Medical imaging education in biomedical engineering curriculum: Courseware development and application through a hybrid teaching model

Article *in* Conference proceedings: ... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference · August 2012

DOI: 10.1109/EMBC.2012.6347134 · Source: PubMed

Weizhao Zhao
University of Miami

Medical Imaging Education in Biomedical Engineering Curriculum: Courseware Development and Application through a Hybrid Teaching Model*

Weizhao Zhao, *Senior Member, IEEE*, Xiping Li, Hairong Chen, and Fabrice Manns, *Member, IEEE*

***Abstract*— Medical Imaging is a key training component in Biomedical Engineering programs. Medical imaging education is interdisciplinary training, involving physics, mathematics, chemistry, electrical engineering, computer engineering, and applications in biology and medicine. Seeking an efficient teaching method for instructors and an effective learning environment for students has long been a goal for medical imaging education. By the support of NSF grants, we developed the medical imaging teaching software (MITS) and associated dynamic assessment tracking system (DATS). The MITS/DATS system has been applied to junior and senior medical imaging classes through a hybrid teaching model. The results show that student's learning gain improved, particularly in concept understanding and simulation project completion. The results also indicate disparities in subjective perception between junior and senior classes. Three institutions are collaborating to expand the courseware system and plan to apply it to different class settings.**

I. Introduction

Biomedical engineering (BME) education has developed as an interdisciplinary engineering training area in the last 30 years. Based on the current ASEE College Profiles [1], BME undergraduate enrollment has become one of the most rapidly growing engineering majors (undergraduate enrollment has tripled from 1999 to 2010). As a key component in BME, medical imaging, combining physics, mathematics, electrical and computer engineering, provides students with a broad view of an integration of different technologies applied to biology and medicine. Recognizing the broad impact of medical imaging education on BME students, many institutions have established such a curriculum. Based on the Whitaker Foundation's BME program database [2], there are 119 universities or colleges that have BME programs in the nation. Through the Internet, we surveyed these 119 universities or colleges and found that 80 of them offered graduate level medical imaging courses, and 68 offered undergraduate level medical imaging courses. We must acknowledge that the survey (in 2010) was based on the Internet available and accessible information and it may not be the most accurate or updated. However, it clearly presents a progressively increasing signal of the BME program and its key component, medical imaging. Medical imaging techniques are now crucial in clinical and research laboratories. Medical imaging also opens career opportunities for students in areas of medical equipment or instrument manufacturing, image or signal software engineering, or even medical physics after further training.

Medical imaging knowledge includes physics principles, mathematical derivations, and engineering implementations from signal detection and measurement to 2D or 3D reconstructions. A comprehensive discussion for undergraduate medical imaging education has been published [3]. The discussion concluded that "Resources available on the Internet, coupled with effective curricular elements such as challenge-based learning with a mix of team and individual assignments and formative assessment, make it possible for institutions without extensive imaging expertise or equipment to offer effective curricula for biomedical imaging education." To deliver the knowledge to students efficiently or create an environment for student learning effectively has been investigated. The practices have been heavily focused on Internet/web-based education (a major subcomponent of the broader term "e-learning") because education through the Internet makes it possible for more individuals than ever to access knowledge and to learn in new and different ways. Efforts have been made in different aspects, such as image reconstruction techniques varying from the physics-based [4], to the math-intensive [5,6], to algorithm efficiency and to image quality improvement [7]. However, limited efforts actually describe, step-by-step and interactively, the process of generation of image data, which is the fundamental education component of medical imaging. On the other hand, while utilizing Internet's accessibility, the Internet's tracking capability, as an assessment tool, is usually neglected too.

In our BME curriculum, we have established a four-course sequence for imaging training from junior to graduate levels. In the last few years, we have developed an Internet accessible, interactive, module-based medical imaging teaching system and a dynamic assessment tracking system. Both systems are inherently integrated together, specifically featuring interactive animation, simulation and providing simultaneous feedback. In this report, we present the design and implementation of the systems and the results applied to junior and senior imaging classes.

*Research supported by National Science Foundation grants DUE0127290, DUE0632752 and DUE1022750.

W. Zhao, corresponding author, is with the Department of Biomedical Engineering, University of Miami, Coral Gables, FL 33146 USA (phone: 305 284 6763; fax 305 284 6494; e-mail: w.zhao1@miami.edu).

X. Li, H Chen, and F. Manns are with the Department of Biomedical Engineering, University of Miami, Coral Gables, FL 33146 USA.

