Computer Simulation and a Realistic Simulator in Conjunction with the New Educational Style *How People Learn* (HPL) to Improve Learning Achievements

Tilo Winkler, Ph.D., Rudolph Mitchell, Ed.D., and Jose G. Venegas, Ph.D.

Harvard Medical School / Harvard-MIT Division of Health Sciences & Technology (HST) / Massachusetts Institute of Technology (MIT)

INTRODUCTION

Traditional lectures are well suited to teaching of systematic content but lack active hands-on experience. The NSF publication "How People Learn" (HPL) suggests that challenging students with realistic problems and high levels of freedom for problem solving motivates students and supports learning. In the case of lung physiology, medical, as well as biomedical, students are expected to understand respiratory mechanics and gas exchange. Learners find this material difficult because of the basic abstract non-intuitive concepts that govern relationships between respiratory pressures, flows and volumes and gas exchange in spontaneous and mechanical ventilation. In addition, they often fail to see the clinical relevance of such concepts when they are presented in lecture.

New learning technologies such as computer simulations and realistic simulators can help students to overcome some of the difficulties they confront in learning respiratory mechanics and gas exchange. With a computer simulation running in real-time, students can elaborate on lecture content by exploring in a cognitively active manner mechanisms and complex interactions within the respiratory system. Although a realistic simulator (computer-controller mannequin) presents clinically measurable parameters with less mechanistic detail, it exposes students to broader physiological interactions between physiological systems and immerses them in a motivating and challenging realistic environment. Including these new technologies into courses that pose conceptual challenges comparable in complexity to that of respiratory physiology may enhance student learning.

The National Science Foundation (NSF) has been funding a major educational program that involves Vanderbilt University, Northwestern University, University of Texas, and the Harvard-MIT Division of Health Sciences & Technology (VaNTH) [1] to develop new educational styles and to introduce them in teaching bioengineering to undergraduate and graduate students. The main thrust of the project is based on concepts presented by the NSF publication *How People Learn* (HPL) [2]. The concept is to challenge the students with a set of realistic problems and give them a high level of freedom on the methods chosen by them for solving them.

As part of the VaNTH program we have incorporated the use of computational and realistic simulations into the teaching of respiratory physiology at the Harvard-MIT Division of Health Sciences & Technology (HST). The project is part of the VaNTH-ERC strategic plan to develop modules for a systems physiology domain. In the program of a course on Respiratory Physiology, we hypothesized that a hands-on laboratory using simulation would challenge the student's knowledge, provide insight into complex interactions, and motivate the students to expand the material taught during lectures. We also hypothesized that improved learning would be achieved by using a realistic simulator based on a computer-controlled mannequin and a computer simulator with a sophisticated mathematical model that allows for exercise of theoretical principles.

METHODS

The Committee on Human Studies of our Institutional Review Board has evaluated our study and declared an exempt from review. We used the Harvard-Anesthesia realistic simulator that includes a computer-controlled mannequin in typical and highly realistic clinical environment. For the realistic simulation each group of three to four students, assisted by an instructor ("respiratory therapist"), was presented with a clinical case for management. This hands-on experience lasts about 30 to 40 minutes. The same time spent students observing the case management of another group from the outside through a one-way mirror while discussing the difficulties and progress of the case with a tutor. At the end, students meet for a debriefing of 60 minutes in groups of six to eight students each.

For computer simulation we used SimuVent, a computer based sophisticated model of lung mechanics and gas exchange during spontaneous and mechanical ventilation. SimuVent provides an intuitive interface (Fig. 1), that is simple to control, and that hides the complex modeling used for the simulation. SimuVent is designed for interactive learning and teaching of basic as well as complex relationships and allows exploration of effects of respiratory parameters and variables of normal homogeneous or pathological inhomogeneous lungs. The program is available to the students during the duration of the course and is integrated to the class in HPL-style modules that promote effectiveness of learning.

During three courses in the years from 2002 until 2004 we evaluated three programs of simulator use: realistic simulator with debriefing followed by computer simulation as interactive presentation (IP), computer simulation as basic homework problem set (BH) before realistic simulator with debriefing, and detailed introduction to computer simulation and more challenging homework problem (CH) set before realistic simulator with debriefing.

