



# Changing learning with new interactive and media-rich instruction environments: virtual labs case study report

Camillan Huang

*Stanford University Medical School, 251 Campus Dr MSOB x228, SUMMIT, Stanford, CA 94305-5466, USA*

Received 22 July 2002; revised 21 August 2002; accepted 25 August 2002

---

## Abstract

Technology has created a new dimension for visual teaching and learning with web-delivered interactive media. The Virtual Labs Project has embraced this technology with instructional design and evaluation methodologies behind the simPHYSIO suite of simulation-based, online interactive teaching modules in physiology for the Stanford students. In addition, simPHYSIO provides the convenience of anytime web-access and a modular structure that allows for personalization and customization of the learning material. This innovative tool provides a solid delivery and pedagogical backbone that can be applied to developing an interactive simulation-based training tool for the use and management of the Picture Archiving and Communication System (PACS) image information system. The disparity in the knowledge between health and IT professionals can be bridged by providing convenient modular teaching tools to fill the gaps in knowledge. An innovative teaching method in the whole PACS is deemed necessary for its successful implementation and operation since it has become widely distributed with many interfaces, components, and customizations. This paper will discuss the techniques for developing an interactive-based teaching tool, a case study of its implementation, and a perspective for applying this approach to an online PACS training tool.

© 2002 Elsevier Science Ltd. All rights reserved.

*Keywords:* Online curriculum; Educational media; Simulation teaching; Interactive teaching; Physiology; Instructional web design; Picture archiving and communication system training simulator

---

## 1. Introduction and background

In an era with rapid technological advancements, new methods of instruction need to be developed to augment the traditional teaching paradigms. Biomedical Sciences has been mainly taught with conventional educational tools—textbooks, lectures, and wet-laboratories. With new web technologies, rich online learning media can supply current biomedical information to the students, provide engaging instruction with electronic media, and promote their technology proficiencies, all contributing to their professional development.

Online teaching material is slowly being developed, but most sites are merely digital textbooks. There is a strong need for new tools in physiology because of the difficulties in learning and visualizing these concepts. Most conventional teaching materials are linear and static which makes physiology more difficult to teach since the content is

dynamic, with time and causal relationships. Thus, regardless of the instructor or pedagogical approach, students have struggled to create correct mental models of the concepts. The dynamic nature of the topic should be taught with a comparable teaching strategy.

In this paper, the pedagogical design and methodologies behind simPHYSIO will be described and then an evaluation of the system will be shown with a case study. simPHYSIO is a product of the Virtual Labs project. It is a suite of customizable and interactive online teaching media designed to integrate and dynamically teach complex systems using media-rich animations, real-time simulations, and virtual environments. It is a system that has been developed, implemented, and then evaluated for its effectiveness of learning outcomes. These educational strategies will then be discussed in a perspective for developing a Picture Archiving and Communication System (PACS) education system. Because of the complexity of the PACS system and segregation of expertise, it requires a proper education system to integrate the diverse team for a seamless workflow.

---

*E-mail address:* [cammy@summit.stanford.edu](mailto:cammy@summit.stanford.edu) (C. Huang).

The heart of simPHYSIO is an immersive online learning environment designed to teach physiology (neuro, cardiovascular, respiratory, gastrointestinal, and renal physiology) using a high level of integrated visual teaching. The goal of simPHYSIO is to augment the curriculum for the Stanford University Undergraduates taking Biological Sciences and human biology courses. The principles behind the pedagogy include learner-centric design [1,2], that integrates self-exploration, active and meaningful learning strategies [3], motivational media [4–7], and visual teaching. The content is designed for a learner to visualize principles, make predictions, learn problem-solving skills with a ‘hands-on’ approach, apply and test scientific methodologies, and see immediate outcomes from their manipulations. This approach can effectively increase comprehension of the material [3].

The main evaluation questions [5,6,8] during our integration of simPHYSIO into the teaching curriculum include:

1. In what way can web-based media be used to enrich and enhance learning for individual students?
2. In what way does the web-based media alter the student–teacher interaction?
3. How can the faculty be made to embrace new solutions for content management and the new teacher–student interaction that may develop?

This project was developed at Stanford University Medical Media and Information Technologies (SUMMIT) and sponsored by the Howard Hughes Medical Institute [9].

