Development of Essential Skills and Knowledge Using Process Education and Internet-Based Learning in an Introductory Biomedical Engineering Course

Jack Wasserman, Richard Jendrucko
University of Tennessee at Knoxville

Abstract

After many years of traditional teaching of an introductory biomedical engineering (BME) course, the shift of perspective to student learning has provided the most satisfying results. Student performance has exceeded all expectations based on past course offerings. In addition, it is now much easier to evaluate student progress in activities that do not require a quantitative result. The student response has been very positive as demonstrated by a 50% improvement in class attendance. The objectives of improved communication, problem solving, and teaming skills in addition to the acquisition of a background in BME applications have been successfully achieved as with projects, papers, and presentations.

This approach to learning has provided additional benefits for the supervision of graduate students and for research planning. Although initially challenging, the benefits to cost ratio is so high that the described method is planned for incorporation in all courses in an BME curriculum.

I. Introduction

This paper introduces the benefits of curriculum design using process education and the use of distance education tools to student learning outcomes in an introductory course for biomedical engineering students. The change in the concept for the conduct of this course was the result of preparing for an ABET 2000 program review and the development of an integrated BME curriculum described in a companion paper[1].

Process Education (PE)[2,3] involves many different concepts as described in detail. The PE curriculum design requires the separation of learning objectives into behaviors, processes, tools, and factual information. As a result, key behaviors of biomedical engineers that students needed to develop were identified and course themes were implemented to help develop these behaviors. With student learning being the focus, PE requires a much more active student participation than for traditional learning models. For this course, lecture time was reduced by 2/3 with this time being spent in the active participation of the student groups using the information developed in their reading assignments.

The broad nature of the field of biomedical engineering makes it difficult for small BME programs to provide all the needed expertise. Utilizing a combination of Course Info and video lecturing, a course segment on biomedical instrumentation was provided by a professional colleague who was located 500 miles from the students. The evaluation of the effectiveness of these techniques was provided by student assessment, external faculty review, and project evaluations as compared to previous year results.

II. Background

Process Education is a philosophy, which emphasizes student-centered learning with faculty facilitation. Dr. Dan Apple, President of Pacific Crest, developed the guiding concepts. Pacific Crest is a source of training institutes and written materials in support of faculty using PE. Application of this philosophy leads to classroom activities shifting away from an emphasis on traditional lectures toward interactive group projects and group discoveries. The responsibility of learning is placed on the student rather than on the instructor. Students are responsible for their reading assignments and lectures are not provided on the material except for spot lectures in response to questions. Critical questions provided before the reading and activities following the reading are used to assess the level of student understanding. Group activities require each student in a group to have read an assignment to be effective participants. The students are required to utilize various methodologies such as reading, writing, presenting, and problem solving. They are also required to assess their weekly performance and the performance of their group.

Elements of the PE system include the following:

a. Methodologies are stepwise plans that aid the student in the development of behaviors to accomplish specific goals. As an example, the reading methodology requires the following steps
    i. Identification of reading objective
    ii. Preliminary scanning of a selected article
    iii. Development of needed vocabulary
    iv. Initial reading
    v. Development of unclear areas and questions
    vi. Final reading of article
    vii. Summary of information
    viii. Development of plan for use and integration of information

It has been found that use of active versus. passive reading required classroom activities such as guided discoveries to provide the model needed for student understanding of the rational for the methodology.

b. Assessments are an essential part of PE application. The assessment format requires the following:
    i. Identification of two strengths and why they are strengths
    ii. Identification of two areas for improvement and a short-term and long-term plan to achieve the improvement
    iii. Insights gained from this reflective process

The process steps require the student to provide a higher level of knowledge and a higher level of acceptance of external assessment.

c. Group activities with clearly defined roles are another essential part of process education. The essential roles for each group member are:

   i. Captain – This individual is responsible for all management functions for the group. The responsibilities include task identification and assignment, meeting planning to meet project time requirements, and group affect management to achieve full group participation.
   ii. Recorder – This individual is responsible for the written documentation of the work of the group. Responsibilities include preparation and delivery of meeting agendas, meeting minutes, and the development of the final project report.
   iii. Spokesperson – This individual is responsible for all oral communication for the group. The responsibilities include the group responses to in-class questions and the project oral presentation. Additionally, this individual serves as the editor for the final draft of the written report.
   iv. Reflector – This individual is responsible for observing and assessing individual and group performance. This individual also assists the team captain on affect management during group activities.

