S. Balakrishna Pai, Ph.D.

Innovation and Excellence in Laboratory Instruction Award

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Summary of BMED 3610 course

BMED 3610 "Quantitative Engineering Physiology II" is a required laboratory course in the Wallace H. Coulter Department of Biomedical Engineering. This course curriculum provides a unique learning environment where students solve biomedical problems working in groups (no more than 5) thereby providing the students with the opportunity to acquire skills that are invaluable as they advance in their careers. During a semester, on an average, 120 students are enrolled in the course. This a research-based senior course where the students are required to come up with a research proposal in a biomedical field and conduct experiments using cell culture model systems to validate their hypothesis. This course provides students with opportunities to develop novel experimental approaches, performing hands-on experimentation in a collaborative environment, analyze data as well as develop communication and writing skills. The format of the course is provided in Appendix A. The key innovative features of the course are: a) students authoring their own protocols and not following predefined procedures, b) ability to carry out hands-on experimentation employing current techniques and technologies in the field and c) providing students with opportunities to identify potentially translatable technologies to biomedical problems. The identification of critical elements in a biomedical problem, strategizing interference approaches for disease state and experimental validation helps to develop an entrepreneurial mindset in students which is critical for their future success in the real world.

Brief Overview of Innovation in BMED 3610

Innovative curricular design of BMED 3610 provides the students with a greater learning experience by allowing students to engineer strategies for intervention of a biomedical problem. Such a pedagogical approach is rare in a research-based curriculum. In majority of research-based or lab courses, students have to learn a set of techniques following a standard protocol. In contrast to this traditional style of teaching, the new structure in BMED 3610 shifts the focus to students developing their own research strategies in a problem-based project oriented learning environment. This problem-based project-driven design has several merits. The students get an opportunity to develop concepts, design strategies and perform hands-on research to test their hypothesis. During this process, not only do students gain valuable experience performing experimentation, they also develop other skills essential in any career: critical thinking, analytical approach, presentation of data and writing skills. The proposals that students put forth are formatted similar to an NIH grant proposal, but on a smaller scale. It includes background, motivation, hypothesis, specific aims, research strategy, expected outcomes, alternative approaches, timeline and relevant references (bibliography). There is constant interaction between the instructor and the students for providing needed information, expertise and resources analogous to grad student-advisor relationship. At the end of the semester, the study results are discussed in a poster presentation. The students also write individual reports of their finding mirroring a draft manuscript that researchers prepare for publication.

Course Outcome Measures

Results on the course performance have provided very encouraging information both on the learning and research fronts. Majority of the students have submitted outstanding reports of their findings and made presentations of their data with great enthusiasm during the poster presentations.

Data on Learning Value: In contrast to traditional lab courses, BMED 3610 instruction provides a better learning environment. The weekly lectures provide the necessary background information followed by discussion and experimentation in the lab. The formulation of proposal allows the students to critically assess the current state of a biomedical problem and propose a testable research strategy. Conducting experiments using appropriate techniques/technologies also allows mastering the methodologies relevant to research in the field. Novel findings also have the potential for Intellectual Property (IP) as well as for publication in a research journal.

Data on Research Innovation: Several unique observations were made during the past semesters. Students performed a wide array of projects to interfere with the major pathways observed in the genesis of cancer. The projects involved using specific small molecules either individually or in combination, molecular strategies such as siRNA application and key receptor binding assays. All the aforementioned approaches will ultimately interfere with pivotal "circuits" (Signaling pathways) of carcinogenesis. The multitude of strategies employed allowed the students to learn an array of techniques such as drug screening, drug synergy/antagonism, cell migration assays, Western Analysis, Flow cytometry and immunofluorescence to assess the mechanism of action of anti-cancer therapy.

Metrics for success of the program

CIOS Surveys

The CIOS survey reports for the past semesters have been very positive with perfect to near perfect teaching effectiveness scores. More importantly, there was a unanimous consensus among students, as seen from the comments, that BMED 3610 offered a unique learning environment where the students had the freedom to propose a strategy as well as to perform hands-on experimentation to validate their strategy.