## 2. Materials and methods

Our goal was to develop interactive media-rich teaching modules in physiology for the undergraduate level and

medical school physiology courses. Student focus groups and interviews with faculty directed us to the conceptually difficult content areas. Physiologically difficult concepts were sorted into their respective teaching module category: neuro, cardiovascular, respiratory, GI, renal.

### 2.1. Design development

Content appropriate for the target audience was developed and the pedagogical construct was designed in a storyboarded-format based on our design protocol. Design strategies and protocols established in the current model can be reused to facilitate further content development. Below is the general iterative design strategy for approaching (educational media) development [2,7,10] (Fig. 1).

#### 2.1.1. Investigate and understand

Know your user! In order to design for the user, know who they are, what their needs are, and provide motivational factors—all based on the user’s background.

#### 2.1.2. Define the problem

Establishing the goals for instruction provides a framework for designing the curriculum and learning activities: content, organization, captivating the user. A designer must also be a teacher. When presenting the information, the designer must not only employ their knowledge of learning theory, information design, and human communication, but also have a solid understanding and interpretation of the content.

#### 2.1.3. Concept generalization and visualization

Remember that ~80% of web-users are primarily interested in content and 15% are influenced by design and graphics. Storyboarding is a primary development step that scripts the events on a page. Design concepts can be tested in an initial prototype for flaws before investing

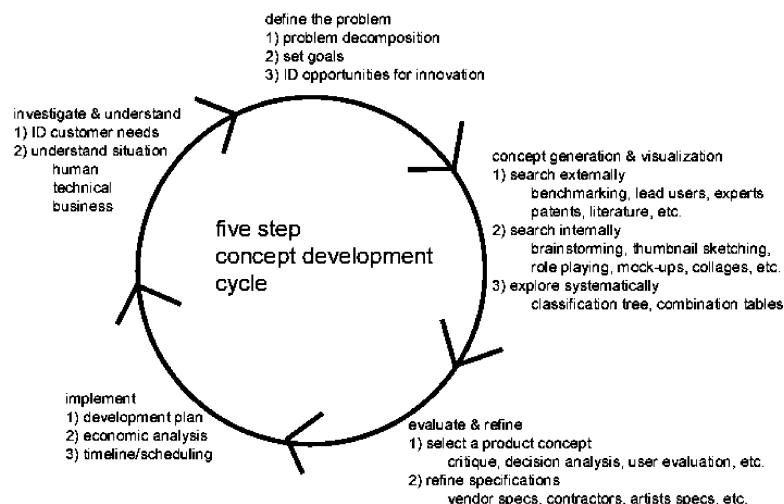


Fig. 1. Development cycle.

costly resources. Interactions are proposed to maximize learner response, reinforce knowledge acquisition by invoking other modalities, and afford rich context for learning by making concepts applicable to the user's everyday life. The key emphasis is user-centric design—design for the user and not the designer or instructor, enrich the content beyond a digital textbook and make the content meaningful and relevant to engage the user, and let them control outcomes with simulations and games.

#### 2.1.4. Evaluate and refine

*Usability testing.* User feedback gives the most valuable information as to user preferences, credibility of the information, and effectiveness of the product, and redesign strategies. This ensures that your goals meet the needs of your target audience.

#### 2.1.5. Implement

Plan for how to introduce and implement your product to your target audience.

### 2.2. Technical development

During the initial phases of the project, different evaluation techniques for the set-up, development, and delivery of Virtual Labs were evaluated. The goal was to establish a database-style architecture for archiving usage data, to author in Director and LINGO for interface interactivity, and Web and CDROM delivery for easy dispersion. The following applications, platforms, and environments were chosen:

- Macromedia Director and Flash—authoring environment.

- Adobe Illustrator and Photoshop—illustrations and diagrams.
- HTML, PERL, and LINGO—primary programming languages and web database development.
- WebCT running on an Apache Web Server—hosting backbone and course management program.

Currently, our primary mode of delivery is with web-based executables in Shockwave, the backend database of user data is established with PERL.

### 2.3. The team

Our development team includes a project director and manager, educational media developers, instructional designers, human computer interaction engineers, usability engineers, content developers, Stanford faculty, and programmers.

