Novel Module Improves Learning of Capillary Filtration

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Abstract

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

Module design was based on the learning and teaching principles outlined in *How People Learn*[1]. It replaces the 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 on-line exercise informs the lecture content and is used by the instructor to tailor it to the learners. A novel java based simulation of glomerular filtration that permits manipulation of independent variables while displaying the dependent variables is projected during the module's lecture (and available for use by learners outside of 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 following implementation of the module was positive, and specific feedback helped guide a re-implementation of the module with more opportunities for learning and formative evaluation before and after the lecture.

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). Future efforts will focus on refinement and packaging of the module for dissemination to other classrooms, such as an undergraduate physiology class at Northwestern University, which has already used the module.

Module Structure

The goals for the new module and pedagogical framework applied are outlined in a previous publication[2].

The module includes two on-line learning exercises, guidelines for a lecture that occurs after the first on-line exercise has been completed and before the second one is started, a dynamic computer simulation of glomerular filtration for use by faculty and students and exam questions that can be used for summative assessment. The time needed for the module is 1 hour of class time and 2 hours of homework (1 for each on-line exercise).

The on-line learning exercises are centered on understanding a patient's response to a drug, through qualitative and quantitative analysis of pertinent physiology. Students are given information and prompted to answer questions on which they receive immediate feedback. Both exercises are delivered using CAPE/elms learning technology that was developed as part of the VaNTH (Vanderbilt University, Northwestern University, University of Texas and HST) Biomedical Engineering Education Research Center (figure 1). One exercise is assigned prior to the lecture and the other following the lecture.

The lecture content is informed by data from student responses collected during the first on-line exercise. Its goals are to reinforce key material, address points of misunderstanding and present new material. The computer simulation is used during the lecture to demonstrate examples and probe student reasoning. It is an executable java file that is easily accessed on-line (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.

There are many innovative aspects of this module. The first is that the first online exercise substitutes for traditional textbook reading. Unlike reading, module completion can be confirmed. Formative assessment during the exercise helps reinforce and redirect student understanding and provides the instructor with data on the learners' understanding prior to the lecture. This enhances the learner and assessment centered aspects of instruction. 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. Finally, the glomerular filtration simulation expands the range of examples that are used in lecture to an infinite number and is effective when used in an interactive manner. Its small file size and user-friendly nature make it easy for faculty and students to use.

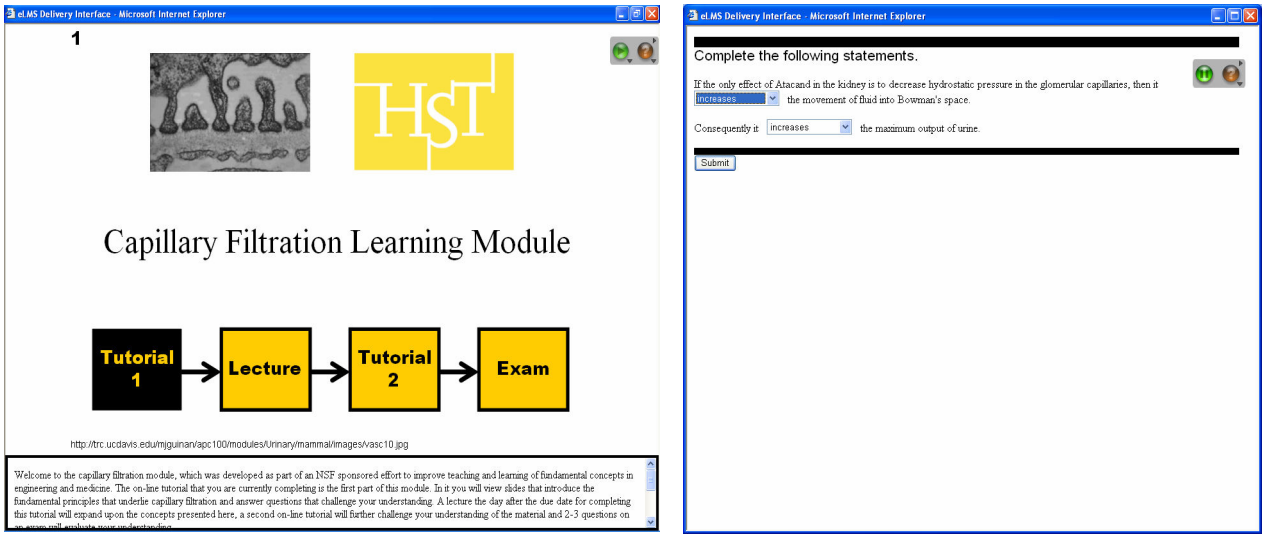

Figure 1:Screen shots of information slide (left) and question slide (right) from an on-line learning exercise

