AC 2012-5224: TEACHING-TO-LEARN SESSIONS TO ACHIEVE SUBJECT RELEVANCE IN AN INTRODUCTION TO BIOMEDICAL ENGINEERING COURSE

Dr. Steve Warren, Kansas State University

Steve Warren received a B.S. and M.S. in electrical engineering from Kansas State University in 1989 and 1991, respectively, followed by a Ph.D. in electrical engineering from the University of Texas, Austin, in 1994. Warren is an Associate Professor in the Department of Electrical & Computer Engineering at Kansas State University. Prior to joining KSU in Aug. 1999, Warren was a Principal Member of the technical staff at Sandia National Laboratories in Albuquerque, N.M. He directs the KSU Medical Component Design Laboratory, a facility partially funded by the National Science Foundation that provides resources for the research and development of distributed medical monitoring technologies and learning tools that support biomedical contexts. His research focuses on plug-and-play, point-of-care medical monitoring systems that utilize interoperability standards; wearable sensors and signal processing techniques for the determination of human and animal physiological status; and educational tools and techniques that maximize learning and student interest. Warren is a member of the American Society for Engineering Education and the Institute of Electrical and Electronics Engineers.

Teaching-to-Learn Sessions to Achieve Subject Relevance in an Introduction to Biomedical Engineering Course

Abstract

The instructor of an Introduction to Biomedical Engineering course senses pressure to touch on a broad set of topics, where any given topic is difficult to address at a reasonable level of depth if a course goal is to achieve even moderate coverage of this growing field. Since such courses often attract a wide array of students from different areas of engineering, this problem of breadth versus depth is compounded by (a) differences in student preparation related to subjects such as biology, mathematics, circuits, and programming, (b) stark variations in the core interests of the students, and (c) cultural disparities between engineering departments regarding reasonable levels of assignment difficulty and commensurate time investments. To help address some of these issues in a junior-level *Introduction to Biomedical Engineering* course, the author has chosen (for four recent Spring course offerings) to set aside two to three weeks of each 16-week course for discretionary topics chosen by the students. Each student or student pair then takes on the role of the instructor and teaches that topic to the rest of the students in the format of a 25-minute seminar. Students must assign homework to their peers and grade the results; these grades are then entered into the course spreadsheet along with regular course homework.

These teaching-to-learn sessions help to ensure a level of relevance and topical interest that is difficult to attain given the wide array of student backgrounds and the semester-to-semester variability in student demographics. Further, the idea behind these sessions is consistent with the experiential knowledge that one understands a subject more deeply when one is required to teach it to others. This seemingly straightforward pedagogical intervention has been surprisingly successful. These sessions are often of higher quality than lectures planned by the assigned course instructor, and both the students and the instructor consider them the highlight of the semester. End-of-semester assessments based on rubrics published to students beforehand point toward excellent performance by the presenters and satisfactory learning by the students. While some of the topics are arguably more superficial than desirable and lead to homework with reduced difficulty, class attendance is improved, and the topic set is more fluid and better matched to semester-dependent variations in student preparation and demographics.

I. Introduction

Kansas State University (KSU) does not currently offer a formal degree in Biomedical Engineering, but many independent biomedical teaching and research efforts are hosted by departments within and outside of the KSU College of Engineering (COE). Within the KSU COE, most of the formalized opportunities in biomedical engineering education have been offered to date through the KSU Department of Electrical & Computer Engineering (ECE).[1] The KSU ECE Department offers these courses in the context of a Bioengineering Option as part of an Electrical Engineering (EE) degree, and this option area has been offered for over thirty years as a Regents-approved opportunity for EE students. *ECE 571 – Introduction to Biomedical Engineering*, is a required course in the EE Bioengineering Option and has multiple goals: to introduce students to this growing field, to recruit students into the EE Bioengineering Option, to encourage students to seek out graduate opportunities in biomedical engineering, and to provide a discussion venue for the multiple KSU research groups that work in this area.

In recent years, the ECE 571 course has become a popular technical elective for students in multiple KSU COE departments as these departments expand their research and teaching portfolios to include biomedical focus areas. In response, this course was recently upgraded to a three-credit offering with an increased enrollment cap to accommodate these other KSU departments, which include Biological & Agricultural Engineering, Industrial & Manufacturing Systems Engineering, Mechanical Engineering, and Chemical Engineering. ECE 571 uses a formal course text[2] supplemented by numerous electronic and hardcopy resources.