## 3. Results

SimPHYSIO, also referred to as Virtual Labs, is an interactive educational website with modules in renal, cardiovascular, respiratory, gastrointestinal, and neuro systems that cover difficult concepts for physiology-related courses at Stanford University. The underlying pedagogy uses learner-centered design and motivational strategies to deliver an active learning atmosphere that is enjoyable and memorable for the students. An additional database website of student usage data was established for evaluation purposes. Last year, simPHYSIO introduced required online problem sets for each topic and a chat room used for online office hours, student forum, or discussion area (Fig. 2).

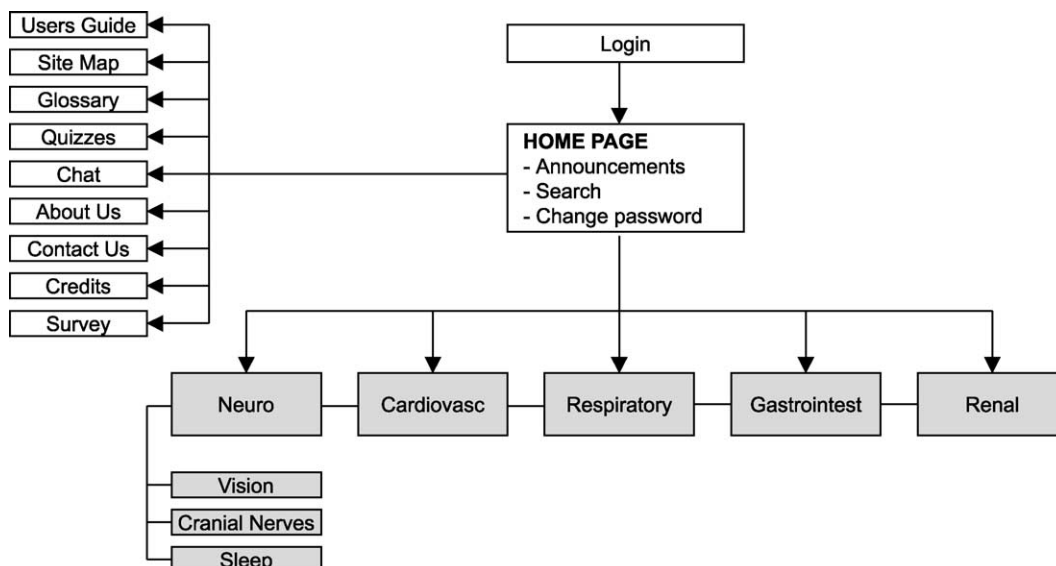


Fig. 2. Site map.

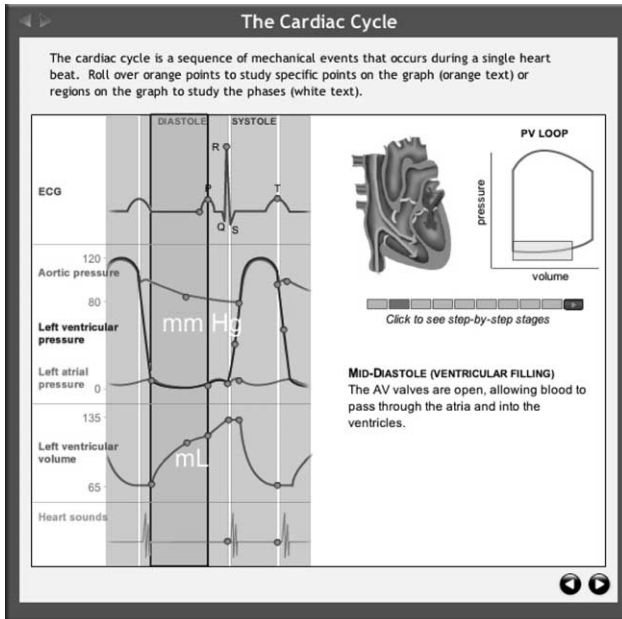


Fig. 3. The cardiac cycle in the cardiovascular module. This is an example of multiple-linked representations. The user can navigate through the animated sequence of events and see how the mechanical events in the heart correspond to electrical activity and changes in pressure and volume.

