AC 2011-26: STUDENT-CENTERED LEARNING FOR INTERDISCIPLINARY COURSES: A MULTIFACETED APPROACH

Naiquan (Nigel) Zheng, University of North Carolina, Charlotte

Dr. Nigel Zheng received his B. Eng from Zhejiang University, China, M.Sc. from College of Medicine, Shanghai Jiaotong University, and M.Sc. and Ph.D. from Univesity of Saskatchewan, Canada. Currently he is an assistant professor in the Center for Biomedical Engineering Systems, Department of Mechanical Engineering and Engineering Science at the University of North Carolina at Charlotte. His research interests include orthopedic biomechanics, sports medicine and rehabilitation, and motion analysis.

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Student-centered Learning for an Interdisciplinary Course:

a multifaceted approach

University of North Carolina at Charlotte

Introduction

An orthopedic surgery often involves use of implants for bone fracture fixation or joint surface replacement. Pre-surgery assessment and post-surgery rehabilitation often involve use of rehab exercise equipment, braces and rehab treatment devices, and evaluation tools of human joint functions. Orthopedic industry has grown to a multi-billion dollar business and is in dire need of well trained biomechanical engineers. In order to better understand the needs and make contributions more effectively, it is important for mechanical engineering students to learn basic and relevant medical knowledge through interdisciplinary courses and get ready for a job in the orthopedic industry. Student-centered learning is a key to success in dealing with new learning difficulties for interdisciplinary courses. WWW-based e-Learning, problem-based learning (PBL) and design-based learning (DBL) are commonly used approaches to student-centered learning.

Current trends in medical education suggest a move toward PBL, with an emphasis on student-centered education and use of information technologies, such as interactive visual images[3]. A group of students are asked to solve complex and realistic PBL problems through identifying what they already know, what they need to know and, gathering diverse kinds of information. Effectiveness of PBL and e-Learning in studying Physiology, Surgery and other courses in medical science and medicine has well been documented[1, 3, 6, 10, 16, 20, 22]. PBL is believed to stimulate students' motivation and their interest toward learning, and help them to become more self-directed and life-long learners. Students are motivated by an interest in the subject material and recognition of its vocational relevance. The PBL approach is well suited to the demands of a rapidly changing field that needs experts who can change and grow through life-long learning[19]. More biomedical engineering graduate programs now turn to PBL approach[7, 11, 13-15, 18, 19]. PBL problems have the possibility of exposing students to the fast paced nature of technological change and the requirement for innovative problem solving across disciplinary borders[19].

Learning anatomy and physiology presents mechanical engineering students with learning obstacles and opportunities somewhat different from those they face when learning other more traditional engineering disciplines. In designing biomedical devices, students will need to address anatomical and physiological issues in order to produce an acceptable design[4]. Design-based learning (DBL) allows engineering students to use their familiar approach to study unfamiliar subject materials. DBL enables students to initiate the learning process in accordance to their own preference, learning styles, and various skills[9]. DBL approach motivates students to learn because of the more obvious application of their knowledge to real life situations[8]. The DBL approach encourages active learning, creativity, team work and enthusiasm.

Teaching engineering students some basic human anatomy, especially the musculoskeletal system, is important to their preparation to be a qualified orthopedic engineer (such as designer and developer of an orthopedic implant). However, in tradition, most learning is carried out in dissection laboratories. Recently WWW-based interactive images, anatomy software applications have made significant progress[2, 5, 12, 17, 21, 23]. PBL encourages the understanding of anatomy and aids in the development of clinical thinking[2]. The rigorous mathematical curriculum is the cornerstone of engineering education. It is challenging for engineering programs to incorporate an in depth study of the systemic interdependence of medical courses. To be sure, many biomedical engineering programs require their students to enroll in anatomy and physiology courses[7]. Often, however, these courses are challenging since they are so different than traditional engineering courses. Traditionally many courses in the area of medical science and medicine have been added to curriculum for the biomechanical engineering students, which can significantly prolong their 4-years to 6-years college life. WWW-based e-Learning enables students to learn medical knowledge (i.e., human anatomy and physiology) that are needed in solving their PBL problems or DBL projects on their own pace, at their preferred time and location. In addition, e-Learning allows students to select learning materials that meet their level of knowledge and interest.

