Work in Progress: Student and faculty perceptions of rotating faculty facilitators for introductory biomedical engineering problem-based learning

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Abstract

Problem based learning (PBL) has been shown to be an effective teaching strategy, particularly for interdisciplinary fields such as biomedical engineering (BME). Due to the broad range of problems and disciplines within the biomedical field, it is desirable to develop and enhance problem-solving and teamwork skills early in undergraduate education. However, PBL requires a broad range of expertise and significant time investment for facilitation and feedback. These are difficult criteria to meet with small instructional teams and large introductory student enrollments. Therefore, we propose using rotating faculty facilitators to address these challenges. A preliminary execution of this strategy in an introductory BME course utilized 25 faculty and 8 graduate students from the Department of Biomedical Engineering, College of Veterinary Medicine, and School of Medicine in a rotating facilitation schedule in addition to 2 full-time instructors and 1 graduate teaching assistant dedicated to course instruction. 98 students who are in a BME minor program were organized into 18 transdisciplinary teams and presented with three open-ended BME problems. These problems included assessing the validity and reliability of wearable health devices, benchmarking and recommending glioblastoma treatment for investment, and modeling and designing experimental studies towards development of pediatric medical devices. Currently, we aim to examine student and faculty perceptions of learning, problem-solving, and teamwork skills with the use of rotating facilitators within an introductory BME course. We will also aim to examine the influence of student population (BME major versus BME minor) on these perceptions.

Introduction: Biomedical engineering (BME) poses several challenges in engineering education. Specifically, the interdisciplinary nature and breadth of the field demands skill and knowledge acquisition across biology, chemistry, computer science, and many engineering disciplines. Moreover, students must also be cognizant of the clinical perspective, both of the medical staff and the patient. This requires students to bridge multiple disciplines with different pedagogical frameworks. In addition to these challenges, medical technology and knowledge is constantly and rapidly evolving, causing some content to become obsolete before graduation. Therefore, it is imperative that BME students develop knowledge acquisition, integrative thinking, and problem-solving skills in order to prepare for and adapt to the breadth and pace of the field.

Drawing inspiration from medical education, problem-based learning (PBL) has emerged as an effective strategy for mitigating these challenges in BME education [1-3]. PBL focuses on student-centered learning and open-ended problem solving within a real-world context [4]. Typically, in groups, students are presented with a complex, open-ended problem and work cooperatively towards a solution. The process is student-centered and requires students to critically examine their knowledge base and knowledge gaps, mediating these gaps, and ultimately developing a solution. In addition to knowledge and problem-solving skills, PBL also develops communication and teamwork skills [2]. Instead of a traditional lecture role, instructors serve as facilitators who neutrally probe student knowledge and understanding while also revealing group behaviors by drawing attention to student actions [5]. As an example, “What is the evidence for your statement?”, “Where did you find this information?”, and “How reliable is this information?” are possible questions a facilitator could pose to the group or an individual student when an assertive statement (correct or incorrect) is made.

However, implementation of PBL is not without challenges. One challenge, specifically in engineering, is that students and faculty are both accustomed to lecture-style courses following a transmission style of learning in which the instructor decides what is important to know and the learner passively receives knowledge. In contrast, PBL utilizes a constructivist model in which the learner is actively working to construct knowledge [1]. This shift in roles and learning environments can be a source of tension and discomfort for both faculty and students [6]. PBL requires a greater time investment, and faculty buy-in for this time investment is mitigated by the institutional value of teaching and acknowledgement of effort [6], particularly at R1 institutions. Another significant challenge is staffing. Ideally, each student team has a facilitator dedicated to that team [1]. However, with large institutions with larger undergraduate numbers, the amount of staff that would need to be dedicated to a single course offering within the curriculum would be vast. ***To address these challenges, we propose the use of rotating faculty facilitators within an introductory BME course.***

Course Structure: The 'Introduction to BME' is a 3-credit course that is required for the BME major and minor programs, and is accepted as a technical elective for several additional undergraduate engineering programs. Due to a common first year model for all engineering students, BME minor students and students taking the course as a technical elective are able to take the course in any semester after the freshmen year. During the Spring 2019 semester, only BME minor students and other non-minor students taking the course for technical elective credit were enrolled. Additionally, the course underwent a significant revision inspired by Newstetter [1]. The focus of the course shifted to emphasize the development of problem identification/solving, critical thinking, group work, and communication skills. Two major deviations from the framework proposed by Newstetter [1] include: (1) incorporation of intermittent individual and team deliverables prior to a final written and oral deliverable (Figure 1) and (2) mini-lecture content related to the target skill of the intermittent and end deliverables (example: "How to Read and Understand a Scientific Article").