II. MOTIVATION AND DESIGN PRINCIPLE

A. Pedagogical Motivation

The motivation to start this project was originated from the idea, "A picture is worth/better than a thousand words," i.e., using pictorial description would be superior to the text-only description. The idea can be extended, i.e., "A moving picture will be better than a static picture." Using animation or simulation (such as Adobe Flash Player or Media Player) will promote and enhance learning and understanding. Furthermore, we added, "An interactive moving picture is better than a simple moving picture." Our hypothesis is that animation and simulation associated with learner's interactivities would be able to match student's learning style [8,9], "I hear and I forget, I see and I remember, I do and I understand." Ultimately, our goal is to build an online user-interactive teaching/learning system, featuring animation and simulation for physical principles, mathematical derivations and engineering implementations in medical imaging education, so as to fulfill the training tasks optimally.

B. Design Principle

In order to develop a system that be shared by as many courses as possible, we disintegrate the system into course, modality, module and component levels. Figure 1 below shows the hierarchy of the medical imaging knowledge.

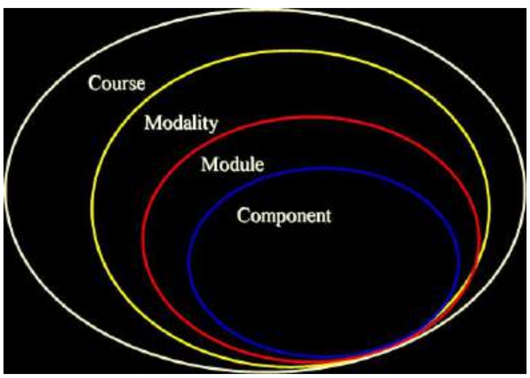

Figure 1. Medical imaging knowledge is built upon different scaled elements that are connected to each other.

Our imaging education sequence includes Four Courses: Foundation of Medical Imaging (math and physics), Medical Imaging Systems (engineering and reconstruction), Medical Imaging Applications (engineering and processing), and Advanced Medical Imaging (advanced topics).

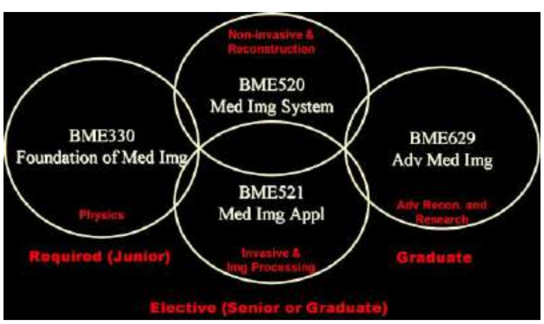

Figure 2. Medical imaging course sequence.

To serve all courses, we organized the medical imaging teaching system (MITS), based on Imaging Modalities, i.e., imaging techniques (X-ray, CT, MRI, Nuclear Medicine Imaging (NMI), Ultrasound, Image Processing (IP)). In order to assess student's learning gain, we also designed an evaluation database that records student's engagement time, pre/post quiz/test results.

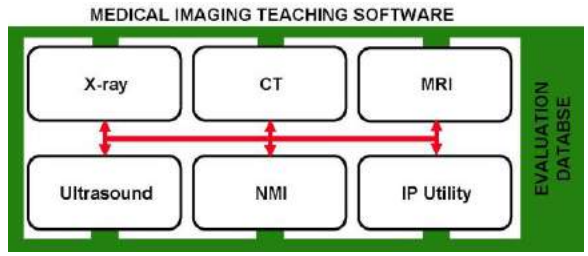

Figure 3. Medical imaging teaching software is organized by imaging modalities and associated with an evaluation database.

Within each imaging modality, we created several Modules. Each module corresponds to a lecture topic. Each module includes five supporting Components (background review, text-figure description-illustration, animation, simulation, and application examples).

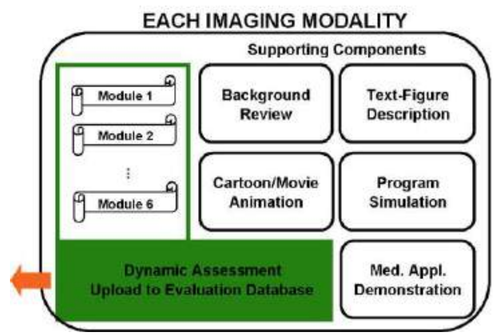

Figure 4. Each module is delivered by five supporting components to ensure the information transferred in all aspects.