The overall purpose of the project was to develop an interdisciplinary course for mechanical engineering students with an emphasis on student-centered education and use of information technology. This project integrated WWW-based e-Learning, PBL and DBL to improve our engineering students' knowledge and skills in orthopedic engineering without prolonging their college life. An interdisciplinary course was developed with an emphasis on student-centered education and use of a multifaceted approach (i.e. WWW-based e-Learning, PBL and DBL).

Background

The University of North Carolina at Charlotte is a fast growing university with 38% and 71% growth in the past decade for undergraduate and graduate students, respectively. The Department of Mechanical Engineer and Engineering Science (MEES) has experienced fast growing in the past decade. In coping with growing student population, the department has recently identified four focus areas and is in the process of developing new courses in these areas. One of these four focus areas is biomedical engineering as orthopedic and healthcare industry has grown to a multi-billion dollar business and is in dire need of well trained engineers. It is important for engineering students to learn basic and relevant medical knowledge to be prepared for a job in the orthopedic industry or the healthcare sector. New interdisciplinary courses will prepare our mechanical engineering students for jobs in the areas of healthcare and the orthopedic industry. The overall objective of an interdisciplinary course is to prepare students to tackle complex real-world problems in orthopaedic engineering. This requires them to become self-directed learners who possess excellent inquiry skills to learn from physicians and therapists. They must also become life-long learner to tackle new emerging clinical problems. And finally they must increase their understanding of effective communication strategies to communicate with clinicians.

PBL and DBL will motivate engineering students to study problem- and design-related medical knowledge. WWW-based e-Learning will provide an effective student-centered learning module. New interdisciplinary courses will prepare our engineering students for jobs in the areas of healthcare and orthopedic industry. Students will be able to improve their self-esteem in interdisciplinary learning, acquire skills for tackling real-world orthopedic problems, and select their own area of focus with improved self-motivation. Students are expected to be more successful in learning and become self-direct learners, knowledge builders and better problem solvers. A multifaceted approach, which integrated PBL, DBL and WWW-based e-Learning, was adopted for student-centered learning in one of our recently developed interdisciplinary courses.

Methodology

MEGR 3090 Intro to Biodynamics is one of such interdisciplinary courses developed in spring 2009 as an elective. In this course, we aimed to obtain the following specific objectives:

1. To improve engineering students' skills in self-directed learning of basic medical knowledge related to orthopedic engineering design and manufacture;
2. To improve engineering students' skills in tackling complex real-world problem in orthopedic engineering.

The course was offered during spring 2009 and spring 2010. The prerequisites were that students completed Dynamics I and Mechanics of Solids with C or better. The study was approved by the Institutional Review Board at the University of North Carolina at Charlotte. Each student was invited to participate in the study and signed informed consent was obtained. An online pre-course self-report survey was conducted on their anatomy knowledge related to both PBL problem and the design project. Their knowledge in the area and their skills of self-directed learning were also surveyed at the end of the course.

The following PBL problem and individual project were assigned:

PBL problem

"John is a 13 year old baseball player (pitcher). He received a Christmas gift from his grandfather which is a weighted training glove (see more info from the link on the course Moodle site). Early this spring, John started to use his glove during throwing baseball. He put all weights (12 oz) on his glove. Weeks later he had the elbow pain and diagnosed as Little League Elbow syndrome. John's grandpa was very upset. Because the company claimed the glove he bought "Not only does it increase velocity, it also helps to reduce injuries". He sent John to a Biomechanics and Motion Analysis Lab and got a set of John's pitching motion data. You are consulted by John's grandpa and need to find out:

1. Peak forces and torques at the elbow during throwing with and without wearing the glove,
2. Possible reasons why John developed the Little League Elbow syndrome,
3. Your opinion on using weighted glove for strength training of pitchers, and
4. Your suggestion for preventing Little League Elbow."