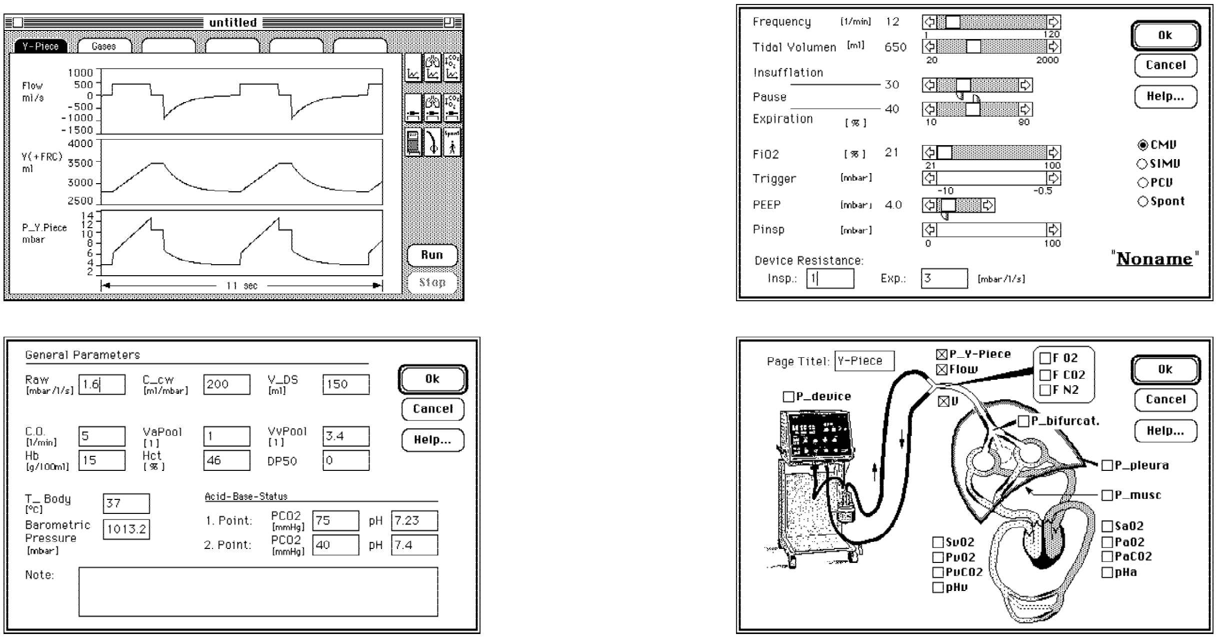

Figure 1. Graphical user interface of the computational model SimuVent. *Top left*: Main window with flow, volume, and pressure curve. *Top right*: Dialog to adjust the ventilator settings. *Bottom left*: One of five dialog windows to set model parameters. *Bottom right*: One of three dialog windows to select model parameters to view.

After the students finished the simulations and debriefing they were asked to evaluate the three components of the simulation exercise: realistic simulation, computer simulation and debriefing. We used six questions for all three components addressing learning of theoretical issues, practical issues, complexity, motivation, difficulty, and extension (Fig. 3).