This design helps maximally utilize the supporting components and also provide the path for a step-by-step learning.

III. IMPLEMENTATION

After the structure of the system was determined, we built the system by completing the supporting components. We briefly describe the implementation for two components. Description for other components can be found in previous publications [10,11].

Background Review contains reviews of related physics and math background (such as modern physics for X-ray, Fourier transform for CT) and historical review of the modality's evolution (such as radiation's discovery, evolution of CT's generations). Our class teaching experience and other reports [12] indicate that students' learning interest is very much stimulated by the stories of scientific discoveries and inventions. Links to websites relating to the scientists or scientific inventions (such as the

“Virtual Nobel e-Museum” [13]) are also included in this component.

Animation and Simulation component was the focus in the MITS system. Cartoon/movie animation provides students an interactive environment to visualize a “dynamic” physical process or a “live” instrument (by Adobe Flash Player, Windows Media Player, or even MS Power Point Presentation). We give two examples as follows.

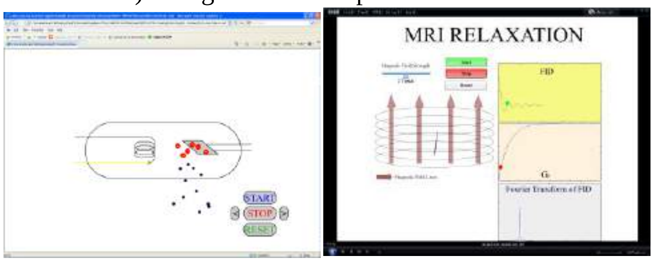

Figure 5. Left panel illustrates a model of an X-ray tube. When the START button is clicked, a current (yellow) will run through the coil, free electrons on the surface of the coil will fly to the plate. The collision will produce heat (red) and X-ray (blue). Step-by-step interaction is also available by clicking > or < button. Right panel illustrates an MRI instrument model. The animation shows how the cellular-level magnetic element in the human body (the small bar inside the coil) reacts under external magnetic field. When the intensity of the external magnetic field is interactively justified, the corresponding reaction of the cellular-level magnetic element in the human body changes accordingly. How the electrical signal induced by the changes is also demonstrated.

The MITS system is connected to a dynamic assessment tracking system (DATS), a username/password required system. An instructor can enroll his/her students into the system. Students can go through each module at a self-paced fashion. Pre-post quiz-test questions have been included in the system and are pulled out by student randomly. The DATS system is illustrated as following.

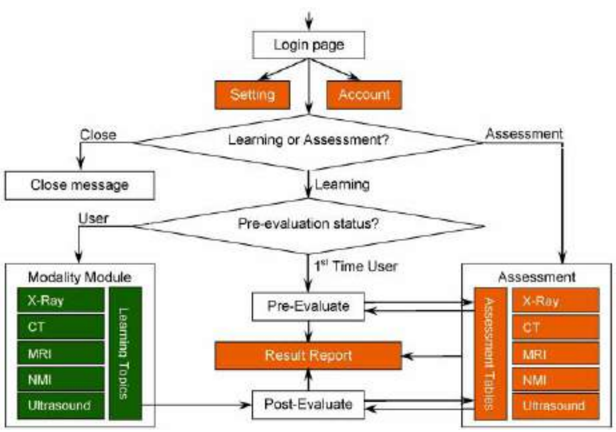

Figure 6. The dynamic assessment tracking system (DATS) enables Independent Administrator Control (instructor). The system allows new instructors to join the system from the same or different institutions as site administrators. This system is username/password protected and Internet accessible. The assessment of student performance can be acquired by instructor through the online database.

We have applied this teaching/tracking system in junior and senior classes in last two years. The MITS system was assigned as a reading material following each lecture. Student’s performance was not counted for their final grade (this protocol was approved by our IRB office). The MITS/DATS system locates http://mis.eng.miami.edu.

IV. RESULTS

A. Class Performance

We tested two classes’ performances on learning all modules associated with X-ray and CT modalities. The tests were given to one class without MITS and the other with MITS through a hybrid teaching model. Students’ academic, and class performance records (mean±SD) of without (n=23, top row) and with (n=21, bottom row) are listed in table below.