While this increased interest in biomedical research and education has led to new opportunities, the participation of such a diverse group of students in this *Introduction to Biomedical Engineering* course has made the assignment of syllabus topics a challenge. The biomedical engineering topic set already presents a breadth versus depth tradeoff, and the participation of students with backgrounds in multiple areas of engineering further increases pressure on the instructor to include topics that make the course relevant to each of these students. This situation is further complicated by (a) differences in student preparation related to subjects such as biology, mathematics, electronic circuits, and programming, (b) variations in students' core interests, and (c) cultural disparities between engineering departments regarding reasonable levels of assignment difficulty and commensurate time investments. A 'traditional' homework, project, and test approach is therefore awkward in this course, which has recently taken on more of a seminar format with higher-level discussions that come with a risk of more superficial assignments and follow-on assessments. For example, electronic instrumentation topics that would previously have been addressed at the circuit level must now be taught at the level of a block diagram so as to engage all of the students. Additionally, team teaching is a temptation, as is a reliance on third-party videos created by experts in the various subject areas. In aggregate, these influences place increased emphasize on the role of a teacher as a course coordinator in addition to a subject expert.

In an effort to address the *Introduction to Biomedical Engineering* topics that the instructor feels are important while also accommodating the diversity of the recent student participants, the instructor has (over the course of the last four years), moved to a scheduling approach where the planned 16-week course topic set accommodates about three weeks of discretionary, student-led learning experiences. These "teaching-to-learn" sessions help to address the issue of subject relevance by directly accommodating the year-to-year fluidity of the student body within this course. This approach requires a student or student pair to take on the role of the instructor and teach a biomedical topic of their interest to the rest of the students in the format of a 25-minute seminar. Students must assign homework to their peers and grade the results, where these grades are then entered into the course spreadsheet along with regular course homework. The added benefit, consistent with experiential knowledge and published research,[3, 4] is that one understands a subject more deeply when one is required to teach it to others. The following sections address the methods through which these sessions are assigned and delivered, the topics chosen by these students thus far, the types of homework that these students tend to assign, the rubric used to assess each student's performance, and a discussion of the overall benefits and drawbacks of this approach when applied to an introductory biomedical engineering course.

II. Methods

A. Static Course Topics

A typical tentative schedule for a Spring offering of the *ECE 571 – Introduction to Biomedical Engineering* course is illustrated in Figure 1. This three-hour course is 16 weeks long and consists of about 45 separate course sessions. In light of the numerous possible topics that might be addressed in this course, the instructor has chosen to focus on the following thematic areas given the teaching and research contingency at KSU that currently work in the biomedical arena:

- ***Background*** – An overview of biomedical engineering and a short section on anatomy and physiology that helps to establish a foundation for the ensuing course dialogue.
- ***Biomedical Data Acquisition, Analysis, & Visualization*** – An overview of medical instrumentation that roughly incorporates the contents of the previous 1-hour version of this course when taught primarily to EE students.
- ***Tissue Properties & Enhancement*** – Techniques to assess tissue properties and create biocompatible materials.
- ***Application Domains*** – Representative application domains that align with KSU research and can therefore change in consecutive course offerings.
- ***Resources*** – Support tools and ways of thinking that enable health care delivery.

Note that six days are allocated to teaching-to-learn sessions based on a recent enrollment of 24 students (2 students per team * 2 teams per 50-minute session), although some students request to deliver a session on their own. Spring 2012 enrollment in ECE 571 is currently at 42 students, which will require an adjustment in the relative amount of time allocated to these experiences and perhaps the way in which they are administrated.