Student Enthusiasm to Continue Research for Publication

Several students who have generated novel data are continuing their research to further support their findings. These studies, when completed, would present additional strategies to treat cancer. These findings will be submitted for publication in peer-reviewed journals. Additionally, if new entities are discovered during the course of the study, these would have potential for filing patent applications.

Benefits beyond Graduation

Students who have graduated have expressed that taking the BMED experience has helped them to successfully perform in their new work environments. During the course, they learnt important skills such as collaborative work in a team environment to carry out experiments, overcome hurdles encountered and employ innovative strategies to accomplish the goals of the projects undertaken. Learning experience derived from these scenarios are of great value beyond graduation when the students enter into careers of their choice.

Potential Impact of the Laboratory Innovation

Several positive outcomes are achieved by this innovative laboratory instruction. The major ones are: a) meeting the demands for undergraduate research by providing opportunities to tackle a research project; b) providing students with a learning and research experience that mirrors what research professionals do; c) empowering students with skills such as developing concepts, designing strategies for problem solving and execution in a collaborative environment which are important attributes needed in their future careers. Additionally, the proposed pedagogical approach would help tremendously those who want to pursue graduate school. BMED 3610 serves as a "bridge" between undergraduate and graduate curriculum helping students to transition with confidence as well as perform well at graduate level. The innovative BMED 3610 can be used as an instructional model for other lab courses in BME as well as in other disciplines such as biology and chemistry at Georgia Tech. The innovative approaches taken in the course are also in line with the goals and objectives of the Georgia Tech Strategic Plan. Novel approaches are fundamental to generate learning and teaching innovation. The problem-based project driven pedagogical strategy will not only preserve educational quality but also pave the way for enhancing excellence in students by creating a positive learning experience thereby laying the foundation for developing future leaders in their respective fields.

Appendix A

BMED 3610 is a required course for all students who graduate with a BME major. The course has 5 modules. Students work in teams of 4 to 5.

Module 1 introduces students to cell culture model systems and experimentation to test the effect of agents on cellular toxicity.

Module 2 is aimed at getting the students familiarized with published research in certain biomedical problem areas (for e.g. cancer). Students present a published article in a journal club.

In **Module 3**, students select one of the experiments from the article and reproduce it in the lab. By the end of Module 3, the students have gained experience in cell culture techniques, and familiarity with how a research project is performed.

In **Module 4**, the students are asked to come up with a research proposal to design strategies to advance their knowledge of a pathological state using an appropriate model system or interfere with the process. One biomedical problem that is currently being tackled is cancer. Students are provided access to appropriate human cancer cell systems (brain, esophagus, liver, colon and prostate). At the end of Module 4, the team presents their proposal and submits a report. The report is required to be formatted similar to an NIH grant proposal, but on a smaller scale. It includes background, motivation, hypothesis, research strategy, expected outcomes, alternative approaches, time line and references.

In **Module 5**, based on the input from the instructor, students refine their strategy and do a pre-laboratory presentation that details the experimentation that they will conduct. After that they proceed to perform the research. At the end of this module, they do a poster presentation of their results and each student submits a report.

Throughout the course, the instructor provides information on various aspects of the problem as well as technical details for performing research. All materials and resources required for the project are provided.

Georgia Tech | Wallace H. Coulter Department of Biomedical Engineering | Georgia Tech College of Engineering and Emory School of Medicine | EMORY UNIVERSITY

January 26, 2017

Dear Awards Committee,

I am writing this letter to provide my enthusiastic support for Dr. Bala Pai for the Innovation and Excellence in Laboratory Instruction Award. I have been a colleague of Bala's for several years and have observed his work both during my time as the Associate Chair for Student Learning and Experience and as a fellow instructor in the Wallace H. Coulter Department of Biomedical Engineering. It is because of his pedagogical innovations in BMED 3610 (Quantitative Engineering Physiology Lab II), and his leadership as the Director of Instructional Laboratories, that I believe he is deserving of this award.