DBL project

"Team MEGR3090 is requested to design a new functional knee brace. As a team member, your job is to provide a list of design criteria for the team. The sponsor would like to have the best knee brace designed by Team MEGR3090. The new knee brace should be comfortable, do not slip during dynamic activities, and most important, provide support to the knee post injury and/or surgery. In order to provide a good list of design criteria to the team, you need to learn the functional anatomy and physiology of the knee. You may borrow anatomy books from the university library or surf the Internet to dig out knowledge for your design criteria. Your project report should cover knee function, major ligaments of the knee, and major muscles of the knee, joint motion of the knee, and mechanical joint of the knee brace, and attachment of the brace to limbs. The report should be at least 1000 words. You must submit your report only through MEGR3090 course Moodle site."

Students worked as a group of 4 on the PBL problem, but were required to work independently on the DBL project. A list of URLs was provided to assist students' WWW-based e-Learning. Three-dimensional computer graphics and animations of human shoulder, elbow and knee joint were also available to meet students' needs in order to tackle both the PBL problem and the DBL project. For the DBL project students were required to present their design criteria for the knee brace in the classroom and answer questions raised by fellow students. Self-reported questionnaires were used to evaluate objective attainment, tools used to study anatomy, hours spent through PBL problem and DBL project. Both the PBL problem and the DBL project were assigned after the first three lectures. Their ability to solve problems and knowledge were rated from 1 to 5: poor (1), fair (2), good (3), very good (4), and expert (5). An evaluation rubric was developed to assess students' skill in tackling complex real-world problem (Table 1). Fifteen traditional lectures were also offered in this course. After every three lectures, a problem session was led by the instructor with one real world biomedical engineering problem for group discussion on student-centered learning experiences, skills learned in tackling the PBL problem, and issues that may involve the DBL project. Students were also exposed to a motion analysis laboratory for motion capture as well as ground reaction force and electromyography (EMG) data collection. An online quiz was also developed to test students' basic medical knowledge. Data were analyzed using paired student t-test (SPSS, IL).

Results and Course Assessment

A total of 38 students participated in the study. They filled out surveys through the design-based training project. One student spent less than 2 hours, 16 spent 2-4 hours, 12 spent 4-6 hours, 4 spent 6-8 hours and 5 spent more than 8 hours studying anatomy. All but one used the Internet, 19 of them used anatomy books, 24 used the textbook and 35 used the lecture notes. The focus of this new multifaceted approach is student-centered. It was up to student to choose approach that he/she thought the most efficient for him/her to study medical knowledge for the DBL project. Combined usage of e-Learning, lecture notes and other materials demonstrated that they all have a role in student-centered learning. Twenty four students reported poor knowledge, 6 students fair and 8 students good before working on the project. After completing the project, 4 students reported good, 33 very good and 1 expert. On average, students' knowledge on major knee joint structure was improved from 1.6 to 3.9. A paired student t-test showed that improvement in their self-reported knowledge was very statistically significant ($t=16.3$, $df=37$, $p=0.000$). Although it was not clear how this improvement was attributable to the use of e-Learning or lecture notes, the student-centered multifaceted approach was effective in learning medical knowledge.

Table 1 Evaluation rubric for students' skills in tackling complex real-world problems

