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TUES Type 2 Project: Development and Application of MITS/DATS Courseware: Advancement, Success, Concern, and Weakness

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Introduction

Medical imaging education is popular in undergraduate engineering curricula. Medical imaging related courses, such as physics of medical imaging, medical imaging signals and systems, image reconstruction principles, etc., are usually offered by electrical engineering, computer engineering, and particularly biomedical engineering programs. Biomedical engineering (BME) education, a part of STEM, has developed as an interdisciplinary engineering training area in the last 30 years. Based on the current ASEE College Profiles[3], BME undergraduate enrollment has become one of the most rapidly growing engineering majors (Fig. 1 below).

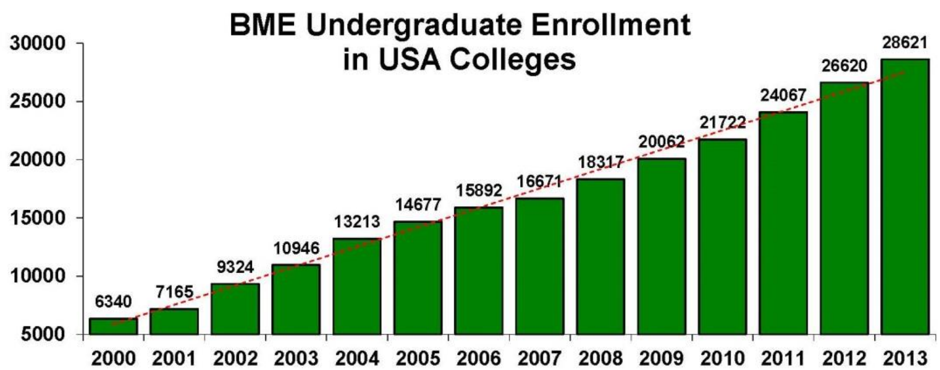

Fig. 1 Undergraduate enrollment in Biomedical Engineering has increased more than four times from year 2000 to year 2013. It is one of the only three engineering majors (with aerospace and nuclear engineering) that have had “monotonically increasing” enrollment since 1999.

Based on the Whitaker Foundation’s BME program database[9], there are 122 universities or colleges that have BME programs in the nation. We surveyed these universities or colleges and found that 80 of them offer graduate level medical imaging courses, and 68 offer undergraduate level medical imaging courses. We must acknowledge that the survey was based on the Internet available and accessible information in 2010, and it may not be the most accurate or updated. However, it clearly presents a significant demanding signal for medical imaging education required by undergraduate engineering curricula. 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. Different imaging modalities involve various physics principles, diverse mathematic derivations for image generation, recognition and reconstruction, special system configurations and specific applications. The significant amount of information and rapid change in the medical imaging field require teaching material to be more flexible to fit into the available class hours. Obstacles to medical imaging education include 1) class hours required because of the interdisciplinary features, 2) sophisticated mathematical modeling required for many imaging systems, 3) inaccessibility or local unavailability of the imaging devices. Finding an efficient way for instructors to deliver medical imaging knowledge and establishing an effective learning environment for students, especially at institutions without associated medical schools or hospitals, have long been goals for medical imaging educators. After more than ten years of development and application of a web-based, interactive, dynamic track-able medical imaging courseware, we have found this is a feasible approach for medical imaging education and have gained experience and knowledge about how students learn and how instructors deliver information in this specific STEM education field.

Educational Hypothesis

Based on pedagogy theory and literature[2], we are looking for an appropriate method or environment to improve student learning in the field of medical imaging. From the published literature and our own experience in engineering teaching/learning, student's learning experience is, "I hear and I forget, I see and I remember, I do and I understand." To match this learning pattern, we are asking what we should let students see and what we should let students do. According to the pedagogy theory, "A picture is worth/better than a thousand words", i.e., using pictorial description would be superior to the text-only description. We extended the idea to a new expression, "A moving picture is better than a static picture," by using Adobe Flash Player or Media Player, i.e., the component of "to see". Furthermore, we leverage the new expression, "An interactive moving picture is better than a simple moving picture," by adding interactivities, i.e., the component of "to do". The hypothesis for our research project is that interactive animation- or simulation-featured online course materials increase teaching efficiency and promote effective leanring. The objective of the project is to design and implement an online user-interactive teaching/learning system, featuring animation and simulation for physical principles, mathematical derivations and engineering implementations, so as to fulfill the medical imaging education tasks optimally.