These roles are rotated within the group for every major project so that every individual can assess their skills for the various required tasks.

d. Curriculum Development Methodology – This methodology has 21 prescribed steps and a continuing need to iterate steps as one progresses through the process. This process has been ongoing for the last year and found it to be time intensive. However, once an instructor has completed the process, the course is easy to maintain and improve. The PE flow chart for curriculum development incudes the following steps:
   i. Development of long-term behaviors
   ii. Identify key learning objectives
   iii. Identify a set of Measurable Outcomes
   iv. Construct a knowledge map
   v. Choose Themes
   vi. Create appropriate methodologies
   vii. Produce key performance criteria
   viii. Identify a set of activities
   ix. Identify 15 selected learning skills
   x. Locate or build key performance measures
   xi. Identify activity preference types
   xii. Allocate time across the themes
   xiii. Sequence the activities across the term
   xiv. Create individual activities from the priority list
   xv. Enhance activities using technology
   xvi. Have the activities peer reviewed

xvii. Design a course assessment system
xviii. Design a course syllabus

e. Course Info Web Site – The University of Tennessee (UT) has adopted Course Info for instructional use. As part of the new biomedical engineering program, every BME core course will have a web site attached for course management and communication. Elements include:

i. Structure – The standard BME sites contain sections on course procedures, course documents, communication, and announcements.
ii. Streaming Presentation – As part of the distance availability, Power Point presentations were used for all lectures. A copy of the presentations was made available on the web site and some streaming audio presentations were also prepared using Real Presenter. Real Player, which is free to the students, allows the student to review all or segments of presentations made in class.
iii. Communication – The communication center allows for both group and class discussion boards, chat rooms, and e-mail facilities. A digital drop box for student papers is also provided.
iv. Instructor Advantages
    I. The web site provides easy access to the students with great flexibility. Students check the site for announcements each day so that assignment modifications or additional information can be provided independently of class meetings.
    II. All documents are available on the web so students can always verify dates and assignments without contacting the course instructor.
    III. The digital drop-box provides an easy way to access submitted documents and return them to the student if they have missed an assignment objective.
    IV. Electronic mail allows communication to the class, particular groups, or individual students without added record keeping by the instructor.
v. Video Classroom

The video classroom provides full two-way interchange with students, however in this format individual students can lose focus. It was found that for spot questions in group meetings resolved this difficulty.

II. Course Construction

a. Overview

The purpose and measurable objectives of an introductory BME course are totally different than what had been previously taught for the last twenty years. The combination of the development of a new BME curriculum and the ABET 2000 program updating process changed the design objective from a content orientation to a skills and tools orientation. The PE curriculum design process promotes a focus on the long-term behaviors needed by biomedical engineers followed by the development of learning objectives that reflect specific methodologies which need to be mastered by sophomore-level students to facilitate their progress through the remainder of the curriculum. The course content is similar to that used in the past in that several areas in BME are presented to the students. However, the students gather and process the majority of the information that their groups utilize. The projects are presented as tasks that biomedical engineers are required to perform and the students are responsible to function as biomedical engineers not as students in their group activities. The students are provided the following statement of purpose:

> "Application of the skills developed in engineering fundamentals for biomedical engineers is achieved. The relationship of anatomy, physiology, and biochemistry to the design of artificial organs, orthopedics implants, medical imaging, and other biomedical applications is explored. The undergraduate biomedical engineering degree is a relatively new degree. The advent of quantitative biology has resulted in dramatic changes in the understanding of biology and the requirements for biomedical engineers. With the rapid changes in the BME program, the emphasis of the curriculum is the development of process skills for life-long learning and continuing growth."