PROBLEM DESCRIPTION

Your group of medical scientists at the private Innovation Hospital was approached by the senior-level administrators. Funds have become available to invest in or purchase a new technology to treat glioblastoma. The administrators ask your group to prepare a summary reviewing the state of the field by comparing a physics-based, a chemical-based, and a biology-based approach for treatment of glioblastoma. Within your summary, you should justify your selection of technology for each approach. Your group will provide an overall recommendation for a specific technology for the administrators to pursue from the three options you have presented. Your summary should also address the challenges associated with treating this disease and assess which technology has the greatest potential for successful outcomes over the largest patient population. Additionally, your recommendation should address the readiness level of your selected technology and the approximate timeline to implementation for patient care.

DELIVERABLES

Assignment	Individual/Group	Percent of Problem Grade
Technology Identification and Summary	Individual	10%
Approach-Based Concept Maps	Group	20%
White Paper	Group	35%
Video Pitch	Group	25%
Peer Review	Individual	5%
Team Assessment	Individual	5%
TOTAL		**100%**

Figure 1. Example problem and deliverables

Table 1. Example Facilitator Week Schedule

	Dr. W	Dr. X	Dr. Y
Wk 9, D1	Team 14	Team 15	Team 2
	Team 10	Team 7	Team 4
	Team 12	Team 17	Team 5

	Dr. W	Dr. X	Dr. Z
Wk 9, D2	Team 9	Team 6	Team 1
	Team 16	Team 13	Team 8
	Team 18	Team 3	Team 11

Students were organized into groups of 5 to 6 students while balancing primary major, disciplinary interests, and academic year (for minor section), resulting in 18 transdisciplinary teams. The teams were presented with 3 open-ended biomedical engineering problems related to the technical emphasis of the department. These problems included assessing the validity and reliability of wearable health devices, benchmarking and recommending glioblastoma treatment for investment, and modeling and designing experimental studies towards the development of pediatric medical devices. Each problem was approximately 4 weeks, with all teams working on the same problem during the same time period.

The rotating facilitator model was as follows: three to four facilitators attended a given class day and each facilitator rotated between three different groups for direct facilitation (Table 1). This resulted in each group having 8 – 10 facilitation periods throughout the semester, with an average of 3 periods per problem. We requested faculty to participate as facilitators for at least two class periods. This resulted in 25 faculty and 8 graduate students from the Department of Biomedical Engineering, College of Veterinary Medicine, and School of Medicine participating as facilitators. A summary guide of *The Tutorial Process* [5] was created and distributed to facilitators the week prior to their assigned facilitation day (Appendix A). Additionally, the course instructor or graduate teaching assistant reviewed the main components of facilitation and the rubrics for assessing the teams (Figure 2; modified from [7]) with each individual facilitator.

	Excellent	Good	Fair	Poor
Inquiry Skills	Actively looks for and recognizes inadequacies of existing knowledge. Consistently seeks and asks probing questions.	Recognizes inadequacies of existing knowledge. Generally asks probing questions.	Occasionally voices areas of inquiry but mostly focuses on what is said by others. Occasionally asks questions.	Takes whatever is left for inquiry. Rarely, if ever asks questions. Fails to recognize limits of understanding/knowledge.
Problem Identification	Issue/problem to be considered is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding.	Issue/problem to be considered is stated, described, and clarified so that understanding is not seriously impeded by omissions.	Issue/problem to be considered is stated but description is superficial and leaves some aspects undefined, ambiguities unexplored, boundaries undetermined, and/or backgrounds unknown.	Issue/problem to be considered is stated without clarification or description.
Evidence towards Solution	Synthesizes in-depth information from relevant sources representing various points of view/approaches and assessing reliability and appropriateness of sources.	Presents information from relevant sources representing a variety of information. Mostly evaluates inquiry by assessing reliability and appropriateness of sources	Presents information from a limited number of relevant sources. Utilizes easily available information of questionable reliability/appropriateness.	Presents information from irrelevant or unreliable sources. Fails to assess the reliability of sources.
Hypothesis & Solution Formation	Critical elements of the proposed solution are appropriately developed and assumptions are justified through theoretical models and/or synthesis of scientific evidence.	Critical elements of the proposed solution are appropriately developed and adequately described	Critical elements of the proposed solution are missing, incorrectly developed, or unfocused	Proposed solution demonstrates a misunderstanding of the problem or the context.
Evaluation of Solution	Evaluates the proposed solution and considers potential limitations, feasibility and impact and offers alternative approaches to overcome issues.	Evaluates the proposed solution and considers potential limitations, feasibility and impact.	Evaluation of the proposed solution is superficial and does not adequately address potential limitations, feasibility or potential impact.	Does not evaluate limitations of the proposed solution. Evaluation of the proposed solution is superficial and does not adequately address potential limitations, feasibility or potential.
Communication	Information was clearly and concisely presented in a logical sequence.	Information was mostly clear and concise, and presented in a logical sequence.	Information was somewhat clear and/or in an illogical sequence.	Information unclear and in an illogical sequence.
Teamwork	Members contribute equally, actively listening and engaging with each other in a respectful manner.	Most members contribute equally. Usually listening to and engaging with each other in a respectful manner.	Some members contribute. Usually listening and engaging with group. Members are mostly consistent in respect for others.	Few members contribute. Minimal listening and engaging within group. Inconsistent respect for others.