Virtually every engineering major has laboratory courses that teach students how to carry out experiments to generate data needed to solve a problem. Students learn how to carry out many of the common procedures employed by scientists in their discipline. For biomedical engineering, this would likely include gel electrophoresis, western blots, polymerase chain reaction, and ELISAs, to name a few. Unfortunately, in many laboratory courses, students are taught these procedures as if they were cooking recipes, largely out of context from why these procedures might be needed for real-world applications. Not in Bala's class. What makes Bala's class so special is that he challenges and empowers his students to find their own problem to investigate. Very few constraints are placed on the students. Last semester, the only constraint was that their problem needed to be about cancer. This is extremely motivating to students because they are given a lot of choice about what problem to solve, what to learn, and they are doing actual research on a real-world significant health issue that affects millions of people around the world.

This freedom could be overwhelming for some students, but Bala has carefully structured his course to position his students for success. In the first part of the course students gain familiarity with the literature doing journal club presentations, learning basic laboratory techniques, and reproducing published experimental data. Weekly lectures are given to bring them quickly up-to-speed on the basics and to prepare them for the last part of the course. In the latter half of the course, students develop a research proposal and then do hands-on experiments of their own design to test their hypothesis. Throughout the course there are student presentations, poster presentations, and a final report. In a typical semester 120 students work in teams of 4 on 30 projects. They use various materials such as drugs, small molecules, and siRNA, and a range of techniques, such as toxicity assays, flow cytometry, and Western blots, to answer their scientific questions.

Remarkably, at least two of the most recent student teams have produced work that is of such high quality and promise that they have continued to work on their projects after the class ended, with Dr. Pai's continued mentorship. He expects them to submit manuscripts to peer-reviewed publications by the end of this semester. In addition, student evaluations of his teaching effectiveness are stellar. Last semester he taught 6 sections. The response rate on the end of course evaluations was 77% and the scores among the sections ranged from 4.8 to 5.0. Here are two examples of the end-of-course comments from his students that illustrate why these scores are so high. One student said: "The best aspect of this class was the final module where we took what we learned throughout the class and were able to propose our own experiment. I really enjoyed this process and felt that it helped me realize how much I had learned during the class". Another student said: "The ability to take our own interests into account was the best aspect of this course. The choosing and creation of experiments that were centered around our interests further motivated me to do more in the class. Also the TAs and Professor were a joy to work with. Always helpful".

In short, Bala is a creative, dedicated, outstanding teacher. I am grateful for his effort to create a truly significant laboratory learning experience for our students. I endorse his Innovation and Excellence in Laboratory Instruction Award nomination in the strongest possible terms.

Sincerely,

Joseph M Le Doux

Joe Le Doux, Ph.D.
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Georgia Tech | **Wallace H. Coulter Department of Biomedical Engineering** at Georgia Tech and Emory University | EMORY UNIVERSITY

January 27, 2017

Dear Awards Selection Committee,

I would like to support the nomination of Dr. Balakrishna Pai for the Innovation and Excellence in Laboratory Instruction award.

Dr. Pai is an academic professional in the Wallace H Coulter Department of Biomedical Engineering. He serves as our Director of Laboratory Instruction. In addition to his responsibilities for oversight of our instructional laboratories in the Whitaker Building, he also teaches one of our laboratory courses, BMED 3610 *Quantitative Engineering Physiology II.* A little over two years ago Dr. Pai assumed responsibility for this senior-level course. Since then, Dr. Pai has done an outstanding job restructuring that course to focus on developing the students' self-directed learning skills. While many would shy away from the effort and uncertainties associated with providing 120 students per semester with the freedom to propose their own projects to address a biomedical engineering problem, Dr. Pai has charged forward with boundless energy and enthusiasm. The problem/project-based approach he has developed for the course is a natural extension to one of our introductory PBL courses, BMED 2250 *Problems in Biomedical Engineering*, developed by Dr. Wendy Newstetter some 15 years ago. Dr. Pai previously served as a facilitator in BMED 2250 and recognized the need and opportunity for the students to circle back to using PBL methodologies along with the technical skills they have acquired in their second and third years to attack some remarkable hands-on projects in the laboratory.

We have collected some very encouraging preliminary data on the impact of the changes in BMED 3610, and hope to develop this into a refereed publication in the Journal of Engineering Education. As far as the students are concerned, the course and Dr. Pai's teaching are highly regarded. His CIOS scores are among the top for any instructor or course in the entire department.

Thus, it is without reservation and with high enthusiasm that I highly recommended Dr. Pai for this award.