The drastic change in the introductory BME course has been a learning experience for both the faculty and the students. It will require three years for the changes to be completely integrated into this course and the other BME courses in the curriculum. The results in student performance and involvement have been dramatic to date, but there will be more gains in the future. We believe that the quality of these students as future graduate students and researchers will more than justify the efforts required for the change in the instructional methodology.

b. Course Structure

The course focused on six selected areas of BME. Each area was allocated about two weeks of time, which require six class periods and twelve external class hours. The first class period was a lecture to provide a context of both engineering and biology to the target application area. The material presented depended on what was available on the web and in the course textbook. As an example, the medical imaging lecture covered the general ideas of input signals, tissue responses, signal processing, and visual perception. The second and third class periods involved in class group activities based on reading assignments, group questions, spot lectures, student presentations, and guided discoveries. The forth period varied depending on the area being studied. The fifth and sixth periods were used for project presentations and exams.

For each focus area, the group members would rotate their roles and then at the end of the exercise they would assess their group and individual student performance. Each assessment required a plan for improvement, which had to be reviewed in the next assessment. All of this material was included in a portfolio, which was submitted at the end of the course with a final assessment of individual progress and the course results after students had reviewed their portfolio.

The initial project involved the gathering and integration of information about cartilage repair. The learning objectives were the independent gathering of information, summarization and presentation to their group, integration of information from group members to result in a problem solution, and the oral and written presentation of the solution. Each group had to determine which method they felt was most promising and which individuals and companies were involved in data procurement. They had to present their finding to the president of Fixit Orthopaedics with a recommendation on which products the company should pursue in this area. (invest, develop, partner, hire consultant, etc.) The final project required the students to select their own topic, research the current state-of-the-art, suggest their own new problem solution, and develop a plan to evaluate their idea. For this project, the students had to hold a poster session for faculty not involved in the course. These faculty provided input to the grading of the final project.

For each project, there was a group grade which was 90% of the total for each project, and the remaining 10% was an individual grade based on the role that the individual played during that project. The first project was not graded, but was assessed using the criteria that would be used for the remaining projects. The final project counted double the other projects because it included all the aspects developed during the term. These project grades counted to 40% of the total course grade. The portfolio was reviewed one time with a grade based on completeness, which counted 30% of the total grade. The exam grades constituted for the remaining 30% of the final course grade.

The projects required about two hours per area to grade, the presentation grades were completed during class, the portfolio required about two hours at the end of the term, and the exams required about 8 hours for design and grading. (class size 25). The course design required about 100 hours. with the daily activities requiring about two hours. Mastering the needed technology required the most effort with about a 200-300 hour one-time investment to learn and apply the methods described. The development of website listings was done by graduate students with Power Point and audio streaming Power Point lectures by the faculty. The e-mail responses required about 1 – 2 hours. a week, but this time was matched by a reduction in office consultations. The maximum benefit was that the e-mails were done at the convenience of the instructor and did not result in disruption of other work. The students reported that they felt they had the best access to an instructor they had ever experienced.

c. Application of PE Curriculum Design

The following sections reflect the current understanding of the application of the PE process to an introducvtion to BME course and the reduction to practice. The sections include some of the structures, example activities, and assessment rubrics used for the introductory BME course.

i. Long-Term Behaviors – The behaviors presented for this course are a subset of the desired behaviors for graduates of the BME program. They represented the behaviors that were felt to be needed for future courses to achieve course objectives. As an example, the first behavior requires the continual application of tools such as the reading methodology to all reading and research materials evaluation. To develop a habit, it needs to be continually reinforced during the term, which is the basis for developing themes in the course.

Throughout a career, a biomedical engineer will

1. effectively gather, evaluate, read, and combine information from varying disciplines for a predetermine objective and understand the culture of the authors of research papers.
2. effectively structure groups to achieve project results
3. effectively evaluate alternative methods of problem solution and select the most appropriate method or sequence based on time and resource limitations
4. effectively listen and communicate ideas within groups, to external groups, to new audiences by understanding the culture of the audience and by understanding the required levels of knowledge needed to achieve understanding.
5. effectively use assessments to improve individual work products, personal performance, and the performance and work of others.

ii. Key Learning Objectives – The information presented may seem redundant to some extent, but it allows the instructor to separate the course in various manners to determine if there are missing elements.