As a side note, the static topics in this course are chosen from a broader listing that takes various forms depending on the published source. Table 1 contains three listings of subject areas related to biomedical engineering that were obtained from the course textbook,[2] the biomedical engineering career guide published by the IEEE Engineering in Medicine and Biology Society (EMBS),[5] and the subject tracks from the 2011 conference of the IEEE EMBS.[6]

	Week	Day	Subject	Material
Background	1	M	***Student Holiday***	
		W	Course Introduction	
		F	Biomedical Engineering	Enderle Ch. 1
	2	MWF	Anatomy & Physiology	Enderle Ch. 3
Biomedical Data Acquisition, Analysis, & Visualization	3	MW	Medical Instrumentation Overview	Enderle Ch. 8
		F	Biomedical Sensors	Enderle Ch. 9
	4	MW	"	"
		F	***Exam #1***	
	5	MWF	Signals and Biosignal Processing	Enderle Ch. 10
	6	MWF	Medical Imaging	Enderle Ch. 15-16
	7	MWF	Biomedical Optics	Enderle Ch. 17
Tissue Properties & Enhancement	8	MW	Biomechanics	Enderle Ch. 4
		F	***Exam #2***	
	9	MW	Biomaterials	Enderle Ch. 6
		F	*T-to-L Topics*	
	10	MWF	***Spring Break***	
	11	MW	Tissue Engineering	Enderle Ch. 7
		F	*T-to-L Topics*	
Application Domains	12	MW	Rehabilitation Engineering & Assistive Technology	Enderle Ch. 5
		F	*T-to-L Topics*	
	13	MW	Telemedicine and Home Care	
		F	***Open House***	
	14	M	Emergency and Military Medicine	
		W	*T-to-L Topics*	
		F	***Exam #3***	
Resources	15	M	Medical Information Systems; Electronic Patient Records	
		W	Medical Facility Design	
		F	*T-to-L Topics*	
	16	MW	Medical Ethics	Enderle Ch. 2
		F	*T-to-L Topics*	
	17	M	***Final Exam***	

Figure 1. Typical tentative schedule for the *Introduction to Biomedical Engineering* course.

Table 1. Subject areas relevant to biomedical engineering teaching and research.

"The World of Biomedical Engineering" as laid out in Enderle Figure 1.9[2]	Topics Addressed in the IEEE EMBS Career Guide[5]	2011 IEEE EMBC Conference: Program Themes[6]
1. Biomechanics 2. Medical & Biological Analysis 3. Biosensors 4. Clinical Engineering 5. Medical & Bioinformatics 6. Rehabilitation Engineering 7. Physiological Modeling 8. Bionanotechnology 9. Prosthetic Devices & Artificial Organs 10. Medical Imaging 11. Biomaterials 12. Biotechnology 13. Tissue Engineering 14. Neural Engineering 15. Biomedical Instrumentation	1. Physiological Systems Modeling 2. Biomechanics 3. Instrumentation, Sensors, & Measurement 4. Micro & Nanotechnology 5. Biosignal Processing 6. Rehabilitation Engineering 7. Neural Systems & Engineering 8. Bioinformatics 9. Genomics 10. Proteomics 11. Imaging & Image Processing 12. Radiology 13. Biotechnology 14. Biomaterials 15. Clinical Engineering 16. Information Technology 17. Telemedicine 18. BioMEMs 19. Robotics in Surgery	1. Biomedical Signal Processing 2. Biomedical Imaging & Image Processing 3. Bioinstrumentation: Sensors, Micro, Nano, and Wearable Technologies 4. Bioinformatics, Computational Biology; Systems Biology, Modeling Methodologies 5. Cardiovascular & Respiratory Systems Engineering 6. Neural and Rehabilitation Engineering 7. Molecular, Cellular, and Tissue Engineering and Biomaterials 8. Biomechanics and Robotics 9. Therapeutic & Diagnostic Systems, Devices and Technologies, Clinical Engineering 10. Healthcare Information Systems, Telemedicine 11. Technology Commercialization, Education, Industry, and Society

B. Supplementary Teaching-to-Learn Topics

As noted earlier, the teaching-to-learn sessions are a supplement to the static topics addressed by the course instructor. Their purpose is to better align the course material with student interests and degree areas given year-to-year variations in class demographics. To that end, students are given a homework assignment early in the semester where they work with one other student to choose a biomedical topic and then design a 25-minute course session that introduces the rest of the class to the topic. The students are told to consider

- the areas of biomedicine discussed the first day of class,
- the subject(s) of interest that they wrote on their index cards the first day of class (index cards are distributed to students so that they can provide the instructor with more details regarding their interests and activities than are provided in the KSU online database),

- the discretionary topic that they chose for Homework 1 (a medical device search where each student pursues information about a device of interest to them), and
- the topics listed on the tentative schedule in the course syllabus.

