Engaging Classroom Instruction, Experiential Laboratory Training and Effective Mentorship to Promote Student Success

As an educator in the life sciences, my teaching philosophy is built upon three core elements: 1) clear and engaging classroom instruction that promotes student participation, sparks intellectual exploration, and leads to in-depth understanding of biological concepts; 2) experiential laboratory training that challenges students to think critically and pursue new avenues of scientific discovery; and 3) effective mentorship that promotes student success through open and honest communication with my students.

One of my overarching goals in both the classroom and the laboratory is to help my students successfully transition from passive to active modes of learning. To accomplish this, I strive to create learning environments where students not only receive information, but where they also develop the skills necessary to actively pursue knowledge. This involves teaching students how to formulate questions, analyze experimental data, and apply scientific principles to solve problems. It also involves helping students learn how to navigate the scientific literature, read and interpret journal articles, and clearly communicate their ideas, both in written and verbal form. I believe that developing these skills is essential to a student’s maturation, not only as a scientist but also as a lifelong learner.

Since joining the Department of Biology at NC A&T in 2012, I have taught nine courses, ranging from introductory undergraduate courses (e.g., BIOL 101, 102, 105) to advanced undergraduate courses (e.g., BIOL 301 and BIOL 501) and graduate courses (e.g., BIOL 703 and BIOL 830). During this time, I have developed three new courses (i.e., BIOL 276, BIOL 277, and BIOL 830) and helped re-design three additional courses to incorporate active learning pedagogies and authentic research experiences into the curriculum (i.e., BIOL 101, BIOL 102, and BIOL 301). Importantly, I have consistently pursued opportunities both in the classroom and in the laboratory to help students grow in their understanding of biological systems and to develop their scientific self-efficacy.

Engaged Classroom Instruction to Promote Active Learning. In the classroom, one of the biggest challenges that I face is communicating abstract, often complex, concepts to students in a manner that is both intuitive and accessible. Not only does this require thoughtful planning and preparation on my part, but it also requires students to be engaged as active participants in the learning process. Therefore, I attempt to create a stimulating classroom environment that engages students in multiple ways while giving them the opportunity to put into practice what they are learning. To this end, I employ several active learning strategies in my courses, including Process Oriented Guided Inquiry Learning (POGIL), Just-in-Time teaching (JiTT), in-class problem sets, and interactive case studies, and provide opportunities for students to engage in service-learning projects (e.g., to promote Diabetes Awareness in BIOL 101). Based on both student feedback and independent measures of student success, these approaches appear to have positively impacted both the students’ depth of contextual understanding and their development as critical thinkers. For instance, consistent with the literature on the scholarship of teaching and learning (SoTL), I have found case studies to be an effective way to bridge the gap between seemingly abstract biological concepts and concrete scenarios to which the students can more easily relate. Not only does this approach help students see the “real world” relevance of the topics that we are studying in class, but it also gives them the opportunity in class to practice critical thinking and problem-solving skills that are essential to their development as scientists and clinicians.

Likewise, I have found that if I can engage students in ways that lead them to use multiple senses, they are more likely to relate to the subject matter and retain the information. To accomplish this, I often utilize visual aids—be they chalkboard illustrations, short videos, or physical demonstrations/activities—to complement and extend the lecture material. For example, to help students better understand the central dogma of biology (i.e., DNA replication, transcription from DNA to RNA, and translation from RNA to protein), I developed a series of “Survivor Challenges” that focus on different aspects of the central dogma. Each challenge requires

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to successfully complete a given task. For instance, to demonstrate the speed and efficiency of DNA polymerase during DNA replication, students are first asked to find foam blocks (i.e., nucleotides) with shapes that are complementary to those on “a template strand of DNA” from a pool of free “nucleotides” and to assemble them as quickly as possible. Most students are able to correctly create a complementary strand of 15 nucleotides within 2-3 minutes. I then blindfold the students and have them repeat the exercise using only the shape of the nucleotides and their sense of touch as a guide. Typically, students are not able to assemble more than 5 nucleotides in the span of 5 minutes (which, I point out, corresponds to a rate of about 1 nucleotide per minute). Finally, I share with the students that DNA polymerase is able to incorporate nucleotides into the growing DNA strand at a rate of approximately 1,000 nucleotides per second—using only the shape and chemical properties of the nucleotides as a guide! Participating in these types of hands-on activities often piques student interest in the subject matter, sparking fruitful discussions that help them think more deeply about the material.