Figure 2. Facilitator Rubric for Spring 2019

For Spring 2019, Faculty perceptions of student learning, communication, and teamwork skills were assessed through rubrics completed by the facilitators. Student perceptions of learning were assessed through mid-semester feedback session conducted by the institution's teaching resource center and end-of-semester course evaluations (free form comments). Mid-semester feedback included the following:

1. What aspects of class are working well? What are the strengths of the class? What aspects of the class are having a positive impact on your learning?
2. What aspects of the class are working poorly? What are the weaknesses of the class? What aspects of the class are having a negative impact on your learning?
3. What aspects of the class do you believe should be changed? How should these aspects be changed? (Please be as specific as possible.)

<u>Discussion:</u> Data on student perceptions and feedback of the course has been collected and being analyzed. Based on preliminary examination, modifications are being incorporated for the Spring 2020 semester course including mimicking an industry environment (group meeting minute requirements) and reorganization of mini-lecture schedules to be temporally closer to the first related deliverable. The Spring 2020 course will also include the first cohort of BME major students (sophomores) and allow for comparisons of perceptions with BME minor students (mixed age and major discipline). Collection tools are also being modified to solicit student perceptions of learning with each problem and to include evaluation of communication and teamwork skills. Finally, facilitator perceptions of the rotating facilitator model in addition to student learning, communication, and teamwork skills will be collected in the Spring 2020 semester. Surveys for the Spring 2020 semester are available in Appendix B. As stated previously, a rotating facilitator model is expected to be helpful for institutions with large enrollments. It is important to note that the current semester enrollment in the course (including BME major, BME minor, and non-minor students) is approximately 100. However, with the anticipated growth of the new BME major program, the enrollment is anticipated to increase to approximately 300 students per academic year. By examining our preliminary smaller cohorts, we will consider this model to be successful if both students and facilitators perceive the rotating facilitators as beneficial towards student skill development and an overall positive experience and manageable demands on facilitators.

References:

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2. Warnock, J.N. and M.J. Mohammadi-Aragh, *Case study: use of problem-based learning to develop students' technical and professional skills.* European Journal of Engineering Education, 2016. **41**(2): p. 142-153.
3. Clyne, A.M. and K.L. Billiar, *Problem-based learning in biomechanics: Advantages, challenges, and implementation strategies.* Journal of biomechanical engineering, 2016. **138**(7).
4. Eberlein, T., et al., *Pedagogies of engagement in science: A comparison of PBL, POGIL, and PLTL*.* Biochem Mol Biol Educ, 2008. **36**(4): p. 262-273.
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6. van Barneveld, A. and J. Strobel, *Implementation of PBL in Engineering Education: Conceptualization and Management of Tensions.* Proceedings of the Canadian Engineering Education Association (CEEA), 2015.
7. Newstetter, W.C. *Plenary Session: Problem-Drive Learning: A Socio-Cognitive Approach to Classroom Design*. in *Annual Conference of the American Society of Engineering Education*. 2011. Vancouver, BC.

Appendix A: Facilitator Instructions

Within the Tutorial Process Summary given to each facilitator, their major tasks were defined to be:

(1) Keep the learning process moving (probe students for them to assess their own problem solving skills; did they skip steps, consider multiple possible explanations?)
(2) Probe the students' knowledge deeply (ask for explanations, challenge student's comments/explanations when you think they are right as often as when you feel they are wrong)
(3) Encouraging all students to be involved in the process
(4) Modulate the challenge (when overwhelmed, encourage to refocus, consider smaller sub-portions of the problem, etc.).