Student should be able to:

1. develop the skills necessary to increase their background in a new area of biomedical engineering.
2. understand the diverse nature of biomedical engineering and the societal contribution achieved by practicing biomedical engineers.
3. understand the requirements of group function and will assign roles to achieve success, and will actively participate
4. have demonstrated skills in project planning and creative design
5. demonstrate the effective use of engineering tools to biological problems solution with an assessment of analysis limitations
6. learn to do quality assessments
7. demonstrate a general working medical vocabulary
8. demonstrate a general understanding of some physiological systems
9. demonstrate levels of knowledge to prepare and answer questions related to design

iii. Key Measurable Outcomes – In accordance with ABET 2000 guidelines, an instructor must identify outcomes that will be measured during the course for evaluation purposes. This list differs from the above list in that the instructor has identified clear manners (quizzes, exam of outcomes, papers, presentations, etc.) in whch the outcomes will be evaluated.

The students must demonstrate:

1. a functional biomedical engineering vocabulary
2. the ability to evaluate an information source type for providing usable information and an author's purpose in producing the material
3. the ability to integrate biological system and engineering papers into a project decision process
4. the ability to investigate new areas in biomedical engineering and present background, issues, and state of the art.

5. the capability of setting project goals, tasks, and time schedules for projects with assessments
6. the ability to communicate effectively at various levels of knowledge.
7. Can provide insight into how BME has contributed to society
8. Produce a grant application based on a new concept
9. Use engineering tools to provide information needed to analyze a biological system application
10. Produce quality assessments of projects

iv. Knowledge Map – The knowledge map allows for a clear planning for both the learning and the assessment. This information was provided to the student at the beginning of the term and was it was referred to at each evaluation point.

Processes
Obtaining needed information
Technical reading
Evaluation of information quality
Evaluation of internet information
Idea generation
Communication
Identifying the audience
Setting objectives & criteria
Structuring the message
Testing and revising
Teamwork
Building shared vision
Defining and fulfilling roles
Using resources effectively
Creative Problem Solving
Defining key issues & assumptions
Isolating and solving subproblems
Integrating and reusing solutions
Assessment
Setting performance criteria
Selecting factors & scales
Collecting quality data
Reporting results

Tools
Application software
Library
Dynamic human
Matlab
Microsoft office
Record Keeping
Personal journal
Technical reports
Take-home exams
Posters
Active Learning
Activity sheets
Cooperative learning
Methodologies
Oral reports

v. Themes – To alter a student's behavior to become more professional in character, there is a need for continual practice of the new behavior. The themes provide a basis for planning for the required practice. When planning the activities for the course, the following themes supported by activity were considered as follows:
1. Development of knowledge to perform tasks and make decisions
2. Processes in communication

3. Application and methods of assessment
4. Application of engineering to medical / biological problems
5. Understand the culture of biomedical engineering.

vi. Knowledge Modules – Every course must contain knowledge information, which the student must understand sufficiently to assimilate the factual information, the context of the information, and the ability to apply the information. The levels of knowledge are often not raised to this level by our students. They may know facts (level 1) and they may have success in limited applications (level 3), but they frequently lack the context of the fact (level 2). Time was spent in each classroom activity to emphasize the levels of knowledge through both the instructor's and the students' questions and answers. Targeted knowledge areas include:

I. Process Education Modules
II. Physiological Background
III. Cell / Tissue Engineering
IV. Biomechanics
V. Medical Imaging
VI. Biomedical Instrumentation
VII. Artificial Internal Organs

vii. Web site
The web site provided the key to continuing communication. The students could find information on each classroom activity for review and could always find updated information about assignments and due dates. Additionally, the digital drop box allowed the instructor to quickly make comments on papers that failed to meet assigned objectives and return them to the student quickly. This ability allowed for a quick initial setting of standards without a lengthy process. The instructors time was about five hours on the initial individual projects, with little additional activity required on the last projects. The student reports project included student histories and their course expectations, self-assessments, and initial course assessments. The Group chat rooms allowed students to hold virtual group meetings without face-to-face meetings. The advantage to this system was the fact that such meetings had electronic archives for review. These archives were especially useful to the instructor.

