Assessing the Effectiveness of Introductory Biology Laboratory Courses

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The realm of science education has recently experienced the exploration implementation of new models of course and curriculum design that look at teaching from a scientific perspective. In line with this nationwide movement, a multidisciplinary team of faculty and students at Calvin College have revamped two introductory biology laboratory curricula -- Biology 224L (Cellular and Genetic Systems) and Biology 225L (Ecological and Evolutionary Systems). The bulk of these revisions have been carried out for the past two summers, and involved integrating Core Competencies and Concepts as delineated in an influential national report called Vision & Change in Undergraduate Biology Education: A Call to Action (AAAS). These Core Concepts and Core Competencies capture what is considered essential to undergraduate biology education and provide a framework for biology educators. We aimed to imbue a sense of relevant, real-world connections into the curricula through introducing topics that students encounter outside of the classroom. Biology 224L was structured around the raw-foods movement, giving the students an opportunity to explore the nutraceutical properties of broccoli, while the curriculum of Biology 225L focused on investigating the species concept through three modules: aster identification, fish phylogenies, and hominid evolution.

The revisions also involved moving away from the traditionally structured format of the prior labs, which led the students in step-by-step instruction that directly mirror the concepts learned in classroom. Commonly known as “cookbook” style instruction, such teaching leaves little room for students to develop higher-level cognitive skills. In contrast, the revised curriculum would allow students to partake in the process of scientific inquiry through multi-week investigations. However, as these courses were introductory classes typically taken by underclassmen, we still aimed to provide guidance and scaffolding when necessary. Although this balance was reached intuitively, upon further examination of existing literature, it became evident that we had attained a middle ground between two schools of thoughts -- science educators who advocate inquiry-based learning and several educational psychologists who champion direct instruction. The voice of the latter has had an impact in the realm of educational psychology, yet their research has not been noted nor incorporated often by science educators. Through the implementation of our revised curricula and manuscript publication, we hope to contribute in filling this missing gap with our experience.

In the initial weeks, our work constituted of attending to data that had been collected for the past two years. As graders, we read through, developing rubrics, and scored a variety of different tests that students took in BIOL 224 and 225. The outcomes from these pretests, posttests, midterms, and finals and subsequent interpretations would form the foundation for our work in future weeks. In addition to this “direct evidence”, we examined responses to SALG surveys (Student Assessment of their Learning Gains) and course evaluations. These “indirect evidences” provided us with another facet of the labs that we could gauge: student perception.

By our third week, we had processed the majority of the raw data and began to draft our first manuscript for publication. This manuscript, now in the late stages of editing, provides a detailed description of the new curricula, the underlying process and rationale behind the construction, student responses (both academically and perceptually), and future revisions to be
made. The manuscript will be sent to *CBE Life Science Education* for consideration. As of now (week nine), two more manuscripts are in development. One manuscript examines the balance that the labs strike between student based inquiry learning and direct instruction. We believe this manuscript will provide a contrasting voice that is currently needed in the sphere of undergraduate biology education. This manuscript is also in the late stages of editing and will be submitted to the *Council on Undergraduate Research Quarterly*. Our last manuscript, still in development, delineates an innovative laboratory assay (assessing myrosinase enzyme levels) that was developed by the research team two summers ago. Currently in use in BIOL 224, we believe this assay, being both innovative and cost efficient, is a valuable addition to the scientific community. The manuscript, once completed, will be submitted to the *Journal of Microbiology and Biology Education*.

In addition to our work on the three manuscripts we had the opportunity to participate in the editing of the current lab curricula. Our data illuminated modifications that should be made in both BIOL 224 and 225; changes we were able to implement through instructor interaction, lab manual refinement, and laboratory exercise development.

The outcomes from our analysis of the effectiveness of the two courses culminated in contrasting patterns. In Biology 224L, significant learning gains were found through the comparison of pre- and post-assessment results. However, the focus interviews, course evaluations, and SALG survey responses demonstrated lower student perceptions pertaining to the affective domain. In interpreting this outcome, we took into consideration a possible implementation dip and previously documented decline in student attitudes towards inquiry-type labs. In contrast, Biology 225L saw negligible learning gains, but was accompanied by higher end of course evaluations. The lackluster learning gains may be explained by the lack of depth in student’s learning, which would have led to acquisition of only the surface level knowledge.

The opportunity to participate in this research has been a rewarding experience for us. One particular benefit that will serve as an invaluable asset in the future is gaining familiarity with the multiple steps involved in a research process. Such an opportunity to actively partake in various stages of research, from identifying potential journals to generating and tweaking a hypothesis, collecting data, analyzing the results with appropriate statistical tests, interpreting the results, writing and editing of the paper, and finally, submitting the prepared manuscript will prove to be important in helping us in attaining our future plans after graduation, as we both consider applying to graduate programs. In addition to gaining competency with the research process, we have learned about what constitutes effective learning and teaching. Although this learning about learning and the research process has taken place within the domain of biology education, such knowledge will still be quite useful and applicable in our respective fields of psychology (Ye In Oh) and biotechnology (Nate Buteyn). The acknowledgement of our contributions in several publications and presentations will also assist in us in our future endeavors. In summary, it has been a privilege to partake in and contribute to this ongoing endeavors to shape the way biology will be taught at Calvin College.