Learn* [1]. It replaces traditional instruction of the same material, which consisted of a lecture, paper based problem set and assigned textbook reading. The module replaces the traditional problem set and textbook reading with two interactive on-line exercises that present content and provide real time formative assessment to students. The first exercise is assigned prior to the lecture and presents basic concepts including hydrostatic and oncotic pressure. Student performance and feedback collected during this exercise informs the lecture content and thus tailors it to the learners. A novel Java simulation of glomerular filtration that permits manipulation of independent variables while displaying the dependent variables is projected during the lecture. It expands the range of examples that are presented by the lecturer and facilitates interaction between students and the lecturer. Feedback from students and faculty was positive, and has led to improvements in the module implementation.

Knowledge based outcomes demonstrate that students taught using the module have improved mastery of the three learning objectives (effect sizes = 0.46, 0.42, 0.25) than those taught using traditional instructional techniques. This assessment was derived from comparison of rubric-based scores of student responses to exam questions following traditional instruction (n=39) and module based instruction (n=46).

In addition, we have found that both student undergraduate major and student graduate program had an impact in their preference of learning tools, when asked to choose between the capillary filtration module versus a more traditional textbook and problem set used to teach the same material. While a majority of all students prefer the new module, Ph.D. students showed a greater preference than MD or MD/PhD students and students with an undergraduate background in biomedical engineering showed a greater preference that those who majored in biological or physical sciences.

Future efforts will focus on dissemination to other classrooms, such as the undergraduate physiology class at Northwestern University, which has already used the module, as well as continued improvements to insure that students from all backgrounds find the module accessible and useful.

MODULE DESIGN

The goals for the capillary filtration module and pedagogical framework applied are detailed in previous publications [2-5]. A brief summary is presented here for those unfamiliar with our previous work. The module includes two on-line learning exercises, an in-class lecture, a dynamic java-based computer simulation of glomerular filtration for use by faculty and students and questions designed to be used as part of a course exam. In order to make the module interesting to a broad range of students, the fundamental concepts of capillary filtration are presented using a How People Learn legacy cycle format, in which a clinical case serves as the unifying challenge and intellectual basis of the module. Students complete the first exercise prior to the in-class lecture. Both on-line learning exercises are delivered on-line using the CAPE/elms learning technology that has been developed as part of the VaNTH (Vanderbilt University, Northwestern University, University of Texas and HST) Biomedical Engineering Education Research Center (figure 1). We present the fundamental concepts and the clinical case for the students to consider using both graphics and text, and throughout the module they are prompted to answer questions on which they receive immediate feedback. The lecturer uses data from student responses collected during the first on-line exercise to inform the content of the lecture. The computer simulation is used during the lecture to demonstrate examples and probe student reasoning (figure 2). Manipulation of the input variables using the sliding bars causes real time changes in the output graphs of hydrostatic pressure, oncotic pressure and filtration rate. Students complete the second exercise following the lecture.

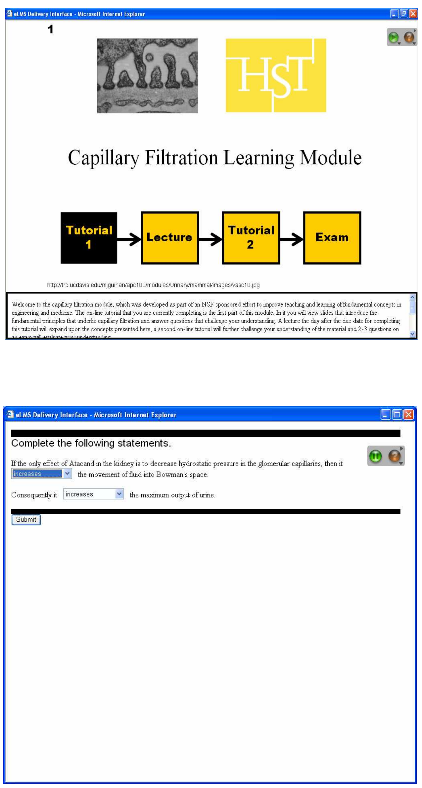

FIGURE 1
SCREEN SHOTS OF INSTRUCTION (UPPER) AND FORMATIVE ASSESSMENT QUESTIONS (LOWER) FROM THE ON-LINE LEARNING EXERCISE

There are many innovative aspects of this module. The first is that the first online exercise substitutes for the traditional textbook reading and problem set. Formative assessment during the exercise helps reinforce and redirect student understanding. In addition, it allows the instructor to gather data on the learners' understanding prior to the lecture. Second, the use of the challenge about patient treatment in both exercises serves to motivate student learning about physical principles underlying capillary filtration and their implications for physiology and pathophysiology. This allows us to reach the biomedical engineers who have seen this material before,
by using a new spin on familiar content. This also allows us to reach medical students by making the topic more related to their studies. In addition, this allows us to help students without strong physical science and engineering backgrounds to feel more comfortable with a potentially imposing and anxiety-provoking material by couching it in a biological context. Third, the glomerular filtration simulation expands the range of examples that can be explored, and its small file size and user-friendly nature make it easy for both faculty and students to use.