3.1. Features of the simPHYSIO modules

- Media-rich graphics and animations
- Interactive simulations and quizzes
- Virtual experimental laboratories and methodologies

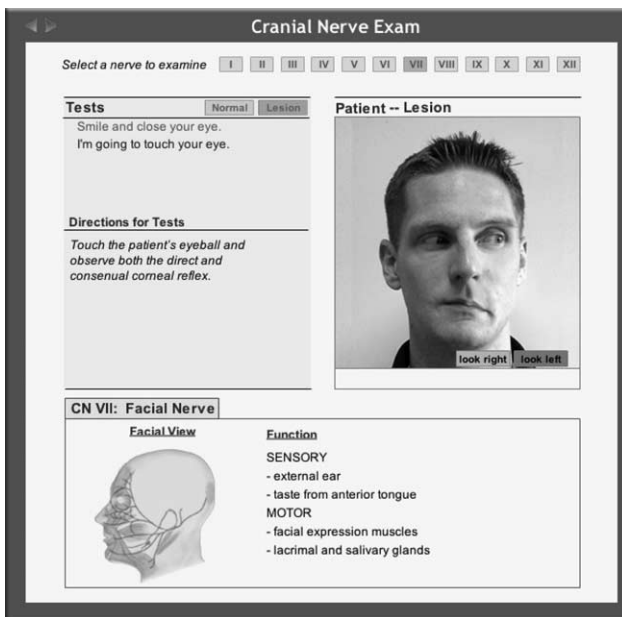


Fig. 4. Cranial nerve exam simulator in the neuro module. After the tutorial on learning the cranial nerves in the brain, the user can go to the virtual patient simulator to apply the knowledge to a clinical setting. In this example, the student learns how to perform the diagnostic tests to a normal patient or a lesioned patient.

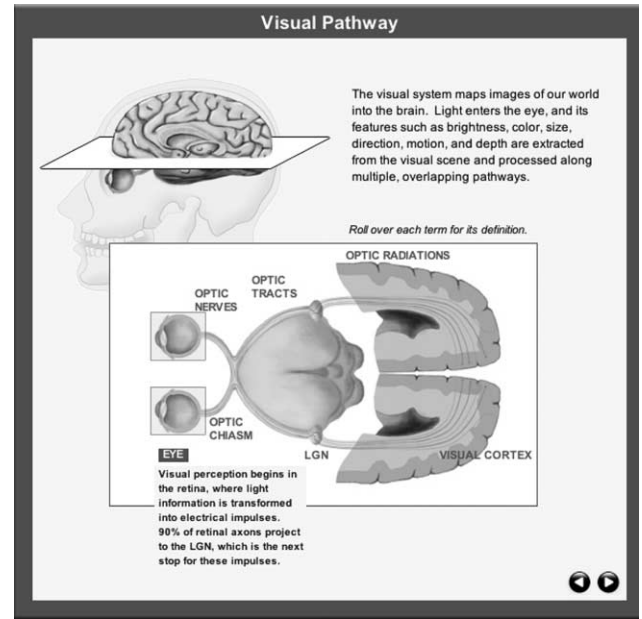


Fig. 5. Tutorial pages: visual pathway in the neuro module. A frame of reference in the upper left hand corner anchors the user to where the visual system is located and shows an animation of how light travels through the visual system.

- Online database-driven problem sets
- Personalized notepad with embedded hyperlinks
- Chat room for online discussions
- Scalable material for curriculum customization
- Web or CD ROM delivery
- Full-featured backend database of usage and user tracking data for evaluation

3.2. Examples

Three examples are shown (Figs. 3–5). The examples shown represent the applicability for an integrated PACS training tool. Fig. 3 incorporates multiple-linked representations showing the different mechanical, electrical, and pressure/volume events of the cardiac cycle. Fig. 4 is a simulator of the cranial nerve exam, designed to teach a person how to see clinical representations of a normal patient versus a patient with lesions. Fig. 5 is an example of a tutorial-type page showing the flow of light information in the visual pathway.

3.3. Classroom implementations

Spring 2000. Demoed renal physiology as part of the classroom lecture, and released the site online to the students as a course supplement. Two classes: Human biology core and biological sciences core.

Spring 2001. Demoed renal and vision physiology, with some topics in cardiovascular, respiratory system and released the site online to the students as a course

supplement. Two classes: Human biology core and biological sciences core.

*Winter 2001.* Demoed all units—neuro, cardiovascular, respiratory, gastrointestinal, renal and released the site online to the students as a course supplement. Instituted a required online quiz database and chat room for online office hours.

