Sci Forschen
Open HUB for Scientific Research
Journal of Medicinal Chemistry and Drug Design
ISSN 2578-9589 | Open Access

EDITORIAL
Volume 1 - Issue 1 | DOI: http://dx.doi.org/10.16966/2578-9589.e101

Challenging Undergraduate Students with Experimental Research-Oriented Questions

Angela K Stoeckman*

Department of Chemistry, Bethel University, Saint Paul, Minnesota, United States

***Corresponding author:** Angela K Stoeckman, Department of Chemistry, Bethel University, 3900 Bethel Drive #2338, Saint Paul, Minnesota, United States, Tel: 651.638.6277; **E-mail:** a-stoeckman@bethel.edu

Received: 20 Oct, 2017 | **Accepted:** 30 Dec, 2017 | **Published:** 04 Jan, 2018

Citation: Stoeckman AK (2018) Challenging Undergraduate Students with Experimental Research-Oriented Questions. J Med Chem Drug Des 1(1): dx.doi.org/10.16966/2578-9589.e101

Having recently made a career move from years in the biotech industry to a primarily undergraduate institution (PUI), I observed numerous graduates with chemistry or biology-related B.S. degrees join the work force as entry-level scientists. While these students from across the Midwest had satisfactory textbook knowledge, the vast majority of them still lacked the necessary skills for success in industry, academic positions, or graduate school assistantships. While they knew how to use a micropipette, conduct a Western blot, generate a standard curve for a protein assay, and even do cell culture, they were underprepared for the criticism, failure, and presentation of data many of their post-undergraduate positions required.

Unfortunately, many PUIs are stuck in a rut of doing "cookbook-style" labs that fool their students into thinking that science always "works." Also, the scientific method is still taught in middle and high schools even though most scientific discoveries occur outside of a hypothesis-driven framework. Undergraduate instructors are busy teaching large classes, maintaining an active scholarship program, and participating in service commitments that they often do not have time or institutional support to focus on transitioning their laboratory courses into inquiry-based learning environments. We are doing a disservice to these students and are placing a heavy burden on graduate programs and industry mentors for training. Even worse, we are setting these young people up for disappointment in their first job or graduate school position out of college. For their future success, this generation of undergraduate scientists must be exposed to (1) independent thinking and experiment design, (2) failure and the iterative process of research, and (3) presentation of data including writing and critical questioning.

With the goal to give our first-year general chemistry students the opportunity to think independently and create their own protocols to answer open-ended laboratory questions, the chemistry department at Bethel University has been active in The Process Oriented Guided Inquiry Learning (POGIL) Project. By giving students the chance to invest in and have ownership of the design of their experimental methods, they have had a more positive attitude about the laboratory portion of the course. A current student in this course shared with me, "I like how we can make some of our own decisions during lab and have a slight variation of outcomes." To date, we have modified a quarter of our General Chemistry I laboratory exercises with the hopes of continual effort in the coming years.

In addition, several institutions around the country have begun implementing course-based undergraduate research experiences (CUREs) in multiple disciplines. As CURE models have been taking place only within the last decade, few comprehensive studies exist with statistics on their success. Most reports are subjective and are based on student opinions (*J Eng Educ* (2007) 96: 283); however, a recent publication from Erin Dolan's group at the University of Texas (*CBE Life SciEduc* (2016) 15: 1) demonstrated that a CURE experience in a first-year course increased retention in STEM by 23% and overall graduation within six years by 17%. As a personal example of a CURE, my upper-level Biochemistry II course had the opportunity to conduct novel research in collaboration with the laboratory of Regents Professor Kent Chapman of the University of North Texas on a plant biotechnology project (*Plant Biotechnol J* (2017) 15: 824). Dr. Chapman is Co-Director of the Biodiscovery Institute and has being doing research with undergraduates for many years. Our joint project involved the introduction of mouse genes into tobacco leaves in order to facilitate lipid production and storage. Many principles of biotechnology, biochemistry, and cell biology were illustrated in the context of discovery-based learning. One of my students this past spring reflected on this project by saying "I loved that the project gave purpose to the lab. Lab work no longer felt as though I was aimlessly checking things off for my grade – the fact that my work could make a difference brought me the motivation necessary to succeed. The overlay of the project taught essential laboratory skills through application and included the important aspect of collaboration by networking with fellow scientists in Texas." In the spring semester, our Biochemistry II class will work with Dr. Chapman's group on terpene-related research in lipid droplets and its application to medical treatment and natural products.