More specifically, the students are instructed to submit the following by mid-semester:

- A session outline that indicates how they wish to allocate their 25 minutes.
- A list of teaching tools they plan to employ to most effectively demonstrate their topic (white papers, journal articles, web sites, videos, personal interviews, props, …).
- An idea or two regarding a homework assignment that will better familiarize the other students with the subject. The assignment should be doable in about an hour and be focused enough that the other students can reflect on one facet of the chosen area. Because two sessions are planned for each 50-minute class period, this points to an expectation of two hours of outside homework for each hour of in-class learning.

Prior to the respective learning sessions, the instructor works individually with each team to finalize the structure of the session and ensure that these students have access to the resources they need. Creativity is emphasized. Given some engineering students' discomfort with public speaking, the students are reminded that this session is not a "presentation," but rather a communication with the remainder of the group, where the format will primarily be up to them. This assignment is viewed as the 'project' portion of this course; it is assigned credit like any of the normal homework the students submit.

In the middle of the semester, the students sign up for the session dates that they prefer. Once each session has been taught, these students assign homework to the rest of their peers, grade the homework, and then bring the graded homework to the instructor for inclusion in the course spreadsheet. These sessions are assessed using variations of the rubric presented in Figure 2. This rubric, in tabular format, is expanded to fill one page and returned to the students with comments and point values.

Student/Team: ______________________________ Total: __ / 100

Overall Perceptions		**Subtotal: __ / 40**
Session Focus and Relevance	10	
Effectiveness of Learning Experience	10	
Creativity	10	
Preparation	10	
Session Management/Delivery		**Subtotal: __ / 60**
Time Management	10	
Communication of Ideas	10	
Organization	10	
Resource Materials (white papers, journal articles, web sites, videos, personal interviews, props, …)	20	
Homework Assignment	10	

Figure 2. Assessment rubric applied to the teaching-to-learn sessions.

III. Results

A. Student Products

The left column of Table 2 lists the teaching-to-learn topics chosen by the students the last four times this teaching approach was used in the *ECE 571 – Introduction to Biomedical Engineering* course. (Note that the Spring 2007/2009 offerings were one-credit-hour courses, whereas the Spring 2010/2011 offerings were three credits each.) All sessions to date have taken the form of PowerPoint presentations, though that is not a requirement of the teaching/learning experience. A typical session will begin with introductory slides that contain web graphics, continue with short video segments from the web that explain topic details, incorporate slides with supplementary discussion material, touch on areas of future work, and then commence with an explanation of the homework assignment. Creativity manifests itself in various ways during these sessions, usually at the level of individual slides as opposed to the entire session format. Creative session elements include items such as the following:

- Case studies that help to illustrate a point
- Voiced-over images/videos to add humor
- Cartoons or image/video 'fails' that help to illustrate a point in an entertaining way
- In-class exercises the students complete while the session is in progress
- Active learning exercises
- Props, such as physical medical devices, often worn or used by the students
- Personal anecdotes, including individual medical conditions, family situations, or employment experiences
- Usage examples that help to illustrate, e.g., human factors tradeoffs
- Scenarios that relate to local hospitals or the community
- Examples of alternative medical treatments prior to the technologies of interest
- Application examples based upon ongoing KSU research

The types and formats of the homework assignments vary significantly, as illustrated in the right column of Table 2. Overall, the assignments tend to be creative, they are not particularly difficult, and they are graded generously. Students like to be nice to their peers. Assignments are rarely quantitative (i.e., require the use of mathematical analyses or engineering tools). Rather, they tend to be concept-based and high-level. Assignment formats often mimic higher-level, individual problems from earlier ECE 571 homework. Repetitive themes include the following:

- Write a summary of an article, web site, or video that relates to the biomedical topic.
- Provide responses to short-answer, true/false, or multiple-choice problems.
- Complete a crossword puzzle that relates to the subject area.

Table 2. Subject areas chosen by the students and the corresponding homework assignments for the recent teaching-to-learn sessions.