*Spring 2002.* Demoed all units—neuro, cardiovascular, respiratory, gastrointestinal, renal and released the site online to the students as a course supplement.

*Other.* Other small content pieces in cardiovascular physiology were built specifically for the medical school level students.

simPHYSIO has been used since 1999 as an online physiology resource available to the students taking the course, as classroom demonstrations, as classroom lectures, as learning environments with required quiz databases. It is designed to be flexible and scalable to the course it is directed towards with customized menus and course announcements.

## 4. Evaluation

Evaluation of the program has been conducted using surveys [8,10], focus groups, interviews, and a back office designed for user-tracking. The biology and human biology core courses, and medical-school level physiology courses have been using the simPHYSIO website for the past 3 years. The students' feedback shows that its acceptance and usage has been increasingly more successful with the addition of relevant course content and ongoing integration with related course material. As a result, students have found it to be an enormous asset to the class. The usage and reception of simPHYSIO in the most recent years has far exceeded our expectations.

### 4.1. Evaluation questions

#### 4.1.1. Learning environment

How can interactive learning tools be used to enrich and enhance student learning? How do we create motivational and meaningful learning pieces for the student? What aspects of learning are suited for interactive learning tools?

#### 4.1.2. Online collaborations

How do online learning materials change peer-peer/peer-instructor interactions? How can web-based learning resources be used for collaborative learning using synchronous (video-conferencing) and asynchronous (chat systems, interactive tools) communication?

#### 4.1.3. Curriculum integration

How should web-based interactive tools be used in the curriculum? What is the best implementation method?

### 4.2. Case study: human physiology biosci 112

In Winter quarter 2001, simPHYSIO (known as Virtual Labs to the students) was most successfully integrated into human physiology (Biosci 112), which is an upper division undergraduate course in clinical physiology. There were approximately 185 students enrolled in the course and the majority of the students found Virtual Labs to be a valuable teaching tool. Results in [Table 1](#).

After surveying the students, the modular and dynamic teaching approach of simPHYSIO (interactivity, user-driven manipulations, animations) was one of the most significant features in helping the student learn the material and enjoy the learning process. The integration of simPHYSIO (a.k.a. Virtual Labs) into the curriculum proved successful, but can be improved by better integration with the course, lectures, other course material, and by structuring content to follow lecture content. The integration would involve working very closely with the course director, teaching faculty, and teaching assistants to customize the content and provide curricular support.

### 4.3. Student feedback

Student feedback is essential to guiding future directions of the project. Below is student feedback for five categories: the value of the content, implementation into the classroom, usefulness in learning, technical difficulties, and future suggestions.

Content/available tools—how did the students find the quality of the content and simPHYSIO/Virtual Labs features (animations, interactivity, quizzes, chat room, etc.)?

“The five sections were well organized and contained very useful material.”

“I think the online info is really exciting and is a valuable additional resource.”

“I like the interactive approach of virtual labs. It made the concepts easier to understand.”

“(I like) those features that allow the user to change specifications and see what happens.”

“excellent diagrams – helped me visualize organs and systems”

“(good) demonstrations of processes in motion”

“was very very useful, quizzes were good-especially good that the polling questions from lecture were online”

“More TA online office hours”

Usefulness in learning—how did the students feel Virtual Labs was useful in helping them learn?

“This is very impressive and useful in that it makes studying interesting and fun.”

“I like the interactive approach of virtual labs. It made the concepts easier to understand. The virtual labs were useful on the midterm and final. It has a very nice setup and very appealing to the eyes.”

Table 1  
Survey data summary

1. Which of the following did you find useful?							
Area	Very useful	Useful	Somewhat useful	Not very useful	Wouldn't use	Would use	Didn't know about it
Neuro	38	65	41	11	6	22	2
CV	50	67	36	3	5	21	4
Resp	39	72	36	6	5	22	6
GI	36	67	40	4	8	23	7
Renal	47	71	31	4	6	23	4
Quizzes	44	62	44	14	3	16	3
Online OH	1	8	23	37	50	35	24
Announcements	28	63	36	17	10	10	14
Notepad	1	11	13	24	42	8	76
2. Why did you use Virtual Labs?							
Quiz	Used in lecture	Announced in lecture	Announced in email	Looks like a good resource	Did not use		
163	43	72	44	107	1		
3. Are you more likely to use Virtual Labs if it was used in lecture?							
Yes: 106 No: 64							

“Great program! I really enjoyed the graphics and I felt that it made learning the material much more enjoyable.”