TABLE I. PERFORMANCE ON LEARNING X-RAY, CT

	GPA	All Prob.	Concept Prob.	Projects
N=23	3.42±0.34	82±9%	76±5%	82±5%
N=21	*[1]3.46±0.44	*[2]89±8%	*[3]91±6%	*[3]90±6%

Statistical comparison (ANOVA, Single factor) of students’ cumulative GPA shows no difference between two classes ($*^1 p \leq 0.7$), indicating similar background of students in two classes. This comparison was conducted to confirm that if any improvement occurred from the application of MITS was NOT caused by students’ background difference. Statistical comparison of students’ correct percent rate for all questions (“All Prob.”) shows no significant difference; however, the low p-value ($*^2 p \leq 0.1$) implies a “trend” of increased understanding to all questions (conceptual and computational). Students’ understanding improved most in conceptual questions (“Concept Prob.”) and in their projects. Both statistical comparisons show significant differences (both $*^3 p \leq 0.05$) between two classes.

We must admit that the small number of samples may bring error to the comparisons in some degree. However, the assessment results (without/with in two classes) show learning improvement, especially in concept understanding.

B. Learning Gain

We conducted a test to examine student’s understanding on imaging principles through the MITS directly. This was done by giving students concept questions before they read the corresponding module (independent of lecture) and immediately after they read the module.

TABLE II TABLE II HISTOGRAM OF STUDENT’S UNDERSTANDING ON 17 MEDICAL IMAGING CONCEPTS

	2011 (n = 22)					2009 (n = 15)				
	Pre-test		Post-test		Gain	Pre-test		Post-test		Gain
Questions	Correct	Wrong	Correct	Wrong		Correct	Wrong	Correct	Wrong	
1	22	0	22	0	**0**	14	1	13	2	**-1**
2	15	7	20	2	**5**	11	4	14	1	**3**
3	17	5	19	3	**2**	9	6	15	0	**6**
4	20	2	21	1	**1**	14	1	14	1	**0**
5	15	7	15	7	**0**	7	8	12	3	**5**
6	20	2	20	2	**0**	12	3	15	0	**3**
7	11	11	14	8	**3**	7	8	11	4	**4**
8	10	12	14	8	**4**	7	8	11	4	**4**
9	9	13	13	9	**0**	7	8	14	1	**7**
10	8	14	12	10	**2**	4	11	11	4	**7**
11	7	15	13	9	**6**	8	7	8	7	**0**
12	19	3	22	0	**3**	13	2	11	4	**-2**
13	9	13	11	11	**2**	6	9	12	3	**6**
14	6	16	16	6	**10**	3	12	12	3	**9**
15	20	2	22	0	**2**	12	3	15	0	**3**
16	8	14	21	1	**13**	5	10	15	0	**10**
17	14	8	15	7	**1**	5	10	8	7	**3**

We did a preliminary calculation of students' learning gain by the normalized equation [14,15], LG= (post-pre)/(100-pre). We found that the average students learning gain (n=37 for both years) on 17 basic medical imaging concepts was 0.36±0.28.

C. Subjective Perception

During the development of the MITS/DATS system, we gave students surveys that collected their subjective perceptions. The feedback surprised us by the disparities between the junior class (Foundation of Medical Imaging) and the senior class (Medical Imaging Systems).

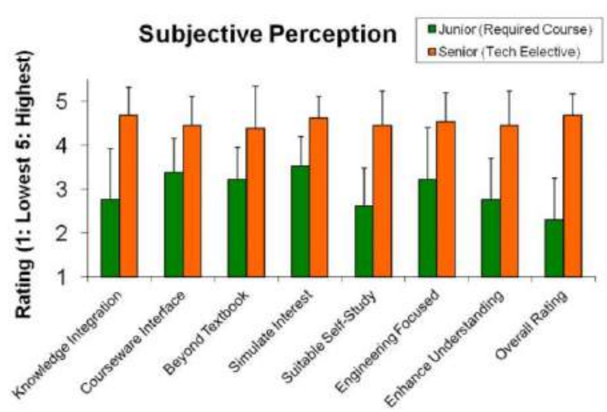

Figure 7. Students' subjective perceptions to the application of MITS/DATS show apparent disparities from different level of classes.

D. Student Engagement

We also surveyed students' engagement with the MITS/DATS system. The engagement was measured by the time used for the first time to sign on the system, each time used with the system, and the time used to study animations and simulations. We noticed a similar disparity between two classes.

