A Capstone Experience for Sustainable Assessment in Science: Biochemistry

By Walter A. Patton and Megan F. Potteiger

Between 2010 and 2014, the American Society for Biochemistry and Molecular Biology (ASBMB, 2014) engaged in the Concept Inventory Project as a response to a national call to establish consensus learning outcomes in undergraduate biology education (American Association for the Advancement of Science, 2011). Building on underlying concepts and theories from physics, chemistry and math (Wright, et al., 2013) and foundational scientific skills (White, et al., 2013), the NSF-funded project led by J. Ellis Bell published a set of essential skills and knowledge that is widely accepted as the expectation for undergraduate students in biochemistry and molecular biology (BMB) programs (Mattos, 2013; Tansey, 2013). At Lebanon Valley College, these skills and expectations align well with our mission, which begins:

> *The intertwined and inextricable disciplines of biochemistry and molecular biology examine the most detailed processes in living systems and seek to explain those processes in terms of the molecules involved and the transformations those molecules undergo.*

The work of Bell and his colleagues, as well as the work of others, has guided curricular development (e.g., the identification of threshold concepts in biochemistry; Loertscher, 2014). In 2015, AAAS published a follow-up report that sought additional effective methods and measures of comprehensive program-level assessment for inclusion in a curated collection of assessment tools for faculty in the biological sciences (AAAS, 2015). However, few examples of defined guidelines and specific assessment instruments are available in published reports (Aguanno, et al., 2015). Herein, we describe a student activity for the upper-division biochemistry laboratory and provide the assessment rubrics that allow us to perform both course- and program-level assessment. It is our aim that these resources be useful for other programs and institutions who seek to develop a sustainable and meaningful program-level assessment.

Our faculty have articulated 11 assessable objectives related to our mission. Five of the 11 are assessed in the 400-level capstone course, Biochemistry Laboratory (BCMB 430). BMCB 430 is a course designed to introduce students to critical discipline-specific methods and techniques as they apply relevant knowledge from all of their coursework in the sciences. A capstone experience, such as a research project, is a natural opportunity to ask students to apply fundamental concepts and skills that they developed throughout their undergraduate experience (Oh, 2005; Paris, 2013). The learning outcomes assessed through this course-embedded experience include experimental competency, communication proficiency, and technology and information conversancy as listed below:

Outcome 3 - Experimental competency
Objective 3.1 *- Apply the scientific method to scientific problems.*
Objective 3.2 *- Identify & utilize the proper methodologies & instrumentation to successfully answer questions*
Objective 3.3 *- Collect scientific data; laboratory notebooks; data analyses*

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Outcome 4 - Communication proficiency
Objective 4.1 *- Demonstrate the ability to communicate effectively in written and oral formats.*

Outcome 5 - Technology and information conversancy
Objective 5.1 *– Effectively access and utilize the scientific literature.*

At the beginning of the BCMB 430 course, students receive the following general information about their upcoming research projects. Below is the information they received during the '16-'17 academic year.

> *For your project, you will be asked to answer a question, design an assay, or look for proof of a particular concept. The project may involve work with proteins, lipids or carbohydrates. If you have a particular interest, talk to me; perhaps we can develop something around your interest. As a matter of practice, students are not allowed to simply work on a research project they are already doing in the laboratory of a faculty member or as part of an internship someplace else. Also, we cannot do experiments that will cost hundreds of dollars - $20 is more like it.*
>
> *This year's projects involve "Biochemical Transformations" or "Sensors & Sensing." Biomolecules are amazing things. Understanding how chemical transformations occur in biomolecules or biomolecules can facilitate the transformation of another molecule is at the very heart of biochemistry. Some transformations are simple, some are complex and elegant and some are elegant in their simplicity. In these research projects, you will be asked to work with biomolecules found in common dietary supplements from the local health food store..*

After approximately six weeks of introduction to essential techniques in biochemistry (e.g., protein assays, protein purification (ion exchange and ligand affinity), enzyme assays (lactate dehydrogenase), and protein electrophoresis, each student group receives information that will guide their specific project; this information is relatively brief, forcing the students to do extensive research on the idea or question they receive. Examples of research project prompts used within the past year include:

- Develop an assay to demonstrate protease activity.
- Can myoglobin be used as an oxygen sensor?
- How can rutin and quercetin be used as sensors?
- Can cinnamaldehyde be used a protein-labeling reagent?
- Demonstrate that you can trap a molecule in the interior aqueous compartment of a liposome and another molecule in the lipid leaflet.

Students must proceed from general learning about the topic area of the project to planning and carrying out experimentation. For some prompts, students may find an established method in the literature, but they are encouraged to think about how they would develop an experiment, given what they know. For example, to work on the project, Demonstrating Protease Activity, a student should rationalize that proteases hydrolyze amide bonds and then ask themselves, "How can I monitor the cleavage of an amide bond? What molecule can I use and how might I detect that change?" Several years ago, one impressive group decided to carry out the synthesis of a small molecule substrate and monitor cleavage of the substrate using MALDI mass spectrometry. Some students enroll in BCMB 430 with substantial research experience, while some student have no research experience, whatsoever; so all students are guided by a detailed list of expectations. For a complete listing of project expectations, please see the supplemental document: http://bit.ly/2msTZzx)

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Prior to beginning the project, students receive general information about how their work on their research project will be graded. Those general guidelines, found in a supplemental document http://bit.ly/2meo2u8, have been used to generate a series of rubrics for assessing student performance on their research projects. The rubrics are used to both grade the research project as well as provide assessment information.

Rubric 1: Objective 3.1 - Apply the Scientific Method to Scientific Problems http://bit.ly/2lsCgTK

Rubric 2: Objective 3.2 - Methodologies and Instrumentation to Test Experimental Hypotheses http://bit.ly/2musAx8

Rubric 3: Objective 3.3 - Methods and Practices for Collecting and Analyzing Data http://bit.ly/2lA7rxm

Rubric 4: Objective 4.1 - Communicate Science Effectively with Peers http://bit.ly/2muCi2N

Rubric 5: Objective 5.1 - Use Literature Search Engines to Find and Use Primary Scientific Literature http://bit.ly/2lA2gh5

Data from student artifacts (n = 12) during the fall '16 semester drew attention to **Objective 3.2: Methodologies and Instrumentation to Test Experimental Hypotheses**; scores were notably lower for items within this objective. The proper use of experimental controls, interpretation of data, consideration of methodological error, thoughtful experimental design, and alternative explanations for findings were all seen as potential areas for improvement. We are now investigating ways to better engage students in critical thinking surrounding experimentation and the gathering of data. Currently, we are incorporating shorter exercises in research design, methodology, and data interpretation into the course so that students can practice and hone their ability to critique both the processes and the products of their research.

We share this assessment, criteria for evaluation, and our findings with the hope that other faculty can modify and use these materials as they seek to engage in meaningful program-level assessment. In our program, the instrument has provided useful results that help to drive curricular and pedagogical growth, which ultimately serves Lebanon Valley College and our students.

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