“I really like the virtual labs. I think they are definitely more interesting than the textbook and visually, it helps to see a system in action.”

“I really think that virtual labs was an excellent source for students. It helped a lot to be able to look at things at my leisure and to be able to go back and review at any time.”

“Virtual labs was overall a really great resource. It was a great interactive way to reinforce what I already had learned from the book and lectures and I think it really helped me better understand. Also I feel like the step-by-step visuals and run-throughs of various systems were very useful.”

“visual simulation clarified many topics”

Implementation into the classroom—how would the students like Virtual Labs to be implemented into the classroom?

“should be integrated more with lecture, could it be combined with automatic email service—update performance on quizzes, etc.?”

“It is a good resource, I wish I had thought to use it more or that it was integrated into class more, instead of having us just do the quizzes.”

Difficulties with Virtual Labs—what kind of problems did the students experience with Virtual Labs?

“I would like it to cover all the topics in lecture. If it did, I would use it more often. Maybe if lecture used the virtual labs more, it would make the concepts easier to

understand during lecture.”

“more quizzes along the ways and not just at the end”

“crashes, bugs, slow downloads” vs. “no bugs”

“this is a nice website but I'm not sure how important it is, it seems like window dressing; I'd rather read a book.”

Improvements for Virtual Labs?

“The online chat/office hours should also be used again but at a higher frequency.”, “...a forum for students to communicate, i.e. ask questions or form study groups”

“MORE QUIZZES”, “more practice questions”, “more quick questions throughout to make sure we were understanding the material”. “The questions are a terrific way to prepare for exams and should definitely be used in the future.

“more virtual patient stuff”, “more advanced/clinical material, links to other websites with more material”, “...more focus on issues of clinical relevance”

“more summaries at the end of each unit”

“more interactive diagnostic tools”, “more animations, those help greatly, more interactive segments where you can set the conditions and see what happens, more games”

“3D models you can rotate, more interactive exercises, a game of some sort for entertainment”

During 2001–2002 academic year, the best method of integrating high-end web-based media into the curriculum for three courses was evaluated. Evaluation data from surveys, focus groups, interviews, and the extensive back office database of user tracking information and student

progress showed that the usage and reception of simPHYSIO has far exceeded our expectations.

## 5. Discussion

Integration of educational media into the curriculum becomes increasingly successful with the addition of relevant content and working closely with the course administration. Our interactive and visual teaching approach was one of the most salient features in helping a student learn physiology AND enjoy it in the process. “Move over, textbooks. Homework’s not just reading in the Core anymore. Today’s human biology students make hearts beat, experiment with surface tension, and stimulate neurons in visual signaling pathways. All of this and more is possible with the advent of the Virtual Labs, an ambitious project designed to bring custom-designed ‘virtual’ physiology experiments and experiences to students of the human biology core.” (Newsletter 2000–2001) [11].

There is a need for electronic learning tools to enhance existing teaching pedagogy and offer alternative learning situations. This kind of media becomes essential today—to widely distribute modular teaching content a convenient, effective, and engaging learning tool. The success of simPHYSIO in other curricula can have a major impact on biomedical science education programs. simPHYSIO can also have a much broader use—continuing education (industry, nursing, pharmaceuticals, physical therapy, etc.); delivery to underprivileged institutions; ‘refresher’ resource for review; keeping up-to-date with current content. The pedagogical and design strategy of simPHYSIO is not limited to the biomedical sciences, it can be applied to teaching any topic.