viii. Assessment and Evaluation Rubrics
The course used assessment of projects during their initial phases. Instead of grades, strengths and areas for improvement were provided as well as suggested plans of action in Table 1 and 2. The basis for both the assessments and evaluations were rubrics such as shown below:

Table 1: In-Class Student Presentation Rubric

ITEM	Audience **10%**	Delivery **30%**	**Effectiveness 20%**	Organization **15%**	Knowledge **20%**	Vocabulary **5%**
Exceptional 90-100%	**Understands needs of audience and addresses those needs first with insight about concerns**	**1. Strong Emphasis on key ideas 2. Clear and easily understood 3. Good eye contact 4. Personality came through**	**Message clearly defined The use of graphics promoted understanding Every idea clearly explained**	**First slides clearly set stage for presentation Logical flow from slide to slide Final summary reinforce final ideas**	**Current information cited Able to answer all questions Background understood**	**Concise language Typical word usage**
Good 80-90	**Has addressed most audience needs in the beginning of paper and kept their focus**	**Paper meets most objectives Some originality Good detail**	**Easily readable Logic demonstration**	**Good overall organization**	**Some current information Basic Understanding**	**Mostly correct**
Average 70-80	**Has thought about audience and paper contains information addressing most of them**	**1. Presented information 2. Could be understood 3. Some eye contact & animation**	**1. Message provided 2. Some good graphic used 3. Most ideas explained**	**1. Needed information was on slides 2. Presentation showed organization**	**Information cited Understanding demonstrated Has some background**	**Some correct terminology used**
Fair **60-70%**	**Some audience needs addressed somewhere in the paper**	**Some objectives met No new ideas Some planning**	**Message poorly defined Few graphics Few ideas explained**	**Some information on slides Little organization**	**Some old information Limited understanding**	**Few concise words used**
Poor **0-60%**	**Has spent no effort considering the specific audience**	**1. Wandered on topic 2. Hard to understand 3. Read information**	**No graphics or words not readable Message not defined No logical explanation of ideas**	**No organization**	**No information cited Poor understanding of material Has not studied background**	**Street language used Terms are incorrect**

Table 2: Project Rubric

Item	Problem Importance **10%**	Problem Definition **20%**	**Knowledge 20%**	Problem Solution **25%**	Plan **30%**	Vocabulary **5%**
Exceptional 90-100%	**1. Clearly defined the cost of problem 2. Defined # of people involved and the impact of problem on these people**	**1. Clear statement of problem 2. Every potential difficulty presented 3. Specific aims show clear logic 4. Problem size is very reasonable**	**1. Background demonstrates current status of problem 2. Background shows how past research relates to current idea**	1. Solution effectively solves problem **2. Difficulties are addressed. 3. Solution show good originality 4. Solution is practical**	**1. Well defined steps to evaluate solution 2. Individual steps will discover potential problems 3. Clear logic shown in plan**	**1. Concise language 2. Typical word usage**
Good 80-90	**Has addressed most audience needs in the beginning of paper and kept their focus**	**1. Problem well defined 2. Major difficulties discussed 3. Good set of specific aims 4. Reasonable problem size**	**Easily readable Logic demonstration**	**Good overall organization Grammar 90%**	**1. Defined steps 2. Individual steps show understandable logic to solution**	**Mostly correct**
Average 70-80	**Has thought about audience and paper contains information addressing most of them**	**3. Problem Defined 4. Some difficulties discussed 5. Used specific aims 6. Problem size questionable**	**1. Background is focused on problem 2. Background shows knowledge for proposed solution**	**1. Solution may solve problem 2. Some difficulties addressed 3. Some originality**	**1. Plan shows thought 2. Solution evaluated**	**Some correct terminology used**
Fair **60-70%**	**Some audience needs addressed somewhere in the paper**	**1. Problem not completely clear 2. Has identified 1-2 problems 3. Has some steps 4. Problem size marginal**	**Some background Unclear relationship to problem**	**Solution won't logically solve problem with information presented Not original**	**Plan shows little thought Poor, or un-thought out steps Incomplete evaluation of solution**	**Few Concise words used**
Poor **0-60%**	**Has spent no effort considering the specific audience**	**1. Lacks clear problem 2. Has not considered problems 3. No specific aims 4. Problem trivial or unmanageable**	**1. Little information cited** 2. **Slight Relevance**	**1. Solution unworkable 2. Old concept 3. Not thought through**	**1. No effective plan 2. Lacks specific steps 3. Would not provide evaluation of solution**	**Street language used Terms are incorrect**