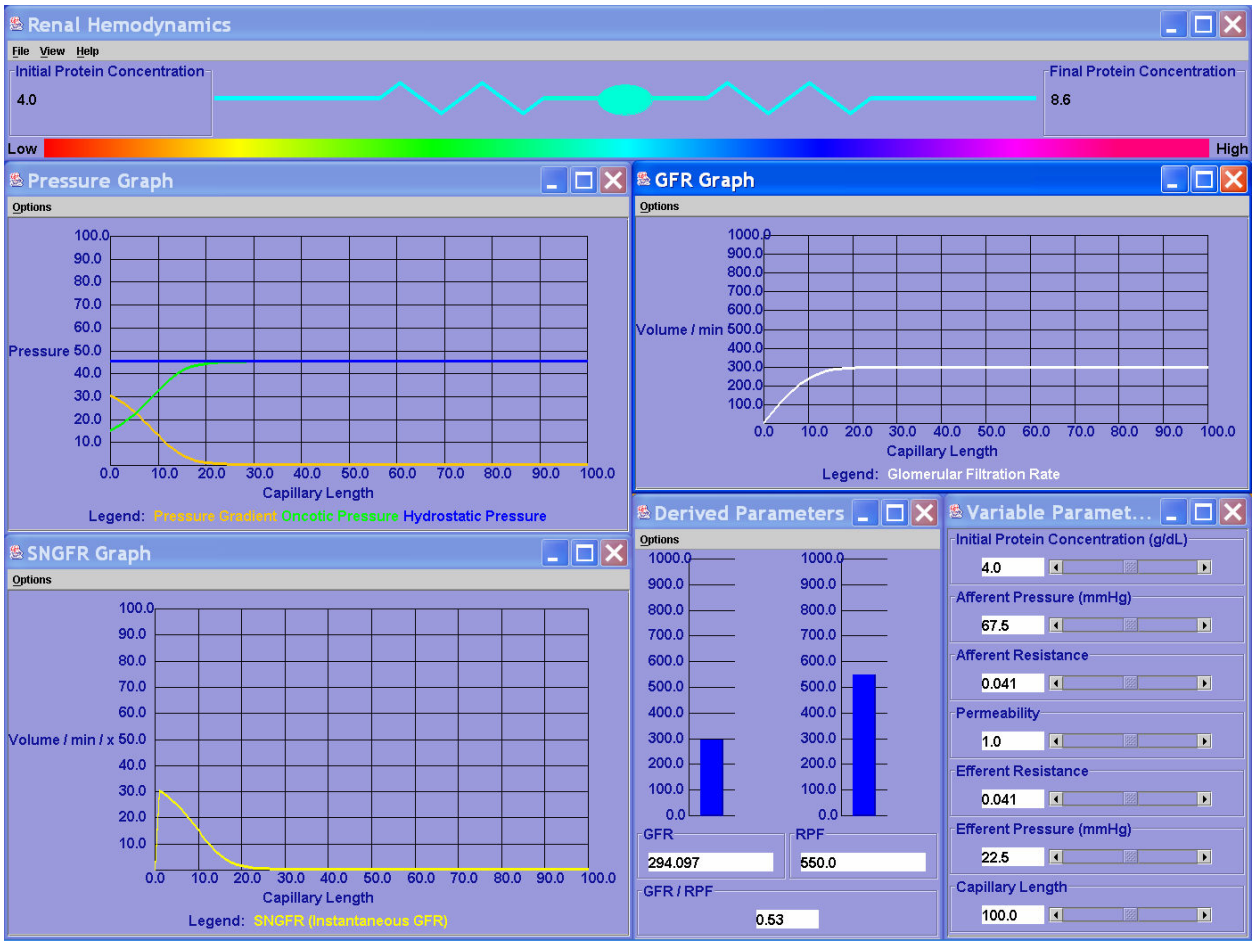

Figure 2: Screen shot of glomerular filtration simulation

Assessment of learning changes

In order to assess the glomerular filtration module, comparisons were made between data collected during administration of the module with those collected during previous course offerings. Important dimensions to be assessed included student learning, student enjoyment and instructor observations. The objective of improving student learning was evaluated using exam responses. The quality of responses to knowledge based glomerular filtration questions from a previous course offering was compared with responses to the same questions by students who are taught using the new module. Both sets of responses were quantified using a rubric that captures the degree to which students demonstrate understanding or lack thereof. Feedback was collected from students and instructors throughout the presentation of the new module to evaluate the degree to which the revised presentation agrees with self reported preferences. This information also evaluated the functionality of the learning tools being used, namely the on-line tutorials and the simulation.

The initial module was piloted each of two sites to different levels of students (graduate/medical students at HST and undergraduate students at NWU) in 2003. A dramatically revised module has been implemented at both sites in 2004. It is this revised module that is being disseminated. Student responses to exam questions following completion of the module are being compared with those collected following traditional instruction of this material in 2002. Assessment of the student responses was performed using a 12-point rubric. Two domain experts independently evaluated each student's responses. Consensus was reached on any points about which they disagreed. The 14 points for each student, as agreed upon by the domain experts, are 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 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. The second version of the module demonstrates mild improvements in student knowledge for all three learning objectives and overall. Assessment of data from the second pilot site is underway.