Advanced Design

Medical imaging education is an interdisciplinary STEM education field. In terms of knowledge, it involves physics, math, chemistry, biology and engineering. In terms of technique, only within the field of engineering, it involves transducer, signal/image processing, software, hardware, and computer integration. In terms of learning subjects, it involves X-ray, CT, MRI, PET, Ultrasound and other imaging modalities. In order to develop a system that can be used by as many courses as possible, we construct the system into course, modality, module and component levels[8]. Fig. 2 below shows the hierarchy of the medical imaging teaching/learning system.

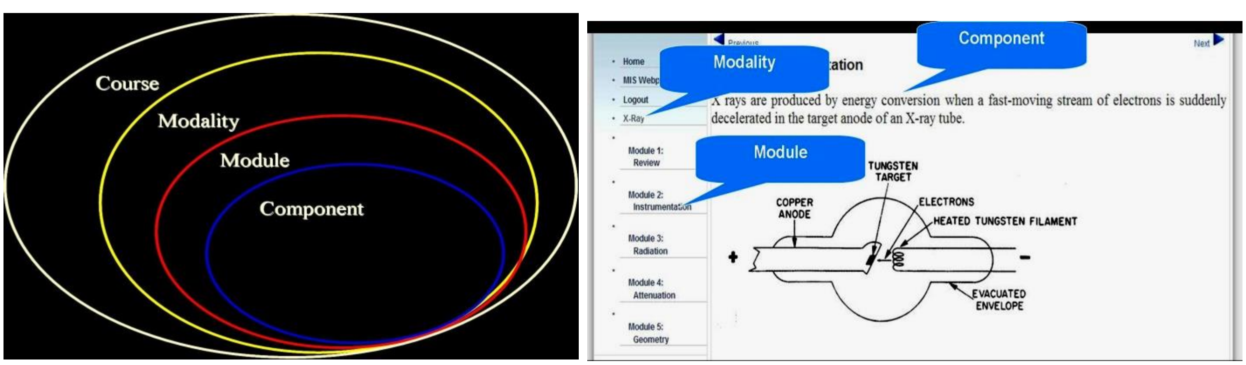

Fig. 2: Medical imaging knowledge is built upon different scaled elements that are connected to each other. Left panel: Concept of nested medical iamging teaching/learning system. Right panel: Design example of the X-ray instrumentaiton within the X-ray imaging modality.

To serve as many courses as possible, we constructed an Medical Imaging Teaching System (MITS), based on Imaging Modalities, which are defined by imaging techniques (X-ray, CT, MRI, Nuclear Medicine Imaging (NMI), Ultrasound) and associated with Image Processing (IP) utilities. 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). This design helps maximally utilize the supporting components and also provide a "path" for a step-by-step learning. In order to assess student's learning gain and obtain feedback from student learning, we also designed an evaluation database that records student's engagement time, pre/post quiz/test results, through the Dynamic Assessment Tracking System (DATS). The figure below shows the MITS/DATS structure.

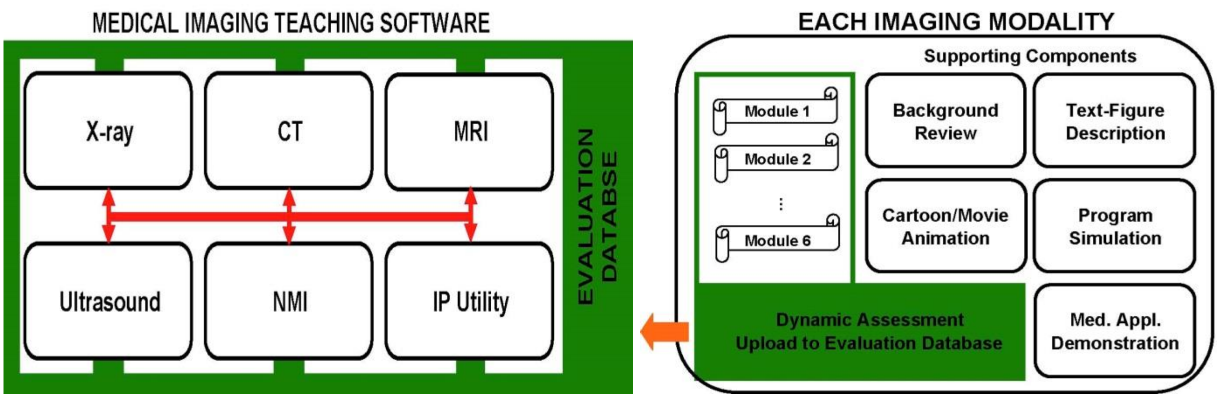

Fig. 3: Medical imaging teaching software is organized by imaging modalities and associated with an evaluation database. Each module is delivered by five supporting components to ensure the information transferred in all aspects.