Spring 2007 Topic	Homework Format
1. Biomechatronics	1. Block diagram and summary for a biomechatronics device idea
2. Lost Instruments	2. Half-page summary of ideas to counteract the lost-device problem
3. Biomechanics	3. Summary of a biomechanics article
4. Tissue Engineering	4. Short answer questions related to cell growth and tissue engineering
5. Diabetes	5. Summary of an Internet article related to diabetes
6. Cochlear Implants	6. Summary of an article related to cochlear implant technology
7. Water Quality	7. Summary of a specific type of wastewater treatment
8. Synthetic Biology	8. Summary of a video related to synthetic biology
Spring 2009 Topic	**Homework Format**
1. Prosthetics	1. Half-page summary of a prosthetic device company
2. BioMEMS	2. Crossword puzzle related to BioMEMS systems
3. Brain-Machine Ethics	3. Summary of an article dealing with the ethics of brain-machine devices
4. Hospital Facility Design	4. Multiple choice and short answer questions on hospital facility design
5. Emergency Medicine	5. Emergency medicine word jumble
6. Augmented Reality	6. Experiment with an augmented reality web site
7. DMX Motion X-Rays	7. Short answer questions related to X-ray imaging
8. Ultrasound	8. Article summaries related to pocket ultrasound & ultrasound technology
9. Emergency Departments	9. Emergency department word search
10. Biomaterials	10. Short answer questions related to stent materials
11. Biomechanics	11. Short answer questions related to the presentation material in class
12. Telemedicine	12. Short answer questions related to telemedicine and home care programs
Spring 2010 Topic	**Homework Format**
1. Artificial Organs	1. Crossword puzzle related to artificial organs
2. EEG and Biosignal Processing	2. Signal analysis in multiple domains
3. Wearable Sensors	3. Short explanation of the operation of a wearable biosensor
4. Breakthroughs	4. Discussion of the pitfalls of emerging oxygen-carrying blood substitutes
5. Genetic Engineering	5. Short paper that addresses genetic engineering ethics
6. Nanotechnology	6. Summarize the research of laboratory that performs nanoresearch
7. Surgical Robotics	7. Short answers to questions related to the ethics of robotic surgery
8. Clinical Simulation	8. Identification of bottlenecks in a discrete hospital simulation
9. Human Factors	9. Six control guidelines as applied to an infusion pump design
10. Hatred of Hospitals	10. Crossword puzzle related to ill favor toward hospitals
11. Joint Health	11. Joint identification and short essay on finger joint replacement
12. Cancer & Obesity	12. Written response to an article on cancer and obesity
Spring 2011 Topic	**Homework Format**
1. Prosthetics	1. Prosthetics crossword puzzle
2. Operating Room Layout	2. Operating room layout exercise with cutout objects on a grid
3. Radiation Therapy	3. Radiation therapy multiple choice, T/F, and short answer questions
4. Ergonomics	4. Four-hour operation case study with proposed solutions
5. Electrooculography	5. EOG multiple choice, T/F, and short answer questions
6. Diabetes Treatments	6. Diabetes crossword puzzle
7. Medical Facility Design	7. Seven short answer questions related to hospital design & effectiveness
8. Nurse Path Tracking	8. Traveling nurse path optimization exercise
9. Bacteriophage	9. Bacteria and virus T/F, fill-in-the-blank, and drawing with labels
10. Near-infrared Imaging	10. NIR word jumble

B. Assessment Results

Assessment results from the teaching-to-learn sessions to date are tallied in Table 3. These results are a collation of two separate assessments: the session definitions that the students provided to the instructor early in each semester (items 1 and 2) and the post-session scores that the students received based on the assessment rubric presented in Figure 2 (items 3 through 13). Each numerical value in the table represents an average percentage received by all students in the class for a given category. For example, the "Effectiveness of Learning Experience" category in Figure 2 is worth 10 points. In Spring 2010, the students received an average score in that category of 9.14/10, or 91.4%. Note that data from Spring 2007 were collected using a different rubric but are included in the table for comparison. Also, the session definition and refinement scores were bundled together in Spring 2010 and 2011. Performance data from the student-assigned homework sets (i.e., the points that students received when their teaching-to-learn homework was graded by their teaching peers) are not included here because they are predictably binary: students that submit these homework responses generally receive a perfect (or close to perfect) score from their teaching peers, so the students that decide not to submit a given homework assignment are the primary sources of score variability. From the last two columns in Table 3, the overall scores are quite good and display a relatively small standard deviation. Table 4 contains a listing of the problems/issues that have often led to lowered scores in these various assessment areas.