Appendix B: Surveys for 2020 Cohort

Survey for Students (per problem)

1. I give consent for my information to be used for this research (research statement included in survey but omitted here for brevity). [Yes/No]
2. I am 18 years of age or older [Yes/No]
3. Please select the option that best describes your reason for taking this course:
    a. It is a required course for my BME major
    b. It is required course for my BME minor
    c. I am taking the course as a technical elective towards my degree, but not seeking a BME minor
4. If your major is NOT Biomedical Engineering, please state your primary major. If your major is Biomedical Engineering, please type "N/A". (Free response)
5. The amount of sessions with a facilitator for a problem was:
    a. Too many, Slightly too many, just enough, Slightly not enough, Not enough
6. The amount of time with each facilitator was:
    a. Very long, A little long, Just enough, A little short, Very short
7. Overall, having the facilitators was beneficial.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
8. Please explain your rating for "Overall, having the facilitators was beneficial?"
9. Having different facilitators was beneficial.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
10. Please explain your rating for "Having different facilitators was beneficial"
11. Did you have the same facilitator for more than one session for a problem?
    a. Yes, no
12. If Yes, was meeting with the same facilitator helpful?
    a. Yes, Neutral, No
    b. Please explain for response.
13. Please indicate which actions you feel your facilitators exhibited (please select all that apply):
    a. Encouraged group member participation in the discussion
    b. Encouraged discussion towards the end goal of the problem
    c. Asked individuals to clarify or explain their statements
    d. Asked questions that made the group consider other issues
    e. Encouraged group brainstorming and interpretation of knowledge
    f. Provided technical expertise
    g. Other (free response)

14. Please indicate which actions you feel your facilitators exhibited **THE MOST** (please select one):
    a. Encouraged group member participation in the discussion
    b. Encouraged discussion towards the end goal of the problem
    c. Asked individuals to clarify or explain their statements
    d. Asked questions that made the group consider other issues
    e. Encouraged group brainstorming and interpretation of knowledge
    f. Provided technical expertise
    g. Other (free response)
15. Please provide any additional feedback regarding your experiences with the rotating facilitators.

Survey for Students End of Semester:

1. I give consent for my information to be used for this research (research statement included in survey but omitted here for brevity). [Yes/No]
2. I am 18 years of age or older [Yes/No]
3. Please select the option that best describes your reason for taking this course:
    a. It is a required course for my BME major
    b. It is required course for my BME minor
    c. I am taking the course as a technical elective towards my degree, but not seeking a BME minor
4. If your major is NOT Biomedical Engineering, please state your primary major. If your major is Biomedical Engineering, please type "N/A". (Free response)
5. At the end of this course, how do I rate my ability to:
    a. Define complex biomedical engineering problems and their critical features.
        i. Poor, Fair, Good, Excellent, N/A
    b. Develop and evaluate hypotheses framing complex biomedical engineering problems.
        i. Poor, Fair, Good, Excellent, N/A
    c. Identify appropriate safety and ethical issues relevant to biomedical engineering problems.
        i. Poor, Fair, Good, Excellent, N/A
    d. Identify appropriate safety and ethics committees related to biomedical engineering research.
        i. Poor, Fair, Good, Excellent, N/A
    e. Evaluate and apply relevant existing research and mathematical modeling towards problem solving.
        i. Poor, Fair, Good, Excellent, N/A
    f. Collaborate effectively within a team to complete tasks and meet objectives towards problem solving.
        i. Poor, Fair, Good, Excellent, N/A
    g. Develop content to effectively communicate solutions to complex biomedical engineering problems in both written and oral formats.
        i. Poor, Fair, Good, Excellent, N/A
6. My interactions with the rotating facilitators during the semester aided in developing my ability to:
    a. Define complex biomedical engineering problems and their critical features.

        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    b. Develop and evaluate hypotheses framing complex biomedical engineering problems.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    c. Identify appropriate safety and ethical issues relevant to biomedical engineering problems.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    d. Identify appropriate safety and ethics committees related to biomedical engineering research.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    e. Evaluate and apply relevant existing research and mathematical modeling towards problem solving.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    f. Collaborate effectively within a team to complete tasks and meet objectives towards problem solving.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    g. Develop content to effectively communicate solutions to complex biomedical engineering problems in both written and oral formats.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
7. CATME Team Assessments were beneficial in giving feedback to my team members.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
8. CATME Team Assessments were beneficial in receiving feedback from my team members.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
9. CATME Team Assessments accurately reflected my contributions to the team.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
10. Viewing the CATME Team Assessments helped develop my self-awareness as a member of a team.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
11. Please provide any additional comments regarding the course here.