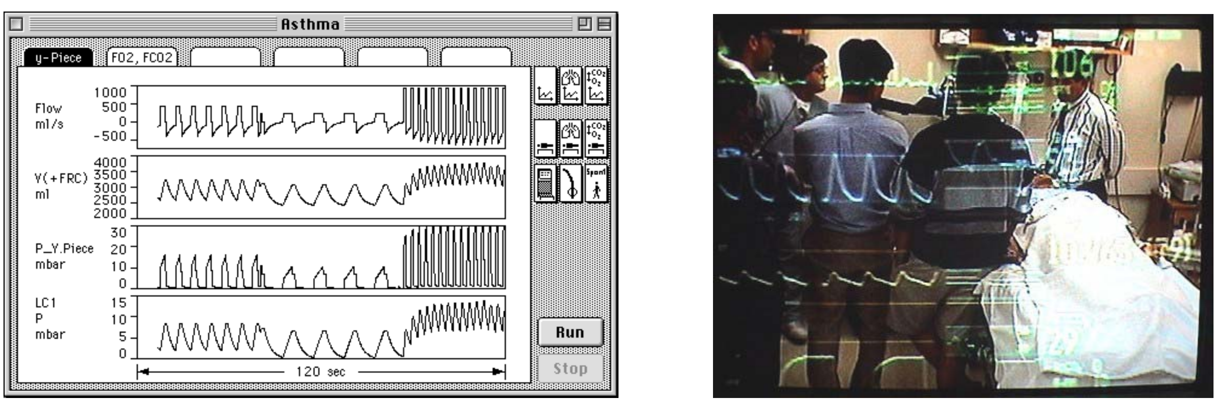

Figure 2. How students work with the simulators. *Left*: Example of a computer simulation to analyze an asthma case and to try to improve the mechanical ventilation as well as blood gases. *Right*: In the realistic simulator session students are challenged to solve a clinical case that involves mechanical ventilation, systemic circulation, and other problems.

	Realistic Simulator	Computer Simulation	Debriefing
I learned many theoretical issues from the …	☐	☐	☐
I learned many practical skills from the …	☐	☐	☐
I learned complex interactions (e.g. inhomogeneous ventilation, or ventilation mechanics and gas exchange) from the …	☐	☐	☐
I was very motivated by the …	☐	☐	☐
Learning and training was too difficult using the …	☐	☐	☐
I would like to do more with the …	☐	☐	☐

Figure 3. Questionnaire for the assessment of the students' responses to the realistic simulator, the computer simulation, and the debriefing. The students were asked to use a scale from 1 (disagree) to 5 (agree) for scoring of the three components of the simulation exercise.

RESULTS

We received 109 responses during the survey: 39 for program IP, 40 for BH, and 33 for CH. Each individual student only experienced one program. Students following the program IP provided the highest scores to all questions about the realistic simulator, except for the detractor question. These scores were markedly higher than those for the computer simulation and debriefing (Fig. 4). Scores provided by students following programs BH and CH were also the highest for realistic simulator, but with smaller differences from the scores for debriefing (Fig. 4). These results demonstrate the impact of the realistic simulator on the students' learning and the value of the realistic simulator as an important technology for teaching.