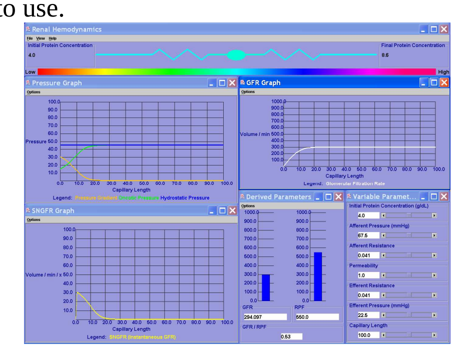

FIGURE 2
SCREEN SHOT OF THE GLOMERULAR FILTRATION SIMULATION

ASSESSMENT OF STUDENT LEARNING

The initial module was piloted each of two sites to different levels of students (graduate and medical students at HST and undergraduate students at Northwestern University) in 2003 (module 1). A dramatically revised module (module 2) has been implemented at both sites in 2004 and 2005. Student responses to relevant exam questions following completion of the module was compared with those collected following baseline instruction of this material in 2002. Assessment of the student responses was performed using a 14-point rubric.

Two domain experts independently evaluated each student's exam responses on each point in the rubric. Consensus was reached on any points about which they disagreed. The 14 points for each student, as agreed upon by the domain experts, were then sorted according to the learning objective they represent and subtotaled within the learning objectives in order to obtain a score for each student with regards to each of the three learning objectives. These scores were normalized to scores between 0 and 1. Averages and standard deviations of the baseline results and those for each version of the module are given in table 1. Averages of the baseline results and those for the first two modules versions are illustrated in figure 3. Effect sizes were calculated by dividing the difference between the module and baseline means by the baseline standard deviation in order to compare the results. We have found that the second version of the module demonstrates mild improvements in student knowledge for all three learning objectives and overall.

TABLE I

COMPARISON OF STUDENT KNOWLEDGE OF CAPILLARY FILTRATION LEARNING OBJECTIVE FOLLOWING THREE INSTRUCTIONAL METHODS.

Learning Objective	Baseline (n=39)		Module 1 (n=46)		Module 2 (n=46)		BL vs. M1	BL vs. M2
	avg	std dev	avg	std dev	avg	std dev	Effect size	Effect size
Oncotic pressure	0.52	0.27	0.36	0.28	0.64	0.32	-0.61	0.46
Flow, resistance, pressure	0.63	0.36	0.71	0.29	0.72	0.26	0.23	0.25
GFR determinants	0.44	0.26	0.35	0.26	0.54	0.28	-0.34	0.42
All questions	0.66	0.19	0.56	0.21	0.49	0.21	-0.34	0.47

Maximum score is 1, n is the number of students, effect size > 0.2 is a mild positive effect of the module on student knowledge, effect size > 0.5 is a moderate effect of the module on student learning

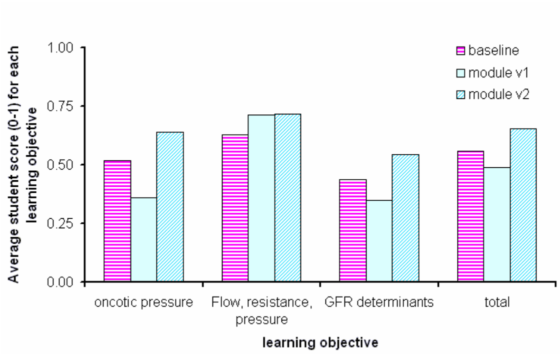

FIGURE 3
EFFECT OF CAPILLARY FILTRATION MODULE ON AVERAGE STUDENT PERFORMANCE

ASSESSMENT OF STUDENT FEEDBACK

Student feedback and demographics were collected at the end of each exercise using the same on-line interface. Subjective feedback has been positive with 72 percent of the graduate students who have been taught with the new module in HST expressing preference for online exercises over a more traditional textbook reading and problem set assignment. Negative feedback has been minimal and related mostly to technical difficulties, which were addressed during subsequent implementations of the module

To take our analysis of student feedback further, we analyzed the effect of student background and program on their stated preference of either computer exercise or textbook reading and a paper based problem set. One might imagine that a student with an undergraduate degree in biomedical engineering would be more adept or interested in a clinical case dealing with core biomedical concepts that were familiar to them. However, it is also possible that students with an undergraduate major in biology might not have as much experience with these core concepts and might appreciate the remediation provided by the module and the use of biology to teach a complex and quantitative concept. Student demographic and feedback data collected during the three years that the novel module was used in the Harvard-MIT Division of Health Sciences and Technology was pooled to investigate this issue. While the majority of students from all backgrounds prefer the capillary filtration module to the traditional textbook and problem set instruction (Table 2 and Figure 4), there were differences among subgroups of students. Interestingly, a background in biomedical engineering makes a student most likely to favor the computer exercises over traditional homework, while those who were biological science majors were least likely to favor the new instruction methods (Table 2 and Figure 4).