Table 3. Teaching-to-learn session definition and assessment rubric results. Each score in the table represents an *average score for all students in the class* for that category.

			Overall Perceptions				Session Management/Delivery					Totals	
	1. Session Definition	2. Session Refinement	3. Session Focus/ Relevance	4. Effectiveness of Learning Experience	5. Creativity	6. Preparation	7. Time Management	8. Communication of Ideas	9. Organization	10. Resource Materials	11. Homework Assignment	12. Total Score (Average)	13. Total Score (StDev)
Spring 2007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	94.8	2.2
Spring 2009	100	97.5	100	96.7	100.7*	99.3	98	101.3*	99.3	85.7	96.4	95.7	2.8
Spring 2010	N/A	93.6	99.5	91.4	86.7	99.5	95.7	96.2	99	89	82.4	92.9	3.4
Spring 2011	95.9	N/A	100	90.6	93.5	92.4	100	95.3	100	96.5	91.2	95.6	2.3

* The two average scores greater than 100% (in the areas of creativity and communication of ideas) were a result of extra credit offered to one team that went far beyond expectations in these areas.

Table 4. Thematic listings of problems/issues that have led to lowered scores in the various assessment areas. The item numbers in the rows correspond to the item numbers in the columns in the previous table.

Items 1 & 2: Session Definition & Refinement
Lack of detail with regard to (a) topic focus (e.g., application domain or scenario), (b) materials and resources, (c) session timeline, and/or (d) a description of the planned homework assignment. The topics themselves, their relevance to the course, and the creativity of the students are usually okay. The primary struggle in this early planning stage is the potential mismatch between the scope/amount of material and the available time – students often try to do too much.
Items 3-6: Overall Perceptions
3. ***Session Focus/Relevance***: Generally fine. 4. ***Effectiveness of Learning Experience***: Limited learning; unmemorable; uninformative; material level – poor match to the backgrounds of the other students; unexplained concepts or confusing explanations; too light on details/engineering concepts; lack of variety 5. ***Creativity***: Lackluster and 'safe' material; lack of customized material 6. ***Preparation***: Not ready; media untested (e.g., video/audio problems); seemingly 'thrown together'
Items 7-11: Session Management/Delivery
3. ***Time Management***: Too short/long; skewed time allocation between presenters; limited 'tag teaming;' too much reliance on videos 4. ***Communication of Ideas***: Ill-conveyed context; poor story line; awkward explanations; specifics presented prior to the big picture 5. ***Organization***: Lack of focus; supporting material not closely related to main topic; awkward flow; poor relative allocation of time between the various session elements 6. ***Resource Materials***: Not enough multimedia; lack of visual aids; superficial technical references; overly textual slides; lack of citations for copied material; too light on technical detail; slides difficult to read (e.g., font too small, dark font on dark background, etc.); too much slide clutter 7. ***Homework Assignment***: Prone to copying; too short/long; too easy/hard; entertaining but not educational; unrelated to the session subject within the course context; not substantive

IV. Discussion

The following paragraphs discuss lessons learned from incorporating these teaching-to-learn experiences in four previous course offerings, specifically with respect to the sessions themselves, student dynamics, homework, and course coordination. This is followed by a short summary of future work that may improve the impact of these learning experiences.

A. Sessions

Overall, the sessions themselves exhibit much variety and are high quality. Most of the students work hard to make this session a good learning experience for their peers and demonstrate a sense of ownership regarding their personal topic. Anecdotal discussions with students indicate that many preparation hours are usually invested in the creation of each 25-minute session, increasing the overall quality of the experiences relative to what one might expect from a typical course session. (In the future, post-session surveys will be a good way to quantify this amount of time.) Therefore, although a performance distribution exists (as with all student work), average scores are higher than typical quantitative engineering work and the standard deviations are smaller, as noted in Table 3 and the accompanied dialogue in the previous section. Additionally, students generally like to hear from other students, not just as a reprieve from listening to the normal course instructor. E.g., faculty find that recruiting efforts for student clubs are much more effective if student leaders rather than faculty engage with potential club members. Since these student-delivered sessions are so well done, both the instructor and the students find these sessions to be a highlight of the semester. Student attendance at these sessions has been nearly perfect – not always the case for normal lecture sessions taught by the instructor.