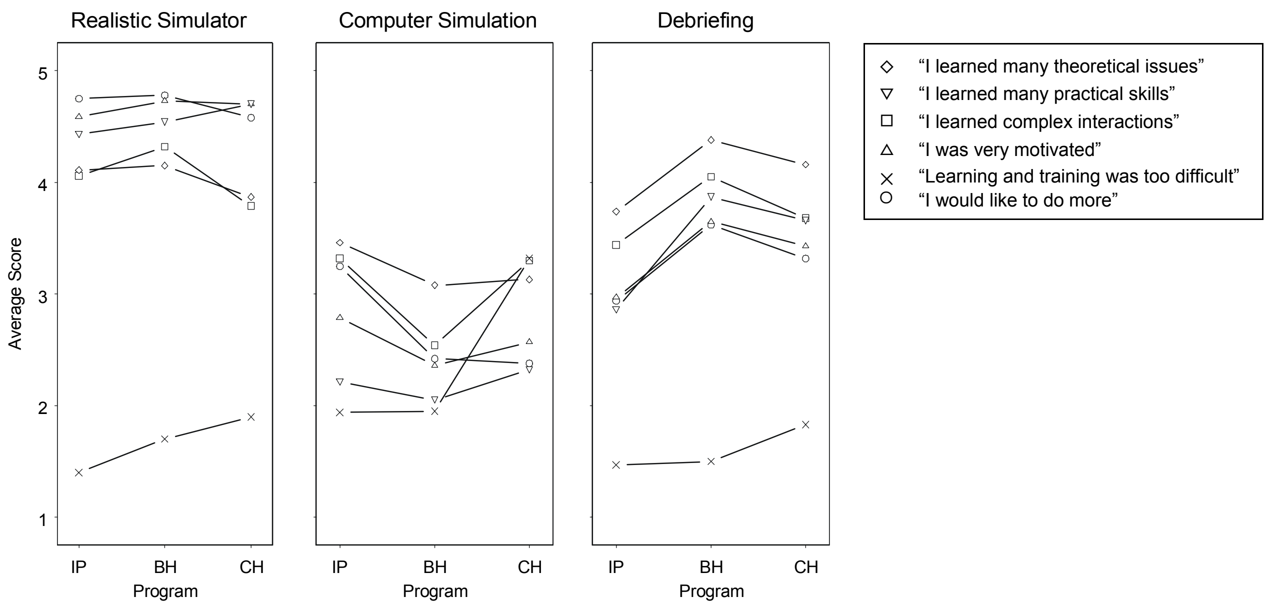

Figure 4. Average scores for each question of the survey show big differences between the three components: realistic simulator, computer simulation, and debriefing. The change of the average scores between the programs computer simulation as interactive presentation (IP), computer simulation as basic homework (BH), and computer simulation as challenging homework (CH) show the impact of how computer simulation is used during the course.

We observed an approximately consistent ranking of the average scores for each question in the different programs. Interestingly, students tend to give similar scores to all positive questions about one component of the study (e.g. realistic simulator) rather than differentiating between questions about issues (e.g. theoretical and practical skills).

The average scores of program IP for computer simulation and debriefing were very close while they showed a clear difference for BH and CH. In program IP the differences between average scores to each question of the survey are higher for computer simulation than for the realistic simulator and debriefing.

Surprisingly, the average scores for debriefing were higher for the programs BH and CH than for IP while they were lower for computer simulation. However, the student's instructor reported that the students during program CH were remarkably better prepared for the realistic simulator than students during program IP.

The standard deviations of the scores as a measure of heterogeneity within each question were in a range from 0.6 to 1.2 with an average of approximately 1.0. This leads to an average standard error of 0.17 for a group of 36 students.

DISCUSSION

The engineering principles behind abstract non-intuitive concepts of respiratory mechanics and gas exchange concepts are traditionally taught in didactic lectures supplemented by readings. Although such lectures and texts are adequate to present the important concepts, they fail to give many students an intuitive understanding of normal or abnormal function of the respiratory system. Concepts such as the effects of mode of ventilation on pleural pressure, flow limitation, alveolar recruitment, and interactions in a multiple compartment model are difficult to teach. A major goal of this project was to enhance students understanding of such phenomena through real-time simulation of the mechanical and physical events of respiration.

The lower average scores for computer simulation in program BH than in IP combined with higher average scores for debriefing in BH than IP was surprising because we expected that the individual use of the computer simulation would provide more freedom for learning and that it would motivate the students to explore respiratory physiology. In program CH the students had more difficulties to solve the homework problem set but they learned important details as the reports of the instructor show. This might also explain the much higher interest for the debriefing in the programs BH and CH than in program IP.

A more extended introduction to the computer simulation and guided sessions for small groups could be a major improvement for the future because the concept of using computer simulation to explore respiratory physiology seems to be still problematic for a subgroup of students.

CONCLUSIONS

Our results show significant changes in average scores by students depending on how computer simulation is used during the course. Use of programs with challenging homework for computer simulation may improve performance in subsequent realistic situations.

The analysis of varying programs for the use of computer simulation allows us to optimize current learning modules and to develop further HPL-style modules for lung mechanics and gas exchange that are suitable for export to other universities. Realistic simulators, however, are very expensive and not available at all universities. Thus we are currently to explore methods to replace the realistic simulation by enhanced tools such as adding realistic movies to the computer simulation.

REFERENCES

[1] VaNTH · ERC: Vanderbilt – Northwestern – Texas – Harvard/MIT Engineering Research Center for Biomedical Educational Technologies. See www.vanth.org

[2] Bransford JD, Brown AL, Cocking RR (Eds.): How People Learn: Brain, Mind, Experience, and School: Expanded Edition. National Academy Press, 2000