TABLE 2

THE EFFECT OF UNDERGRADUATE MAJOR ON STUDENT PREFERENCE FOR LEARNING TOOLS

UNDERGRADUATE MAJOR	**NUMBER OF STUDENTS WHO PREFER COMPUTER TO TEXTBOOK AND PROBLEM SET**	**TOTAL NUMBER OF STUDENTS**	**PERCENTAGE OF STUDENTS WHO PREFER COMPUTER TO TEXTBOOK AND PROBLEM SET**
PHYSICAL SCIENCES	**34**	**47**	**72.3**
BIOMEDICAL ENGINEERING	**13**	**16**	**81.25**
BIOLOGICAL SCIENCES	**24**	**35**	**68.6**
ALL	**71**	**98**	**72.4**

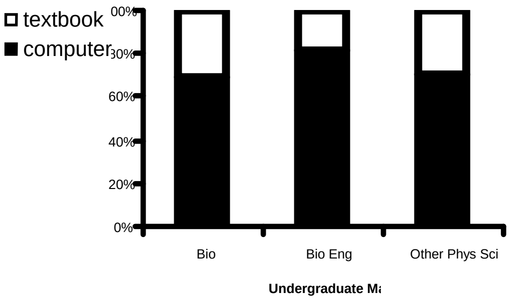

FIGURE 4
EFFECT OF UNDERGRADUATE MAJOR ON LEARNING TOOL PREFERENCE

In addition to their previous undergraduate program, the graduate program that a student has chosen to pursue may also provide a different academic background or reflect a different set of interests that may be reflected in their preferences for the new capillary filtration module versus traditional instruction (Table 3 and Figure 5). In our sample, Ph.D. students prefer the online exercises more than the M.D. or MD/Ph.D. students, who were equivalent in their preferences.

TABLE 3

THE EFFECT OF GRADUATE PROGRAM ON STUDENT PREFERENCES FOR LEARNING TOOLS

GRADUATE PROGRAM	NUMBER OF STUDENTS WHO PREFER COMPUTER TO TEXTBOOK AND PROBLEM SET	TOTAL NUMBER OF STUDENTS	PERCENT OF STUDENTS WHO PREFER COMPUTER TO TEXTBOOK AND PROBLEM SET
MD	35	53	66.0
MD/PH.D.	13	19	68.4
PH.D.	23	28	82.1
ALL	71	100	71

Variability in total number of students between table 2 and 3 is due to students who did not report all of their biographical information, so could not be included in both tables.

While the majority of students prefer the new capillary filtration module to traditional instruction of the same material, we are most effectively reaching students with a background in biomedical engineering that have chosen to pursue a Ph.D. In future alterations of the module, we will try to specifically target the learning preferences students with a background in biological sciences and physical sciences, as well as the MD and MD/Ph.D. students. One element of their relative dissatisfaction may be due to a persistent lack of understanding of the core concepts.

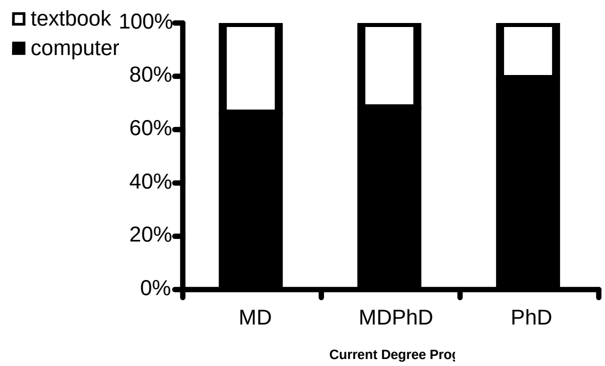

FIGURE 5
EFFECT OF GRADUATE PROGRAM ON LEARNING TOOL PREFERENCE

In the implementation for 2006, we have incorporated more specific feedback on the formative assessments. For the questions with set responses, for example, whether a variable will increase or decrease, we give specific feedback to the student based on their answer to the question. For the quantitative questions, we have gone through and analyzed the patterns of incorrect response and developed specific remediation to address the core concepts that have been confused by the student. This way we can specifically address each students individual needs in real-time. Thus we hope to make one module an individualized experience for students from different backgrounds and with divergent goals and programs, allowing us to achieve optimal interdisciplinary impact.

SUMMARY

We have created a learning module for glomerular filtration that replaces traditional teaching of the same material in a renal pathophysiology class offered by the Harvard-MIT Division of Health Sciences and Technology. This curricular revision focuses on improving assessment centered and knowledge centered aspects by providing feedback during learning and focusing on fundamental concepts. Qualitative feedback from students and instructors has been positive and quantitative analysis of student responses on examinations indicate that student learning of three learning objectives improved following instruction with the new curriculum compared with that following instruction with the original curriculum. We have identified subgroups within the learners who respond particularly well to the material. Our current goal is work on the learner centered aspects of the curriculum by providing mechanisms for students of different backgrounds to customize the module to their needs, based on the results of their formative assessments and their interests. Future efforts will also focus on packaging the module for easy dissemination to other classrooms and institutions.

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