Table 1: Comparison of student knowledge of capillary filtration learning objective following three instructional methods, maximum score is 1, n is the number of students, effect size > 0.2 is mild positive effect of the module on student knowledge, effect size > 0.5 is a moderate effect of the module on student learning.

Learning Objective	Baseline (n=39)		Module 1 (n=46)		Module 2 (n=46)		BL vs. M1	BL vs. M2
	ave	St dev	ave	St dev	Ave	St 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

Student feedback has been positive with a majority of students expressing preference for on-line exercises over textbook reading. Negative feedback has been minimal and related mostly to technical difficulties, which have been addressed. Instructors have noted that the pre-lecture exercise prepares students for the lecture and that the feedback generated during the exercise helps identify student difficulties that they otherwise might not have identified.

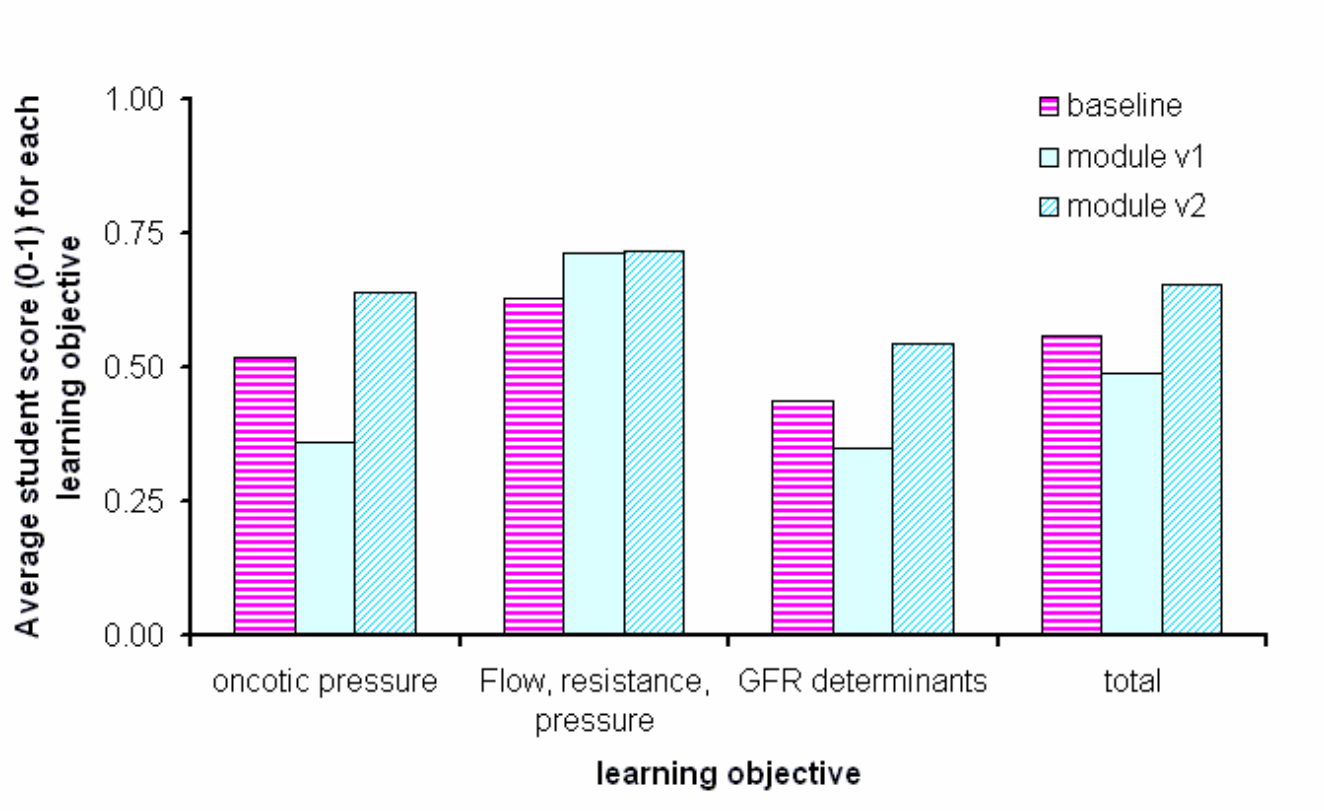

Figure 3: Effect of capillary filtration module on average student performance

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. Two versions have been used during the past two offerings of the course. 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. Future efforts will focus on packaging the module for easy dissemination to other classrooms and institutions.

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References

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Biographies

HEATHER E. GUNTER received her Ph.D. in Medical Engineering from the Harvard Division of Engineering and Applied Sciences and the Harvard-MIT Division of Health Sciences and Technology in 2003 and expects to receive her M.D. from Harvard Medical School in 2005. Her interests in engineering education stem from observations made during two decades as an education consumer and more recent experience as an education provider.

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