Sincerely,

Paul J. Benkeser

Paul J. Benkeser
Professor and Senior Associate Chair

Dear Awards Selection Committee,

It is my great pleasure to express my support for Dr. S. Balakrishna Pai's nomination for the Innovation and Excellence in Laboratory Instruction Award. After taking his course, Quantitative Engineering Physiology Lab II (BMED 3610), last semester, I cannot think of a more deserving candidate. Dr. Pai went above and beyond in all aspects to design and instruct a course in which each student had the opportunity to expand their repertoire of wet lab techniques, learn how to read and analyze peer reviewed journals, and make a novel contribution to the field of cancer based on the group's interests.

On one of my first individual encounters with Dr. Pai regarding his course, he mentioned something along the lines of "many undergraduates at Tech have the opportunity to work in the lab and do research, and the lucky ones get to co-author a paper. My goal is to help you become the first author, not just a co-author". Throughout the semester, he continually gave so much of his time, expertise and support to enable to do just that. For example, in addition to holding office hours and attending lecture even after the lecture-section of the semester was over to help teams, Dr. Pai spent the entire day Monday, Tuesday and Wednesday of Thanksgiving week sitting in lab to help groups. I have never had a professor sit in class or lab for 30-40 hours over three days with the sole intention of helping us learn. This didn't only happen over Thanksgiving; Dr. Pai was consistently in lab for the majority of the work day throughout the semester. His support of us doesn't even end when the semester is over. If a team is interested, Dr. Pai is more than willing to support them as they continue their project and pursue publication. When my team expressed interest, he told us that it was our job to design and carry out the experiments, and it was his 'job' to find the money, resources and make the time to give us the advising we would need.

More related to his effective teaching style, Dr. Pai did an incredible job creating a learning environment that was both engaging and informative for every individual. I would imagine that, as a teacher, one of the biggest challenges is ensuring that every student learns and grows despite very large differences in prior experience and knowledge. Dr. Pai excelled at this. A majority of our lab section had never cultured cells before, while others had been heavily involved in undergraduate research culturing mammalian cells. Despite this difference in experience, we all took a lot away from the course. More experienced students got to help teach their peers how to passage cells while getting experience identifying an impactful research question, designing appropriate experiments, and helping their team analyze and reflect on the results. Furthermore, since we had so much freedom to plan our own project, we were able to cater our study design to allow us to learn new techniques and protocols, regardless of past research experience. Dr. Pai was around to help us through whenever we needed guidance, advice, or to walk us through the steps in person as we learned these techniques.

Furthermore, this lab class wouldn't have been successful in enabling us to fully engage in the process of investigation and analysis without the research infrastructure and resources that Dr. Pai provided us. Over the semester, each group of four students was funded around $100 by the department for the entire semester—one antibody we purchased for our first experiment cost four times that amount, not to mention the wound healing assay kit, cell viability kit, multiple antibodies and materials for the western blot, and all the technology that allowed us to conduct our experiments. Dr. Pai writes grants for government money to fund this class, and, as a result, we are able to design and run our experiments without worrying about how much they cost, just that they will be a good learning experience. Based on a few graduate school recruitment visits that I have attended this spring (including Duke University), and one of my peer's research experience at Johns Hopkins University, the quality and availability of the technology that Dr. Pai has provided to us is unparalleled. In the past year or two, he has purchased an iBlot Western Blot system, flow cytometry equipment, an automated cell counter, EVOS FL microscope (both florescent and phase) and qPCR machine, likely among other things. If Dr. Pai wins this award, I would not be at all surprised if he uses the money to further improve the class's resources since his priority is very obviously providing his students with the best research technology on the market.

In conclusion, I truly cannot think of a more deserving professor for the Innovation and Excellence in Laboratory Instruction Award. Dr. Pai has done an incredible job redesigning BMED 3610 to engage students in a collaborative environment, investigating and answering novel, real-world research questions that they identified. By facilitating independent, yet collaborative, learning, he is deepening our fundamental understanding not only of cancer and research techniques, but is teaching us the way of thinking that transcends into any post-graduation field. He has done an amazing job designing and teaching this course and is an exceptional candidate for this award.

Sincerely,

Jacqueline Larouche