To further promote discussion and maximize student engagement, I also strive to integrate technologies into my courses that “shrink” the classroom. For instance, to gauge the entire class’ understanding of a given concept or to get their perspectives on a particularly controversial topic, I often employ the Top Hat and PollEverywhere class response systems. Top Hat and PollEverywhere are text- and web-based class response systems that support various question formats (including short answer), allowing each student to respond to questions individually. I find that the relative anonymity that is associated with the class response system encourages participation from students who otherwise might not have the courage to share their ideas. Moreover, once they see that other students may share the same questions or misconceptions, they are emboldened to engage in future class discussions. I particularly like to ask the students open-ended questions because, not only does having students articulate their responses help me, as the instructor, assess the students’ understanding of key concepts in real-time, but it also helps the students develop vital communication skills that serve to strengthen and reinforce their contextual understanding of the subject matter. Moreover, in many cases, the students’ responses reveal misconceptions that lead to productive discussions.

In addition to formative assessment tools, such as Top Hat and PollEverywhere, I also employ summative assessment mechanisms at the end of each course. These include both the university’s course evaluations and independent assessment tools, such as student assessment of learning gains (SALG) surveys, that ask students questions that are tailored to the specific course objectives. Together, the utilization of formative and summative assessments allows me to continuously refine and improve the course to more effectively help my students achieve academic success. For instance, during the redesign of the BIOL 101/102 (Concepts in Biology I & II) curriculum, SALG assessment data revealed that students reported the greatest learning gains from case studies and in-class problem sets. Therefore, in subsequent years, we progressively incorporated more case studies and in-class problem sets into the course, which helped students more effectively learn and apply the concepts that we were studying in class.

**Experiential Laboratory Instruction to Develop Critical Thinking Skills.** One of my primary objectives in lab is to help my students develop their self-efficacy as scientists. Therefore, in the laboratory sections that I teach, I employ a combination of guided and open inquiry models designed to help students develop critical thinking skills. For example, during the open inquiry labs, students are presented with a problem and each group is asked to formulate a hypothesis and then devise an experimental approach to test it. Though I work with the students to develop both their hypotheses and experimental questions by asking questions that will lead them toward a tractable question/experiment, I am careful not to tell them “what to do”. Once the question and experimental approach have been established, I place a premium on putting each experiment into context and encouraging students to think critically about the experiment at hand. I accomplish this by working with them to outline the experiment, reviewing concepts that we have discussed in class, and asking students what they expect to discover from each experiment. Throughout the lab, I continue to reinforce key concepts while
bringing to light practical considerations about the design and execution of the experiment. Finally, at the conclusion of the lab, I encourage students to evaluate their data carefully and to draw conclusions based on what they actually observed (versus what they thought that they were supposed to observe). As a culminating experience, students are given the opportunity to analyze their data and present their findings to the class as an oral presentation. This approach has generated a great deal of positive feedback from my students.

Similarly, together with Dr. Misty Thomas, I re-designed the laboratory portion of our BIOL 301 (Molecular Biology) course such that “cookbook labs” were replaced with a semester-long research project where students learned and applied core Molecular Biology approaches, such as polymerase chain reaction (PCR), molecular cloning, bacterial transformation, protein expression, and protein purification, in the context of an authentic guided-inquiry research project. During the lab, students cloned, expressed, and purified novel variants of the fluorescence resonance energy transfer (FRET)-based biosensor, A-Kinase Activity Reporter 3 (AKAR3), with the ultimate goal of crystalizing the fragments for structural characterization. The students worked in groups of 3 or 4 and were responsible for all aspects of the project. Throughout the project, students kept a laboratory notebook in accordance with good laboratory practices (GLP). At the conclusion of the project, the students summarized their findings in the form of a scientific research article. Based on feedback from assessment surveys, the students both appreciated and enjoyed this approach, expressing that they were excited about coming to lab each week because they wanted to move the project forward. In fact, several students continued to pursue their projects in my laboratory after the class ended. Importantly, students also expressed that they better understood how molecular biology techniques could be used to solve research questions.