Successful Implementation

Animation/simulation focused MITS system: After the structure of the system was determined, we built the system by completing the supporting components. We only briefly describe the implementation for the animation component. Description for other components can be found in previous publications[1,7,10]. *Animation and Simulation* components are 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 an example as follows.

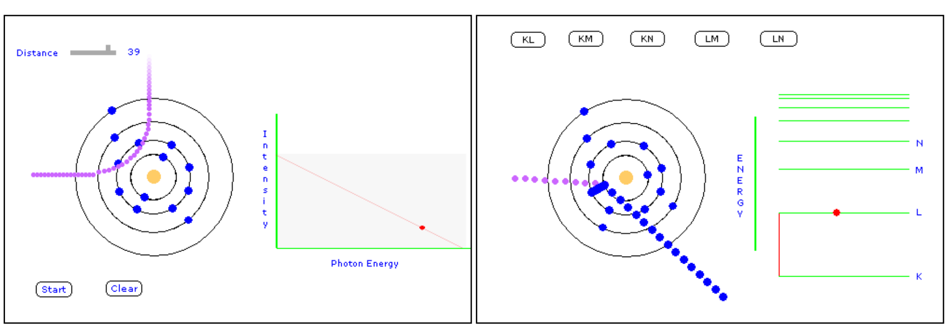

Fig. 3: Examples show X-ray's generation by animations. Principles of the X-ray's physics for the general radiation and the characteristic radiation can be animated (left and right panels above). The "general radiation" animation lets the user change the electron's distance to the nucleus (on the top left corner of the middle panel) and displays the output X-ray energy level. When the user clicks the *Start* button, he/she can see a *flying particle* (animating an electron) *pass around* the nucleus with a changed direction; and the extra energy emitted (i.e., X-ray) is marked on the right side (a continuous function). The "characteristic" radiation (right panel) depends on the nucleus' electron binding energy. When the user clicks the *KL* button, he/she can see a "physical reaction" sequence in which a *flying particle knocks out* an electron in the K-shell (the most inner shell in the figure) of the atom; then an electron in the L-shell (the shell next to the K-shell) replaces the vacancy in the K-shell; and the output X-ray energy is shown by an energy transition on the right side (a discrete function). The purpose of an animation is to generate a dynamic "picture" for a physics (chemistry or biology) concept or principle.

<u>Online evaluation enabled DATS system</u>: In order to assess the teaching/learning efficacy, we use a Dynamic Assessment Tracking System (DATS), a username/password required system, to obtain feedback from the MITS 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 follows.