## 6. Perspective of using simPHYSIO technology for PACS training

Current training of the whole PACS involves taking a course or having an on-site trainer—both types of training require a devotion of time and coordination with many departments [12]. The methodologies behind simPHYSIO can be applied to the development of an online training course for the integrated PACS. Successful implementation of PACS requires a multidisciplinary team:

1. PACS manager—needs to understand the whole PACS system including hardware, software and dataflow.
2. IT personnel—need to know the components of the system, system integration, addressing failures of the system
3. Hospital administrators—need to understand the overall concept of how data flows through the hospital to maintain efficiency of the workflow

4. Technologists—need to know the workflow inside the PACS and how patient data moves from one point to another
5. Radiologists—need to learn how to use the workstation to acquire image
6. Nurses and physicians—need to know how to access the images and find solutions to problems from IT or the administrators

A centralized interactive online training system for the integrated PACS based on the simPHYSIO technology would offer the convenience, ease of distribution and access, customization/modularity, and efficient pedagogical training that would benefit its implementation and operation. A training system like simPHYSIO offers the convenience of learning the material when time permits each of the team members. Housing a tutorial online would provide anytime anywhere access to the training material using a computer with an Internet browser. Since these tutorials are modular, they can be scaled and customized for each level of the team in terms of appropriateness and level of depth. An interactive training tutorial is also beneficial in terms of delivering high quality content in a dynamic way, e.g. simulations. This strategy will engage the user to problem solve and understand the whole PACS. The resulting benefit is the coordination of the knowledge-base for the different hierarchies of background for improved workflow.

## 7. Summary

The PACS requires a diversity in personnel to interface with the intricate and complex system. To successfully implement PACS, a comprehensive education program would enable personnel to interleave all of its components seamlessly. SimPHYSIO’s pedagogical design and methodologies can be applied to build an educational environment for all levels of personnel involved in integrated PACS. simPHYSIO is a suite of interactive online teaching media designed to integrate and dynamically teach complex systems using media-rich animations, real-time simulations, and virtual environments in physiology. The strength of simPHYSIO also includes internet distribution, scalability, and content customization.

## Appendix A

Demo of content pages: <http://portabello.stanford.edu/virtuallabs>; <http://www.simphysio.com>

Project information: <http://summit.stanford.edu/hhmi>

## References

- [1] Alessi SM, Trollip SR. *Multimedia for learning: methods and development*. Boston: Allyn and Bacon; 2001.
- [2] Cooper A. *About face: the essentials of user interface design*. New York: Wiley; 1995.
- [3] Bransford JD, Brown A, Cocking R, editors. *How people learn*. Washington, DC: National Academy Press; 2000.
- [4] Kozma R. Learning with media. *Rev Edu Res* 1991;61(2):179–211.
- [5] Lepper MR, Malone TW. Intrinsic motivation and instructional effectiveness in computer-based education. In: Snow RE, Malone TW, editors. *Aptitude, learning, and instruction: cognitive and affective process analysis*. Hillsdale, NJ: Erlbaum; 1987. p. 255–86.
- [6] Malone TW, Lepper MR. Making learning fun: a taxonomy of intrinsic motivations for learning. In: Snow RE, Farr MJ, editors. *Aptitude, learning, and instruction: cognitive and affective process analysis*, vol. 3. Hillsdale, NJ: Erlbaum; 1987. p. 223–53.
- [7] Shneiderman B. *Designing the user interface: strategies for effective human-computer interaction.*, 3rd ed. Reading, MA: Addison Wesley; 1997.
- [8] Nielsen J. *Designing web usability: the practice of simplicity*. New Riders; 1999.
- [9] Howard Hughes Medical Institute Grants (NAME; 1998–2002, 2002–2005).
- [10] Nielsen J. *Usability engineering*. Los Altos, CA: Morgan Kaufmann; 1994.
- [11] Human Biology Newsletter. Stanford University; 2000–2001.
- [12] Zhou ZH, Huang HK, Liu B, Cao F, Zhang J, Mogel GT. PACS simulator: a standalone education tool. *Proceedings*, vol. 4685.; 2002. p. 446.

**Camillan Huang** is the Virtual Labs Project Director at SUMMIT (Stanford University Medical Media and Information Technologies) developing on-line interactive physiology teaching modules (SimPhysio) for the Human Biology Program. She has a Ph.D. in Molecular and Cell Biology from the University of California, Berkeley. She also has a B.A. in Classical Civilizations (from UCB), studied Shakespeare at Oxford, and has training in traditional and digital arts, educational media development, and information and instructional design. Her goal is to integrate teaching of the sciences with arts and technology. SJ Mercury News interview 7/23/02: <http://www.bayarea.com/mld/mercurynews/living/health/3717371.htm>. For more information about the project: <http://summit.stanford.edu/hhmi>.