In terms of scheduling, even though students are asked to sign up for the time slots that work for their schedule, from past experience it is best to massage the schedule so that the first few teaching-to-learn sessions are led by capable students that over achieve. This raises the bar in terms of quality and increases the self-expectations of the other students. It can also be helpful to match sessions to planned course topics so that material presented by the students can solidify concepts presented in the instructor-led sessions. The chosen subject matter in these sessions often aligns with student degree areas and research endeavors, but the divergence to alternative topics seems to be a tempting means to obtain variety. Because topics can align with student research or are unique to students' personal experiences, some students prefer to create and deliver a learning session on their own.

Regarding resource materials, the support and reference material used by these students is weighted toward easier-to-find Internet material that is less technical than traditional engineering textbook content. Students demonstrate a propensity toward the use of videos and expert comments (e.g., from phone or in-person interviews) because the students do not yet have the level of expertise to teach these subject areas that interest them. For this reason, successful operation of these multimedia resources (Internet, audio/video tools, etc.) must be tested ahead of time, as these tools are the most common cause of inefficiencies that make sessions run late.

B. Inter-Student Dynamics

Inter-student dynamics (i.e., the relationships between the students and the ways in which they interact with one another during these sessions) are an important part of this process. As one would expect, students are supportive of one another, which sets a positive tone conducive to learning. Introverted students (students whose fundamental energy lies in spending time alone and who embody a large percentage of the engineering demographic) are often over-prepared as a means to minimize the uncertainty of the event. As noted earlier in the paper, the instructor attempts to minimize anxiety by reminding the students to view each session as a "communication" rather than a "presentation" in order to lessen the stress of presenting and steer their focus back to the learning that should occur. This lowers the formality level and encourages dialogue in an active-learning sense.

C. Learning

From the instructor's viewpoint, learning levels are high for the presenters and moderate for the other students because of (a) the limited topic depth that can be addressed in each 25-minute session and (b) the newness of these subject areas to most of the presenters, which implies a general inability on their parts to concentrate the topical details into the most salient points. In other words, many of the students treat this material like a seminar class and therefore do not expect to learn much detail about each subject, other than what is needed to complete the short homework assignments. From a positive perspective, recall that one primary purpose of the host course is to excite students about biomedical engineering and help them better understand how they can become engaged in biomedical work within their engineering domain.

Note also that the addition of these sessions had not had a measurable positive or negative effect on the learning that would normally occur in the instructor-led portion of the course. First, the student-led portion of the course is naturally scheduled at the end of the semester so that the instructor can take the time to cover the topics that they consider essential. Second, students are not normally given a session topic that the instructor would cover the same way and in the same amount of time, so the two learning models are difficult to compare. Finally, the student-chosen topics are quite diverse within the larger biomedical topic space, so they tend to flavor (rather than supplement) topics that have already been addressed by the instructor.

D. Homework

Homework assigned for these sessions often involves less technical problem solving than is desirable, and the level of innovation ranges from menial and lackluster to highly creative. In some cases where quantitative homework is assigned, the homework has been overly difficult, since students are unused to thinking through the difficulty level of an assignment within the context of the backgrounds of all of the other students. On average, the homework appears to take much less time than the target time of one hour per 25-minute session topic. Students are quite forgiving when grading other students' homework and therefore give high scores on average. In terms of timing, homework needs to be handed out after each session or the students will try to work on it during class to save time.