These rubrics are provided to the student as they prepare their projects. During the first month, student assess other student groups' projects and presentations using these rubrics. The student involvement with the process promotes rapid improvement and little complaint when later projects are evaluated.

ix. Activity Design

The following is an example of the design of a classroom activity. The purpose is to define the flow of the activity and the measurable outcomes that one can assess for future planning. After each class, five minutes is spent assessing the activity for next year's reference. This diary is a part of the activities associated with the ABET 2000 continual improvement objective.

The following is an example activity:

Facilitation
Bone and Biomechanics
9/21/00

Why

There is a clear need to understand bone in both biological terms and engineering terms to be able to effectively attach prosthetic devices, aid in healing, and provide other services to orthopedic patients.

1.0 Outcome

The outcome of this activity is have the students understand the ways that engineers look at materials in contrast to the biological presentations. The students will have the ability to relate bone to other materials by:

1. Modulus of elasticity
2. Modes of failure
3. Concepts of fatigue
4. Stress concentrations
5. Creep, Relaxation, and viscoelasticity
6. Wolf's Law

Students are also able to understand the difficulties of facture fixation. The model will be the development of Intramedular Rod (IM) using bone plate as a starting point.

Pre-assessment of knowledge

Ask for questions on reading from specific individuals

Assess the retention from the previous lecture on strength of materials and material science.

Set-up Activity

Develop concepts of what is needed to be known about materials before you can build something.

1. To design an fracture fixation device, the following must be done

a. Define the Problem
    i. Look at past solutions
        1. Cerclage wire
        2. Bone Plates
    ii. Look at past difficulties
        1. Surgery at site of damage
        2. Compromise of blood supply
        3. Infection
    iii. Determine what the optimal solution should do
    iv. Decide if there are sub problems that need to be solved
b. Look at general engineering solutions
c. Examine each solution for biological implication
d. Brainstorm on sub problems
e. Integrate problems to final solution

IV. Results

a. Course Content

The course content was reviewed with consideration given to the follow-up courses required in the BME curriculum. The resulting changes provided the students with a higher level of current information with a reduced level of detailed background, which would be utilized in the following courses.

b. Papers

The quality of the papers was much higher than in previous years. Because the papers were edited, there were few grammatical errors, which allowed the emphasis to be on the content and organization.

c. Presentations

Student group presentations were all done on PowerPoint, with emphasis given to speaking to a specified audiences. The groups determined that they would work with their spokesman to provide the best quality presentation. By the end of the term, the student presentations were better organized and clearer that previous senior student presentations

d. Exams

The exams were constructed to provide evaluation of three levels of knowledge. Level 1 facts were evaluated using fill-in-the-blank questions weighted 30% of the grade. Level 2 information was checked using short answer questions that required the demonstration of the context of the information. These questions were worth 30% of the grade. The final questions were long answer questions that required the application of the knowledge to new situations. These questions were weighted 40% of the grade. During one of the early course activities, the groups determined how they could help their group members to achieve higher scores. As a reward structure, each student in the student group with the highest average score received two additional points. The resulting exams had very high average scores compared to past experiences.

e. Attendance

The attendance for this course was improved by 50% over previous years. Only one group of five had any pattern of classes missed by team members.

f. Student Assessments

i. Questionnaire

The students reported strong feeling of confidence in their abilities to function as a biomedical engineer. They were given a set of 31 questions that they could strongly disagree(1), somewhat disagree(2), neutral(3), somewhat agree(4), and strongly agree(5). These questionnaires were unsigned and were submitted as a group. Some of the results are reported below:

- Course met objectives 4.3
- Requiring BME behaviors was good experience 4.6
- More confident in presenting 4.35
- More confident in group problem solving 4.4
- More interested in BME 4.5
- Use of distance technology will aid me in the future. 4.5
- It is worth the difficulty of distance tools to have access to a true expert 4.2
- Learning is independent of instructor format or presentation method 1.45

ii. Blind Assessment

Additionally, the students provided some of their assessment of the strengths of the course at this time. Some of the results are reported below:

Working in groups (13 responses)
a. group roles sharpened teamwork skills
b. working in groups & project research (2)
c. working in groups (9)
d. group roles sharpened teamwork skills
e. working in groups and making presentations

Technology (7 responses)
a. Blackboard online part of course (3)
b. putting lectures online for review
c. technology incorporated into class (3)
d. making web section functional part of class

BME subjects (9 responses)
a. vast array of different BME areas covered (6)
b. course was helpful in defining what a BME does (3)

Learning (5 responses)
.
a. independent learning
b. allows students to explore their own ideas and teach what they have learned
c. learning various applications and making presentations
d. self learning
e. varied structure of course

iii. Final Assessment

At the end of the term, the students were asked to do a class assessment with their portfolio. Some of the results are provided below:

- Enjoyed interactive activities instead of just lectures
- Rotation of roles because it allowed you to practice things that you were not good at
- Challenge-The project assignments force the students to strive and open their minds, which allows endless possibilities and outcomes
- Variety-There is a paper, presentation, assessment, and reflector's report due with every project, which gives each student practice in the areas that are most important for engineering work.
- The distance teaching by Dr. Neuman from Memphis was excellent
- Group work is important to have in the classroom setting. – Our "people skills" improved
- Assessments were a strength of the course because it allowed us to improve
- This class brought out my interest in the major – I found myself at the edge of the seat.
- This course taught me many organizational skills.
- The course helped me to be more creative as well as back up my ideas with previous research.
- The greatest strength for this course would be the fact that there is so much group interaction and group learning.

4. Conclusion and Recommendations

The revision to an introductory BME course has provided the students with the strongest skills in communication and group interaction than in any previous effort. The quality of the paper and presentations required a total revision of the grading rubric. This change allowed a concentration on much higher levels of communication.

The student satisfaction with the course was evident by both the class attendance record and the assessments provided. At a level of 4.6 of 5.0, they felt more committed to the profession. Students felt that playing the role of a biomedical engineer was an excellent way to learn about the profession and they felt that they had gained a tremendous level of understanding of several areas within biomedical engineering practice fields.

The combination of changing the teaching focus and using new teaching technologies required a significant one-time time commitment. Over 300 additional hours were spent on the administration of this course, however, the learning provides a much quicker path for future courses. All course documents have now been developed for the following years and the outline would allow alternative instructors achieve the same results. These approaches will applied to four additional courses during the current academic year. An instructor should not expect that he/she will be able to apply successfully all the various approaches the first time in a course. This process will remain a multi-year activity with a component of life-long growth for the instructor. The learning from this course has resulted in improvements in supervising graduate students, improvements in personal efficiency and in research productivity.

The greatest difficulty and fault of the course was limited organization. Although I had prepared material had been prepared in advance, a clear image on the requirements and flow of the course, was not realized until about one half way through the term. All student criticism centered around the issue of organization. However the work developed during the term should solve the majority of the problems when the course is next offered.

The use of PE planning has allowed each course in the curriculum to have very different but complementing objectives with the each course adding to the student recognition of the importance of life-long learning and growth.

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JACK WASSERMAN

Jack Wasserman is a professor in the Department of Mechanical and Aerospace Engineering and Engineering Science where he has taught in the biomedical engineering program for over twenty-five years. He serves currently as Coordinator for the Biomedical Engineering Degree Program. Professor Wasserman is the recipient of 7 teaching awards and he holds the position of Fellow in the Center for Undergraduate Excellence and the Interactive Technology Center.

RICHARD JENDRUCKO

Richard Jendrucko is currently Associate Department Head and Professor in the Department of Mechanical and Aerospace Engineering and Engineering Science. He has served as the Program Coordinator for the department's Biomedical Engineering Program and has been active in teaching biomedical engineering for over twenty-five years. Professor Jendrucko has also served as ASEE Biomedical Engineering Division Chair.