In addition to traditional undergraduate laboratory education, I also strongly encourage students to participate in research projects, both in my own lab and in the labs of colleagues. I believe that research is invaluable to the development of students as scientists, providing them with the opportunity to tackle bona fide research problems and exposing them to the techniques and thought processes necessary to solve these problems. Therefore, I have worked diligently to develop a research program that maximizes undergraduate student participation and scientific development through independent research. To this end, not only have I worked with over sixty (60) undergraduate students in my own lab on several research projects, but I also helped found the university’s first international Genetically Engineered Machines (iGEM) synthetic biology team, serving as the team mentor since its inception. Synthetic biology is an emerging biological discipline that uses molecular biology approaches to “forward engineer” biological systems to do novel functions. To date, this program has provided research experiences to over thirty-five (35) undergraduate students and five (5) high school students, leading to presentations at eleven scientific conferences. Likewise, eight students on the iGEM team participated in the Build-A-Genome synthetic yeast project, an international effort to synthesize the world’s first fully synthetic eukaryotic genome (NC A&T was one of only ten universities across the world engaged in this cutting-edge research). Together, these initiatives have led to our NSF-funded Research Experiences for Undergraduates (REU) program in Synthetic Biology, where students engage in interdisciplinary synthetic biology research projects during the summer, and the NSF-funded Build-A-Genome (BAG) Network for Synthetic Genomics, where we help instructors at diverse institutions incorporate elements of the BAG course-based undergraduate research experience (CURE) into their curricula. Likewise, to provide additional research opportunities for students, I have worked with Dr. Roy Coomans to develop the SEA-PHAGES Phage Hunters course at NC A&T. SEA-PHAGES is an HHMI-sponsored CURE during which students learn and apply core microbiology, molecular biology and bioinformatics techniques to isolate, characterize and annotate the genomes of novel bacteriophages (viruses that infect bacteria). As a culminating experience, students submit their annotated sequences to GenBank and present a poster at the SEA-PHAGES symposium at the HHMI research campus in Alexandria, VA. Together, these initiatives have given undergraduate students the opportunity to participate in authentic research experiences critical to their development as scientists.
Though independent research experiences are consistently recognized as a high impact practice (HIP) that promotes student persistence and success in STEM fields (particularly for underrepresented minority students), many of our students often struggle to engage in independent research projects because they must juggle classes and work commitments, leaving little time for research training.\footnote{Bonney, K.M. (2015) Case Study Teaching Method Improves Student Performance and Perceptions. \textit{J. Microbiol. Biol. Ed.} 16:1} Therefore, to help catalyze research training for our students, I actively pursue opportunities to support both undergraduate and graduate student research training that provides financial support for student researchers. To date, these efforts have led to nearly $3.7M in funding as PI or Co-PI and another $1.6M as Co-I. For example, I served as co-PI of the NSF-sponsored iBLEND biomathematics research training program from 2014-2016, where I oversaw the day-to-day operations of the program. This NSF-sponsored program supported systems and synthetic biology research experiences at the math-biology interface for students from across the university. During this time, the program supported over 85 undergraduate students in mentored research experiences, the majority of whom have presented their research at research conferences. Likewise, I have served as a mentor and an advisory committee member for the NIH-sponsored Maximizing Access to Research Careers (MARC) research training program and a mentor for the NIH-sponsored Research Training Initiative for Student Enhancement (RISE) program. Currently, I lead our NSF-sponsored REU in Synthetic Biology at NC A&T, where we introduce students to the interdisciplinary field of synthetic biology while helping them develop professional skills necessary for success in STEM research. Most recently, I worked together with Dr. Margaret Kanipes and colleagues in the CoE and JSNN to establish the NIH-sponsored NC A&T Enhancing Science, Technology, Engineering, and Math Diversity (NC A&T ESTEEMED) undergraduate research training program. The overarching goal of this program, which focuses on freshman and sophomore students, is to significantly increase the preparation and production of high achieving underrepresented minority students who will enroll in Ph.D. programs in bioengineering or STEM fields and pursue careers in biomedical research. Together, these initiatives have helped students engage in research training that is critical to their development as scientists.

**Effective Mentorship to Promote Student Success.** Finally, a key component of undergraduate education is honest and effective mentorship. As students make decisions about their educational and career goals, it is essential that they receive sound advice and guidance from mentors invested in their success. On several occasions I have had the opportunity to offer advice to both my academic advisees and students in my courses about topics ranging from career planning to academic success. During these conversations, I always listen carefully to what the student is asking and try to identify the most effective course of action to help him/her achieve success—whether by employing novel study strategies or by outlining the steps necessary to achieve a given career goal. Importantly, I believe that it is essential that I provide the student with my open and honest assessment of the situation, even if that means asking tough questions or helping the student confront hard truths. In these cases, however, I make it a point to offer viable alternatives that point the student toward future success. I have a special sense of satisfaction knowing that the guidance and advice that I have given these students will positively impact both their lives and their careers.

By nature, I am an outgoing person who enjoys helping others to grow and achieve their goals. As I continue to grow as an educator, I am excited to share the knowledge and skills that I have obtained in the classroom, in the laboratory, and as a mentor with undergraduate and graduate students who are in the early stages of their scientific careers, as well as with postdocs and even junior faculty members as they develop their research programs at NC A&T.