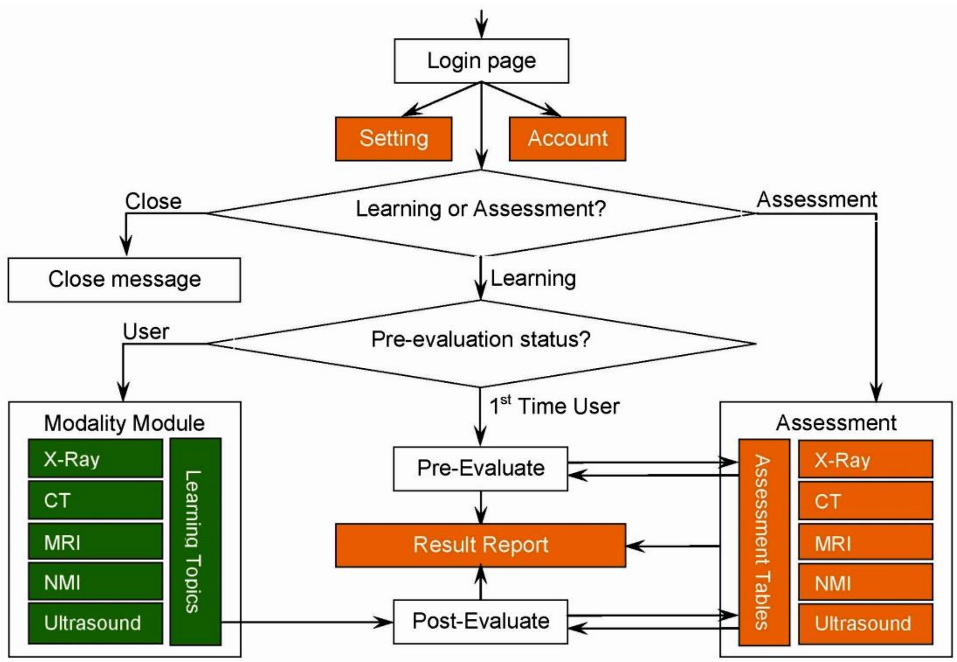

Fig. 4: The dynamic assessment tracking system (DATS) enables Independent Administrator Control (instructor). The system allows new instructors to join the system from the same or different institutions as site administrators. This system is username/password protected and Internet accessible. The assessment of student performance can be acquired by instructor through the online database.

<u>Hybrid teaching/learning application</u>: The system has been subscribed by more than 20 institutions nationally and internationally. They use the MITS/DATS system either as a

courseware or as a reference website. In our practice, we used a hybrid approach, i.e., the MITS/DATS system and classroom lectures are mixed and referenced by students iteratively.

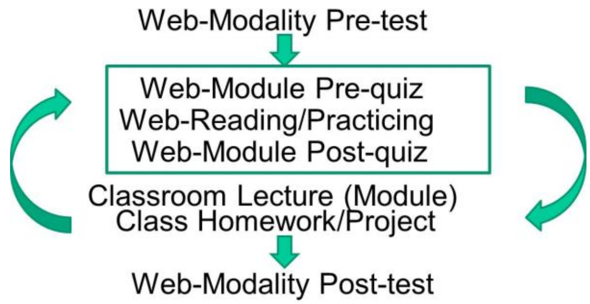

Fig. 5 Students start from a imaging Modality's (X-ray, CT, MRI, PET or Ultrasound) pre-test, and get into each of the modules (topics) within the modality. Lectures are then given. Students' homework and project assignments are iteratively completed by re-reading web-based courseware and lecture notes.

Results

We have opened this teaching system in different size classes on all or selected imaging modalities during the last few years. We expect two major outcomes from the project: 1) Student's concept understanding will be improved. This will be measured by a set of currently developed key "medical imaging concepts". We try to establish these key concepts as the "medical imaging concept inventory". 2) Student's simulation ability will be improved. Medical imaging education is an engineering training field. Due to the hardware inaccessibility in medical imaging, student's software simulation will demonstrate their acquired engineering ability. The assessment result (pre/post) shows increased learning gains, especially significant in concept understanding.

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[6] before they read the corresponding module (independent of lecture) and immediately after they read the module. We did a preliminary calculation of students' learning gain by the normalized equation[4,5], LG= (post-pre)/(100-pre). We found that the average students learning gain (n=52 total) on 17 basic medical imaging concepts was 0.36±0.28.

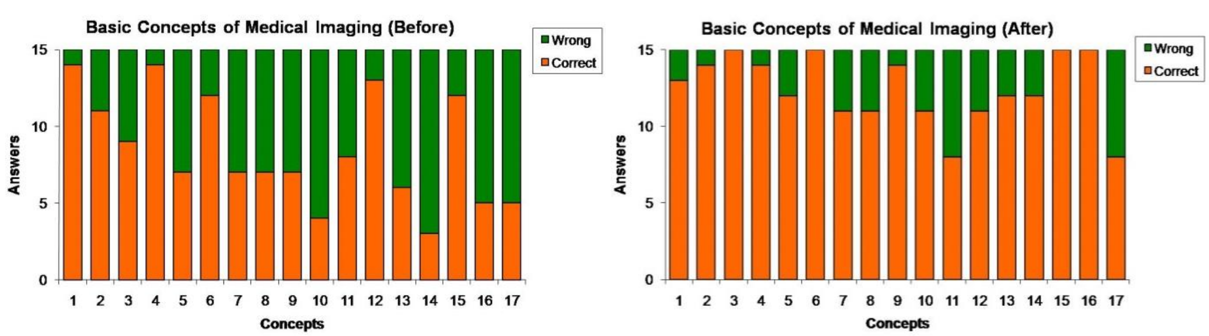

Fig. 6 Results came from two medical imaging classes (n=52 senior undergraduates) where MITS/DATS was used as courseware. Concept questions within the "teaching modules" were

given to students before they used the MITS/DATS system. They answered the same question after they finished the modules.