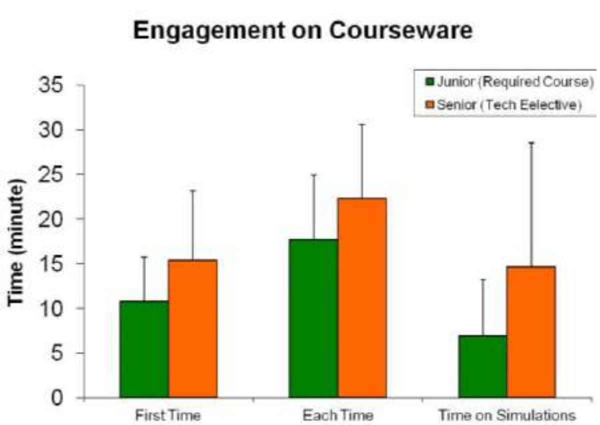

Figure 8. Students' engagements with the MITS/DATS system also show strong disparities from different level of classes.

Various reasons might cause the disparities. However, it is noticeable that the engagement is proportional to the subjective perception. The more use of the system, the more positive feedback is collected from the users.

V. CONCLUSION

Based on the outcomes and the evaluations of different assessments, we conclude that the developed MITS/DATS system is suitable and applicable for medical imaging education to undergraduates. We plan to scale up the development and application (large number of student enrollment) through the efforts by other participating institutions to produce a professional medical imaging teaching product that can be adopted by interested academic institutions.

ACKNOWLEDGMENT

Authors are grateful to participating institutions, Florida Atlantic University and Florida International University, for using the developed courseware. Authors thank Dr. Thomas Harris and Dr. Auter Kaw for their valuable comments and suggestions to improve the courseware.

REFERENCES

[1] Gibbsons MT: "Engineering by the Numbers", URL: http://www.asee.org/publications/profiles/upload/2010ProfileEng.pdf

[2] The Whitaker Foundation: Biomedical Engineering Curriculum Database. URL: http://www.bmesphotos.org/WhitakerArchives/

[3] "A White Paper for the Whitaker Foundation Biomedical Engineering Educational Summit 2005," (WhitakerAR05.pdf) URL: http://www.bmesphotos.org/WhitakerArchives/

[4] Zeng G: Image reconstruction – a tutorial. Computerized Medical Imaging and Graphics 25:97-103, 2001.

[5] Vandenberghe S, Asseler Y, Van de Walle R, Kauppinen T, Koole M, Bouwens L, Van Laere K, Lemahieu I and Dierckx R: Iterative reconstruction algorithms in nuclear medicine. Computerized Medical Imaging and Graphics 25:105-111, 2001.

[6] Formiconi AR, Passeri A, Guelfi MR, Masoni M, Pupi A, Meldolesi U, et al: World Wide Web interface for advanced SPECT reconstruction algorithms implemented on a remote massively parallel computer. Intl. Journal of Medical Informatics 47:125-138, 1997.

[7] Acharya R, Wasserman R, Stevens J, and Hinojosa C: Biomedical imaging modalities: a tutorial. Computerized Medical Imaging and Graphics 19:3-25, 1995.

[8] Bransford JD, Brown AL, Cocking RR. Eds. How People Learn. National Academy Press, Washington, D.C., 1999.

[9] Gentry, JW: "What Is Experiential Learning?" in James W. Gentry (Ed.), Guide to Business Gaming and Experiential Learning, East Brunswick, CN: Nichols/GP Publishing, 9-20, 1990.

[10] Zhao W, Li X, Manns F: Medical imaging teaching software development and dynamic assessment tracking system for biomedical engineering program. Proceedings of 2011 ASEE Annual Conference, Vancouver, Canada, June, 2011.

[11] Li X, Manns F, Zhao W: Work in Progress: Medical Imaging Education by a Multi-level Module-based Online Teaching and Assessment System. Proceedings of the 40th IEEE Frontiers in Education Conference, Washington DC, October, 2010.

[12] Millard D: Work in Progress - Engaging Future Engineers by Leveraging the Past, 35th ASEE/IEEE Frontiers in Education Conference, F3H5-6, Oct. 2005.

[13] Nobel Prize Home page. URL: http://www.NobelPrize.org

[14] Goldman K, Gross P, Heeren C, Herman G, Kaczmarczyk L, Loui MC, et al: Identifying Important and Difficult Concepts in Introductory Computing Courses using a Delphi Process, Proceedings of the 39th ACM Technical Symposium on Computer Science Education, Portland, Ore., 12-15, Mar. 2008.

[15] Hake R: Interactive-engagement vs. traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses, American Journal of Physics, 6:64-75, 1998.