Failed experiments and "negative" data are an inevitable part of the research process. Months of hard work and effort can go by without the generation of any usable results. In our era of immediate feedback and continual positive affirmations on social media, today's young people can easily become frustrated with the lack of progress. An important role of professors is to counsel students on how to handle this failure as a necessary gateway to success. Stuart Firestein from Columbia University has authored two "mustreads" for scientists-in-training titled "Ignorance: How it drives science" (*Oxford University Press*, 2012) and "Failure: Why science is so successful" (*Oxford University Press*, 2015). He stressed the importance of failure best when he said "One must try to fail because it is the only strategy to avoid repeating the obvious." Recent graduates able to persevere through times of failure will be better prepared for their future careers in science and even the hardships of life in general.

Finally, it is imperative that undergraduates in the sciences be exposed to the rigor of technical writing and the uncomfortable experience of being questioned (sometimes critically) during an oral or poster presentation. These experiences could take place in an independent project with a research advisor, as a senior capstone project, or even as a culminating event in a CURE (see above). Scientific writing is much more than the sentence fragments sent *via* text messages and jotted into laboratory notebooks. Organizing scientific protocols and thoughts into a coherent argument that can be submitted for publication or as a thesis takes time and involves rounds of drafts. Further, thinking "on one's feet" and politely and professionally acknowledging the unknown must be practiced. I recall my first research presentation in graduate school and the dread with which I anticipated the questions that would inevitably follow. Looking back, I would have appreciated a lesson in answering and asking questions like the flow chart featured in the September 2017 issue of ASBMB Today. Recognizing that questions can be patronizing or are asked to promote one's own work or intelligence may assist students with framing an appropriate answer. Our current undergraduates need to do more than just present scientific material to their friends, families, and classmates, but at national meetings hosted by the American Chemical Society (ACS) and the American Society for Biochemistry and Molecular Biology (ASBMB) and others.

Despite recommendations of the ACS to require undergraduate research credits and millions of dollars for internships supplied by private industries and governmental agencies, obstacles to implementation on a large scale remain. As mentioned earlier, undergraduate science professors are often over-committed; filling the hours of their days and nights with course preparation and assessment, advising and committee responsibilities, correspondence, scholarship activities and the search for funding sources, etc. No wonder the idea of developing and/or maintaining open-ended inquiry-based activities to replace historical lab experiments seems to be an overwhelming task as well as one that is not often rewarded in the current structure of promotion and tenure. Additionally, many of these inquiry-based laboratories require an unknown amount of resources, as a student's discovery may lead to the need for purchasing new reagents or different reagents for each student. Cut-and-dried experiments usually involve inexpensive chemicals or supplies that can be obtained in bulk. Beyond time and cost, successful implementation of these experiences requires increased one-on-one interaction with students which can be a challenge for contingent faculty and teaching assistants. All of these obstacles could be addressed with stronger institutional support from academic administrators. Ideally, administrators have been research scientists themselves and will understand the importance of these goals, although this is not often the case and we must "educate the educators" so-to-speak on this essential investment in the next generation of scientists.

As we look to the future and anticipate population increase, food and energy shortage, exponential growth in technology, climate change, and burdens on healthcare for better diagnosis and drug design, we must not only increase retention in the sciences to meet the demand for a workforce required to take on these issues, but equip these students and trainees with the tools necessary to become confident and competent scientists who are motivated by discovery and resilient in response to criticism and failure.