Board 9: Work in Progress: Collaborative Learning to Develop Laboratory Modules that Support Knowledge Gain and Professional Development in a Biomedical Engineering Graduate Course

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Introduction

The National Institute of Biomedical Imaging and Bioengineering's (NIBIB) Ruth L. Kirschstein National Research Service Award (NRSA) Institutional Research Training Grants (T32) are designed to prepare predoctoral and postdoctoral trainees for research careers in fields of biomedical imaging, bioengineering, and health informatics [1]. The Tissue Microenvironment (TiME, NIBIB award number: T32EB019944) predoctoral training program at the University of Illinois Urbana Champaign (UIUC) focuses on three scientific themes (bioengineering, imaging and sensing, and computational modeling and analytics) and includes curricular and extracurricular training and professional and career development experiences. For trainees interested in tenure-track academic careers, it is beneficial to have strong research, teaching, and service skills. Trainees selected for T32 positions demonstrate strengths in their research and most have significant outreach/service experience. Research training is abundant through lab experiences, specialized skill workshops, and discussions at conferences, and many graduate students participate in service through student organizations or personal interest volunteering. However, few have had opportunities to develop and strengthen their instructional design skills, which aligns closely with traditional "apprenticeship" style of doctoral training in which research training is prioritized [2] and in some cases teaching experience is viewed as taking away from research time [3]. Additionally, most teaching assistant experiences support existing, well established courses, and there is little opportunity to learn how to design and create material for a new course. For many young faculty, the first time they attempt instructional design is during the first few years of their career. Therefore, providing instructional design experiences during predoctoral training offers an opportunity to support professional development, while also strengthening the T32 training curriculum.

Students selected for the TiME training program are required to take BIOE 598. This sixteen week seminar style course meets for 80 minutes twice a week and invited speakers present on topics related to the tissue microenvironment such as cancer metabolism, chemical and photoacoustic imaging, mechanobiology, hormone signaling, and biomaterials and stem cell niches. At the end of the course, students should be able to (1) discuss how changes in the tissue microenvironment influence cancer progression and stem cell behavior in complex environments, (2) describe and, when possible, quantify microenvironmental factors affecting cancer cells and stem cells and their impact on tissue physiology, (3) critically review and assess studies that seek to measure, model, and reconstruct the microenvironment, and (4) create case studies to demonstrate use of scientific/engineering fundamentals in analysis of the tissue microenvironment.

To support creation of laboratory modules related to course content and to support the fourth course learning objective, we utilized a collaborative learning framework to engage students in

developing laboratory modules for a lab course that will ultimately be a companion to the existing BIOE 598 course. Collaborative learning involves students and instructors working together to create knowledge with goals being (1) students take an active role in the learning process and (2) students work together to complete a task [4]. Herein, we describe an opportunity for students in a graduate course to develop their instructional design skills by creating a laboratory module relevant to the course content.

Course description and student demographics

For the spring 2022 semester (n=9), 56% of students were T32 trainees, 44% were female, 85% were 3+ years into graduate training, and four disciplines were represented, and in fall 2023 (n=14), 57% of students were T32 trainees, 57% were female, 98% were 3+ years into graduate training, and six disciplines were represented. The project idea was implemented to (1) strengthen student's instructional design skills, (2) utilize collaborative learning to support course relevant knowledge gain, and (3) develop laboratory modules to complement the existing lecture course. In addition to the scientific lectures related to the tissue microenvironment, multiple project check-ins with instructors and peers as well as two educational lectures were added (a teaching and learning specialist in the university's Center for Innovation in Teaching and Learning described Bloom's taxonomy and how to develop learning objectives and a faculty member from the College of Education described how to modify content for different audiences and technologies to support learning). Students initially created a table of contents (i.e., topic list) for a tissue microenvironment laboratory course then presented their ideas to instructors and peers, received feedback, and discussed general themes. With peer and instructor feedback, several module ideas naturally developed. Students then chose teams by selecting the topic of most interest to them and related to their research.

To facilitate collaboration, a cloud drive folder was created and shared between students and instructors. Each team created their own folder, and any white board sketches or other notes from project check-in meetings were uploaded. For the remaining check-in points, student teams presented updates and received feedback from instructors and peers. At the end of the semester, teams presented overviews of their modules and submitted written lab modules that included learning objectives, introduction/background information, materials and equipment list, a detailed protocol, and references. A few modules also included pre-lab questions, post-lab questions, experiment timeline, and supplementary reading. Five modules were developed in spring 2022, and four modules were developed in fall 2023 (Table 1).

Table 1. Titles of laboratory modules developed.

Module topics
• Characterization of the mechanical microenvironment of collagenous tissue
• Noninvasive determination of hematopoietic stem cell differentiation stages using Raman microspectroscopy and machine learning
• 2D vs. 3D cell culture: understanding key differences in cellular characteristics and processes
• Studying the influence of angiogenesis toward breast cancer using chicken chorioallantoic membrane (CAM) model

- In vitro modulation, imaging, and analysis of phagocytosis by macrophages in a co-culture model (part 1); quantitative multiphoton imaging and digital analysis of ex vivo tumors in 3D label-free (part 2)
- Utilization of CRISPR/CAS9 gene editing tools to knockout the expression of angiogenic factors in human cell lines
- 3D coculture & encapsulation
- Measuring and analyzing cellular metabolism in the tissue microenvironment
- Integrated data analysis to identify if there is a relationship between gene expression, angiogenesis, and metabolism

Reflections and suggestions for adoption in other courses

We knew this would be an opportunity to support student's career development but were unsure of the usability of the modules. However, the students were very engaged and exceled. They contributed insightful ideas in discussions that shaped module content, worked well in their interdisciplinary teams to iteratively redesign modules based on feedback, refined learning objectives, and contributed not only to their groups but to the class. Throughout the process, students learned about each other's own research which is beneficial in growing one's network and establishing future collaborations.

While there were many positives in the course, there were also areas of improvement which could be incorporated by anyone planning to include this structure in a course. In spring 2022, students were initially confused about how to begin; so, in fall 2023, we added extra project check-ins and invited a student from the spring 2022 course to describe his experience, the process through which his team worked to deliver a module, and how to gain the most from the project. Hearing from a fellow student who had been through the course worked extremely well, and students immediately began moving forward in the project process. If a fellow student is not an option, providing additional lectures on educational design would be beneficial. The modules developed included excellent content; however, the layout of the modules was not consistent and required reformatting and organization before creating a lab manual. In the future, it would be beneficial to offer a template with sections that students complete. Ninety-eight percent of students in the fall 2023 offering were upper level graduate students, and on an observational note, it felt the teams moved quicker into their topics and started deeper conversations earlier, whether this is due to the research maturity of the students or something else cannot be concluded. Finally, we did not quantify gains in student's pedagogical knowledge, but this could be added through pre/post surveys and student reflections.

Next steps

A pilot of the developed modules is planned for fall 2024 to identify what works, areas of improvement, and finally to ensure reproducibility before offering as a course. Several students who developed modules indicated interest in participating in the pilot and will be participating.

Human subjects statement

The institution's IRB determined that the project does not meet the definitions of Human Subjects Research according to Federal regulations (UIUC Project IRB24-0171).

References

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