	Below Expectation	Meets Expectation	Exceeds Expectation
Problem definition/ Design criteria	Fails to identify the problem, specify design criteria.	Identifies the problem, and specifies design criteria	Easily identifies problem, specifies design criteria, and identifies constraints that will affect the solution
Create models/ Hypotheses	Provides poor approach, disorganized and/or confused approach or understanding	Provides well organized approach, explores alternate solution, identifies potential obstacles	Provides mastery approach, explores alternate solution, identifies potential obstacles, clearly defines hypothesis/design
Inquiry	Identifies what he/she does not know, prioritizes learning needs, fails to conduct self-directed inquiry and study	Identifies what he/she does not know, prioritizes learning needs, sets learning goals and objectives, conducts self-directed inquiry and study	Identifies what he/she does not know, prioritizes learning needs, sets learning goals and objectives, conducts self-directed inquiry and study, identifies tasks for each member, allocates resources to clarify expectations
Analysis	Fails to share the new knowledge with the group in an effective manner	Share the new knowledge with the group in an effective manner, determines the performance of the proposed solutions	Share the new knowledge with the group in most effective manner, determines the performance of the proposed solutions
Decision/ design	Identifies some key elements in problem approach and solution, fails to determine the solution	Determines the solution that achieves the problem/design specifications/criteria, help to reach group consensus, identifies most of key elements in problem approach and solution	Determines the solution that best achieves the problem/design specifications/criteria, reaches group consensus, Inspires others to approach problem in interesting ways, demonstrates both mastery and creativity in problem approach and solution
Communication	Participate in group discussion, contribute little to final report and presentation	Actively participate in group discussion, writes report and gives oral presentation with help	Actively participate in group discussion, communicates with all of key features of the problem, writes report and gives oral presentation
Assessment	Fails to give feedbacks on the effectiveness of the problem-solving or design process	Gives feedbacks on the effectiveness of the problem-solving or design process, identifies areas of weakness	Gives feedbacks on the effectiveness of the problem-solving or design process, identifies areas of weakness and strategies for improvement

The averages of objective attainment before and after the course were obtained from 38 students. After working on the PBL problem, students' knowledge on the elbow anatomy was significantly improved from 1.8 to 3.9 with 1 as poor and 5 as expert (t=9.3, df=37, p=0.000). Through this course students learned mechanics of human skeletal muscles (significantly improved from 1.8 to 4.3, t=8.4, df=37, p=0.000). Students were able to describe anatomic terminology after this course (significantly improved from 2.4 to 4.6, t=7.6, df=37, p=0.000). After this course the ability of learning medical knowledge through www-based content was significantly improved from 2.4 to 4.5 (t=7.7, df=37, p=0.000). Almost every student met expectation or exceeded expectation listed in the evaluation rubric for their skills in tackling complex real-world problem. They were able to command basic medical knowledge through WWW-based e-Learning for their projects and homework assignments. Every student received a 70% or higher on their online quiz.

Overall, students liked the course, PBL and design-based training approach. They learned how to learn medical knowledge from the WWW-based e-Learning for their complex real-world problems. The course received 4.0 out of 5 rating from students' evaluation as among the best, above the average 3.5 out 5.0 of the college of engineering.

Conclusions and Improvement

There are massive amount of multi-modal (including text, images, animations, video clips etc) medical information on the Internet. WWW-based e-Learning provided our students a new rich content for their needs in solving complex real-world problem or completing a DBL project, or homework assignments. This interdisciplinary course adopted a student-centered multifaceted learning approach. Besides WWW-based e-Learning, students were assigned BPL problem and DBL project. Through student-centered learning, students were motivated for knowledge, able to command basic skills in acquiring medical knowledge through WWW-based e-Learning and skills in tackling complex real-world problems. Overall, this course implementation of student-centered learning was deemed a success, and this paper has presented the overall framework for how WWW-based e-Learning, PBL and DBL were integrated with traditional lectures of an interdisciplinary course. In the future, more PBL problems and DBL projects will be developed. The number of lectures will be reduced and PBL problems and DBL projects will be increased. At the same time, students will be expected to spend more time with WWW-based e-Learning. By working on multiple complex real-world problems students will command medical knowledge and other skills that may meet the needs as a mechanical engineer in the orthopedic industry.

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1. Abraham RR, Vinod P, Kamath MG, Asha K, Ramnarayan K. Learning approaches of undergraduate medical students to physiology in a non-PBL- and partially PBL-oriented curriculum. *Adv Physiol Educ.* Mar 2008;32(1):35-37.

2. Boon JM, Meiring JH, Richards PA, Jacobs CJ. Evaluation of clinical relevance of problem-oriented teaching in undergraduate anatomy at the University of Pretoria. *Surg Radiol Anat.* 2001;23(1):57-60.