Survey for Facilitators (per problem)

1. I give consent for my information to be used for this research (research statement included in survey but omitted here for brevity). [Yes/No]
2. I am 18 years of age or older [Yes/No]
3. Please state your primary appointment/department. (ex. Assistant Professor, Biomedical Engineering) (Free response)
4. Which problems did you attend?
    a. [Options based on problems given in that semester]
5. The materials given to facilitators (summary sheet of "The Tutorial Process", problem statement with deliverables, rubric for team assessment) were helpful in understanding my role as a facilitator.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree, Not Applicable (Did not read)
6. Please provide any feedback on the materials given to facilitators.
    a. Free response
7. How many sessions did you participate as a facilitator?
    a. 1, 2, 3, 4, 5, 6

8. The amount of sessions I participated was:
    a. Too many, Slightly too many, just enough, Slightly not enough, Not enough
9. The amount of time spent with a group was:
    a. Very long, A little long, Just enough, A little short, Very short
10. Please provide any additional feedback on the number and length of sessions for facilitators.
    a. Free response
11. For any sessions, did you participate as a facilitator via web conferencing?
    a. Yes, No
        i. If Yes, please describe the value of having facilitation in this format. If possible, please compare to in-person facilitation if applicable.
12. Overall, having facilitators engaging with the groups is beneficial towards developing the following abilities in our students:
    a. Define complex biomedical engineering problems and their critical features.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    b. Develop and evaluate hypotheses framing complex biomedical engineering problems.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    c. Identify appropriate safety and ethical issues relevant to biomedical engineering problems.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    d. Identify appropriate safety and ethics committees related to biomedical engineering research.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    e. Evaluate and apply relevant existing research and mathematical modeling towards problem solving.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    f. Collaborate effectively within a team to complete tasks and meet objectives towards problem solving.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
    g. Develop content to effectively communicate solutions to complex biomedical engineering problems in both written and oral formats.
        i. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
13. Having facilitators engage with different groups is beneficial for the students.
    a. Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree
14. Please explain your rating for “Having facilitators engage with different groups is beneficial.”
15. Did you have the same groups for more than one session for a problem?
    a. Yes, no
    b. If Yes,
        i. Do you believe this helpful for the students? (Yes, Neutral, No)
        ii. Was this helpful for you as a facilitator? (Yes, Neutral, No)
        iii. Please explain for responses to the above questions.
16. Would you have preferred to have interacted with the same groups if participating for more than one session?
    a. Free response
17. Please indicate which actions you feel you exhibited as a facilitator (please select all that apply):
    a. Encouraged group member participation in the discussion
    b. Encouraged discussion towards the end goal of the problem
    c. Asked individuals to clarify or explain their statements

    d. Asked questions that made the group consider other issues
    e. Encouraged group brainstorming and interpretation of knowledge
    f. Provided technical expertise
    g. Other (free response)
18. Please indicate which actions you feel you exhibited **THE MOST** as a facilitator (please select one):
    a. Encouraged group member participation in the discussion
    b. Encouraged discussion towards the end goal of the problem
    c. Asked individuals to clarify or explain their statements
    d. Asked questions that made the group consider other issues
    e. Encouraged group brainstorming and interpretation of knowledge
    f. Provided technical expertise
    g. Other (free response)
19. My motivation for participating as a facilitator was (select all that apply):
    a. Desire to contribute to the undergraduate BME program
    b. Sense of responsibility to contribute to the undergraduate BME program
    c. Contributes to teaching portfolio for promotion
    d. Interest in participating in problem-based learning
    e. Interact with and possibly recruit undergraduate students
    f. Enjoy undergraduate teaching
    g. Other (free response)
20. My **PRIMARY** motivation for participating as a facilitator was (select one):
    a. Desire to contribute to the undergraduate BME program
    b. Sense of responsibility to contribute to the undergraduate BME program
    c. Contributes to teaching portfolio for promotion
    d. Interest in participating in problem-based learning
    e. Interact with and possibly recruit undergraduate students
    f. Enjoy undergraduate teaching
    g. Other (free response)
21. Please provide any additional feedback or suggested improvements regarding your experiences with facilitating in (COURSE NUMBER).