E. Course Coordination

From an instructor viewpoint, coordinating a course where student-driven topics are interspersed with instructor-chosen topics can be a challenge. While these learning experiences have been overall positive, the primary downside of this approach is that it compresses the course schedule in terms of the number of desired topics the instructor can address. The move from a one-hour to three-hour course helped in this regard, as it made more time slots available. Another challenge of this teaching approach from a course-coordination perspective is the increase in spreadsheet clutter and paperwork traffic: two sets of homework must be received, graded, recorded, and returned per day of sessions. However, while the process of administrating the sessions, helping individual student teams make decisions about session content/format, and grading the results are time consuming, these teaching-to-learn sessions arguably save the instructor time overall because the students handle most of the preparation and grading. Starting these sessions early in the semester helps to compensate for inevitable delays due to sickness, snow days, etc.

F. Future Work

Based on these lessons learned, several thoughts come to mind for improving the impact of these learning experiences in future semesters. First, spelling out clear *learning objectives* would arguably help the students better understand the importance of this learning approach and provide a useful baseline against which to compare assessment results. Further, *end-of-semester surveys* will generate student self-assessment data regarding the value of the learning experiences, the ways they can be improved, and the amount of time invested by the students to prepare their sessions. This would also be a good means to gather student feedback regarding the perception of some individuals that having the students teach the class is a means for the instructor to avoid work rather than a means to improve student learning.   To improve the depth at which these concepts are delivered and learned, subsequent offerings of this assignment will require *more substantive material* garnered from engineering journals, textbooks, and trade magazines as opposed to primarily Internet content. Spreading the learning experiences throughout the semester may help in this regard, especially if topics can be anchored to corresponding static biomedical topics that are already planned into the syllabus. Further, the instructor will stress the need for *quantitative and substantive homework* that takes the students enough time that they must think more deeply about each subject in order to generate meaningful homework responses, which should lead to increased learning. Student teachers may also be tasked with identifying topical ideas that are fair game to include on *normal semester exams*.

It is worth noting that both the instructor and the host department desire to grow the size of this class in upcoming semesters so as to create increased overall interest in biomedical engineering within the KSU College of Engineering. If enrollment numbers continue to increase, the natural question is whether these types of teaching-to-learn sessions can continue to be sensible. For example, the Spring 2012 enrollment in this course is 42 students, just short of twice the largest enrollment in previous semesters. As an experiment, the instructor is moving ahead with teams of two students, where each team creates a 25-minute learning session. This means that at least ten course sessions must be dedicated to these sessions, or three weeks worth of course sessions. Lessons learned from this semester will help to determine whether (a) an enrollment cap should be placed on this course to maintain its current form or (b) the instructor should reevaluate the sensibility of this teaching approach within the context of large enrollments.

V. Conclusions

Within the context of an already broad *Introduction to Biomedical Engineering* course, year-to-year changes in student demographics increase the challenge of making course topics relevant to the students. Teaching-to-learn sessions, where students choose topics of interest, present those topics to their peers, and then assign homework based upon those topics are a sensible means to ensure subject relevance in such a course. Each 'teacher' learns more deeply about a subject that is important to them because they are required to teach it, and their student peers experience a high-quality session usually backed by extensive preparation time. While the topics and associated homework assignments are sometimes superficial when compared with assignments in other engineering courses these students take, the benefits of these experiences outweigh the drawbacks, and the experiences are often perceived as the highlight of the semester. Rubric-based assessments of these teaching-to-learn sessions indicate that these learning experiences are effective for both the presenters and the other students. Minor changes to the way these sessions are administrated and scheduled will help to increase their impact in subsequent course offerings.

References

[1] "Department of Electrical & Computer Engineering," Kansas State University, 2012, http://www.ece.ksu.edu/.

[2] Enderle, John D. and Joseph D. Bronzino. **Introduction to Biomedical Engineering**, Third ed. Boston, MA: Academic Press, Elsevier, 978-0-12-374979-6, 2012.

[3] Bargh, John A. and Yaacov Schul. "On the Cognitive Benefits of Teaching," *Journal of Educational Psychology*, vol. 72, pp. 593-604.

[4] Benware, Carl A. and Edward L. Deci. "Quality of Learning with an Active Versus Passive Motivational Set," *American Educational Research Journal*, vol. 21, Winter 1984, pp. 755-765.

[5] "Designing a Career in Biomedical Engineering," IEEE Engineering in Medicine & Biology Society, 2003, http://www.embs.org.

[6] "33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC '11)," IEEE, August 30 - September 3, 2011, http://embc2011.embs.org/program/themes/.