3. Corrigan M, Reardon M, Shields C, Redmond H. "SURGENT" -- student e-learning for reality: the application of interactive visual images to problem-based learning in undergraduate surgery. *J Surg Educ.* Mar-Apr 2008;65(2):120-125.

4. Cudd TA, Wasser JS. Biomedical device design discovery team approach to teaching physiology to undergraduate bioengineering students. *Am J Physiol.* Dec 1999;277(6 Pt 2):S29-41.

5. Dangerfield P, Bradley P, Gibbs T. Learning gross anatomy in a clinical skills course. *Clin Anat.* 2000;13(6):444-447.

6. Dantas AM, Kemm RE. A blended approach to active learning in a physiology laboratory-based subject facilitated by an e-learning component. *Adv Physiol Educ.* Mar 2008;32(1):65-75.

7. DiCecco J, Wu J, Kuwasawa K, Sun Y. A novel approach to physiology education for biomedical engineering students. *Adv Physiol Educ.* Mar 2007;31(1):45-50.

8. Doppelt Y. Implementing and assessing project-based learning in a flexible environment. *The International Journal of Technology and Design Education.* 2003;13(3):255-272.

9. Duppelt Y, Mehalik M, Schunn C, Krysinski D. Engagement and achievements in design-based learning. Journal of Technology Education. *Journal of Technology Education.* 2008;19(2):21-38.

10. Dupuis RE, Persky AM. Use of case-based learning in a clinical pharmacokinetics course. *Am J Pharm Educ.* Apr 15 2008;72(2):29.

11. Enderle J. Encouraging hands-on experience in BME education. *IEEE Eng Med Biol Mag.* May-Jun 2007;26(3):4, 76.

12. Ernst RD, Sarai P, Nishino T, et al. Transition from film to electronic media in the first-year medical school gross anatomy lab. *J Digit Imaging.* Dec 2003;16(4):337-340.

13. Fries RC. An industry perspective on senior biomedical engineering design courses. *IEEE Eng Med Biol Mag.* Jul-Aug 2003;22(4):111-113.

14. Glatz CE, Gonzalez R, Huba ME, et al. Problem-based learning biotechnology courses in chemical engineering. *Biotechnol Prog.* Jan-Feb 2006;22(1):173-178.

15. Goldberg J. Service learning opportunities in biomedical engineering senior design projects. *IEEE Eng Med Biol Mag.* Jul-Aug 2004;23(4):14-15.

16. Jippes M, Majoor GD. Influence of national culture on the adoption of integrated and problem-based curricula in Europe. *Med Educ.* Mar 2008;42(3):279-285.

17. Levine MG, Stempak J, Conyers G, Walters JA. Implementing and integrating computer-based activities into a problem-based gross anatomy curriculum. *Clin Anat.* 1999;12(3):191-198.

18. Marceglia S, Bonacina S, Mazzola L, Pinciroli F. Education in biomedical informatics: learning by doing bioimage archiving. *Conf Proc IEEE Eng Med Biol Soc.* 2007;2007:5924-5928.

19. Newstetter WC. Fostering integrative problem solving in biomedical engineering: the PBL approach. *Ann Biomed Eng.* Feb 2006;34(2):217-225.

20. Sachdeva AK. Surgical education to improve the quality of patient care: the role of practice-based learning and improvement. *J Gastrointest Surg.* Nov 2007;11(11):1379-1383.

21. Van Ginneken CJ, Vanthourout G. Rethinking the learning and evaluation environment of a veterinary course in gross anatomy: the implementation of an assessment and development center and an E-learning platform. *J Vet Med Educ.* Winter 2005;32(4):537-543.

22. van Mook WN, de Grave WS, Huijssen-Huisman E, et al. Factors inhibiting assessment of students' professional behaviour in the tutorial group during problem-based learning. *Med Educ.* Sep 2007;41(9):849-856.

23. Yiou R, Goodenough D. Applying problem-based learning to the teaching of anatomy: the example of Harvard Medical School. *Surg Radiol Anat.* May 2006;28(2):189-194.