Subjective Perception and Student Engagement: 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 and the senior class. We also surveyed the same 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. 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.

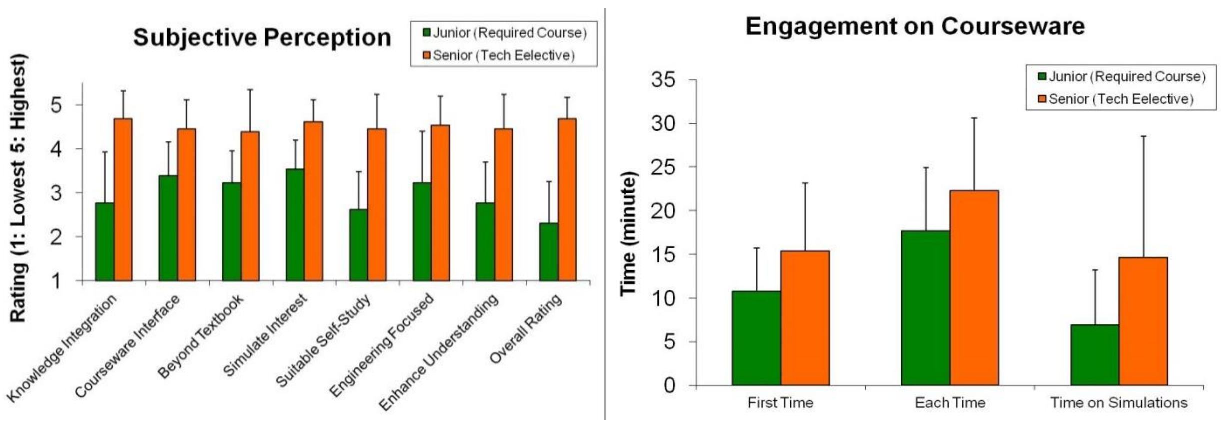

Fig. 7: Students' subjective perceptions to the application of MITS/DATS show apparent disparities from different level of classes. Students' engagements with the MITS/DATS system also show strong disparities from different level of classes.

Concerns

Based on the outcomes and evaluations of different assessments, we summarize that the developed internet-accessible teaching software (MITS/DATS) is convincingly suitable and applicable for medical imaging education to undergraduates. We plan to scale up our current MITS/DATS system to a new level to create a National Medical Imaging Education Portal. We will address the following concerned questions:

Web-based Learning (Functions and Formats): Online teaching material can be established through a website, though the challenge is in the interactivity between instructor/student and the teaching material. Our prior NSF funded development partially solved the problem by creating interactive protocols. However, the student perception/engagement disparity between different classes raises a pedagogical question of how to enable the online teaching/learning strategies to benefit all students equally or targeted groups.

General STEM Education (Broader Impacts): Medical imaging is an important component in biomedical engineering and related engineering or science fields applied for health care. It is a "further" branch of STEM education. The demanding question we ask here is how we can expand the developed NMIEP system to a broader range of applications. In other words, what will be the broader impacts of NMIEP on general STEM education?

Broader Involvement (Faculty Development): The faculty's broader involvement is the key to improving undergraduate STEM education. Educational research is often neglected, downgraded, or placed at a lowered priority in some institutions. Part of the reason is the long-term outcome of the research. How we can promote a new sustainable teaching/learning strategy to the faculty in STEM fields?
Sustainability (Software and Contents): Establishment of an online teaching system is a "one-time" effort (we acknowledge that it is a time-consuming effort). However, the system must be sustainable beyond the funding cycle(s). A "live" teaching system must be an upgradeable (continuously-optimizing) system. "Static" online teaching materials have become commonplace for years. What should be upgraded, how it should be upgraded and who shall do the updating after the funding cycle(s)?
Assessment (Evaluation): Traditional academic assessments are based on paper or via an online survey. There lies a dilemma in how to provide our instructor "dynamic" feedback for his/her students learning on current teaching contents. How can we automatically categorize, without waiting to the end of the class, students' learning performance and contribute it to STEM education?

Conclusion

Based on the outcomes and evaluations of different assessments, we conclude that the developed MITS/DATS system is suitable and applicable for medical imaging curricula 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.

Acknowledgement

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