Integrating Course-Based Undergraduate Research Experiences (CUREs) in Advanced Forensic Science Curriculum as an Active Learning Strategy

Sulekha Rao Coticone[1*], Lora Bailey Van Houten[2]

[1]Department of Chemistry and Physics, Florida Gulf Coast University, Ft Myers, FL 33965
[2]California Department of Justice Crime Laboratory, Fresno CA 93740
**corresponding author: scoticon@fgcu.edu*

Abstract: In an effort to improve student learning outcomes and retention in advanced forensic science curricula, a research-based curriculum has been developed at the university. During the first six weeks of the semester, students are introduced to fundamental research techniques in a forensic biochemistry course. These include presumptive tests, DNA extraction, DNA quantitation, short tandem repeat-based polymerase chain reactions and capillary electrophoresis. Using this fundamental knowledge, students develop a research problem/hypothesis, identify suitable protocols using a literature survey, plan and collect samples, determine variables, analyze data and present their results as a formal laboratory report as well as an oral presentation. Students specifically design experiments dealing with changing variables (e.g. temperature, reaction conditions) in the collection, storage and extraction of DNA for forensic DNA analysis. Data from student assessment of learning gains (SALG) surveys administered at the end of the semester supported gains in student learning. Additionally, pre- versus post- survey data showed that students gained confidence in organizing and presenting their data as well as a deeper understanding of the applications of biochemistry in forensic science. We conclude that incorporating CURE research projects in other forensic science courses will help provide students with opportunities to be innovative and learn important critical thinking skills for their future careers.

Keywords: CUREs, Forensic Science, Active learning

Introduction

One of the center pieces of scientific education for undergraduate students with a science major is the incorporation of laboratory experiences (1). In the history of chemical education, four different laboratory instructions have been developed and identified in science based curriculum: traditional (expository), inquiry, discovery and problem based (2, 3). The traditional (expository) style is the common instruction style (recipe based or cookbook labs), whereas the inquiry method is closer to how scientific research is conducted (4, 5). The traditional method tends to test knowledge and comprehension with little emphasis on evaluation, analysis, and creativity. Inquiry based labs are more student centered, requiring them to formulate a problem, design experiments, gather and analyze data and communicate their conclusions. The National Research Council (NRC) has emphasized the need for a revision in traditional laboratory courses to focus more on critical thinking skills and a deeper understanding and knowledge application (6). This has led to a number of new initiatives in scientific laboratory instruction (7-9).

It has also been shown that engaging students in an undergraduate research experiences is a highly effective strategy for increasing interest and retention in STEM degrees (10). These experiences inspire students to pursue advanced degrees and careers in STEM fields. Hands-on experience gained by students performing undergraduate research leads to improved technical skills within their discipline, enhanced critical thinking and communication skills, and provides them with the knowledge and skills necessary to be life-long learners. Studies have shown these enriched connections are specifically beneficial for underrepresented minority students in STEM (11).

More recently, original research and course based research experience (CUREs) have gained a lot of attention as a high impact strategy to improve learning outcomes resulting in improved student learning (12, 13). Additionally, several instructors have integrated research experiences into introductory science courses to improve undergraduate student interest and preparation for their science careers (14, 15). These research based courses differ from expository (traditional) experiences since students are asked to develop procedures where outcomes for the experiments are not known. The benefits include learning important problem solving, critical thinking, communication skills and gaining a deeper understanding of their field of study. These experiences have been shown to have positive outcomes for students including better grades, persistence and retention and increased interest in graduate education.

The forensic biochemistry course has been developed to support a new Bachelor of Science in forensic science program at the university. The course was formulated based on the interest of popular television shows such as Crime Scene Investigation (CSI). The course combines important concepts in biochemistry with criminal justice studies to encourage student interest using the forensic science theme. Students learn the essential techniques used to solve crimes using forensic DNA analysis improving their critical thinking and problem-solving skills. We have recently included a CURE research based laboratory component to the course to expand access to authentic research experiences. Students are challenged to develop "real world" based forensic questions, design experiments, acquire and analyze data and finally defend their projects as a formal presentation in front of their peers.

Methods

Course organization

The prerequisites for the special topics course are a full year of general chemistry and organic chemistry. The course which is worth three credits meets twice a week for 2 hours and 15 minutes. The first one hour of the class is devoted to lecture and the remaining hour and 15 minutes dedicated to laboratory exercise/CURE research project. The final grade is based on a two-part assessment. The first part is a set of three exams, weekly quizzes and laboratory exercises (70% of grade) that evaluates critical thinking and problem-solving skills, including interpretation of data. The remaining 30% of the grade is based on the CURE research projects, final project presentation and a manuscript-based laboratory report.

Course design and implementation

Students are first introduced to research techniques and background information in forensic DNA typing. The lectures function by providing students with the basic and fundamental source of information on forensic DNA analysis. Students learn how forensic DNA is extracted, stored, quantitated and analyzed using PCR and capillary electrophoresis. The laboratory experience spans the entire semester and is divided in two major components. In the first part, students are exposed to experiments with known protocols, which are used to familiarize the students with the main laboratory techniques. These experiments have defined outcomes and serve as controlled investigations for following hypothesis driven research. Armed with this basic knowledge, students are divided into groups of 2-3 students and given the task of developing a CURE project. This involves performing a literature survey, developing a hypothesis and designing experiments to test the hypothesis. Examples of student projects include: does the pH of the beverage affect DNA recovery from glass bottle rims? Does the substrate (cotton, leather, nylon) affect the amount of DNA recovered? Does the quality of the buccal swabs affect the amount of DNA extracted? Can you obtain DNA from tears or ear wax? The students collect data, repeat the experiments (iteration) and make appropriate changes to their experimental design which is a critical factor in CUREs (12). Students analyze their data and provide appropriate results and discussion. Finally, student learning is evaluated by a group presentation at the end of the semester. The presentation focuses on the research groups' unique hypothesis, results and discussion and future direction. The presentations are graded by the instructor using a rubric as well as by their peers (peer review). A manuscript-based laboratory report is also generated by each group using a standard template provided. The template follows the layout of a journal article and includes sections on abstract, introduction, materials and methods, results and discussion and conclusions. Crime laboratory analysts from local crime laboratories are also invited to share their expertise and interact with the students. Additionally, students are surveyed for their opinion on their research projects. This comprehensive assignment exemplifies the core ideals of the thinking, discovering, and writing in an interdisciplinary course that stimulates critical thinking and original ideas.

Results

Course assessment

To assess student learning, we utilized five different methods of assessment. These include a Pre/Post CURE project survey, a Students Assessment of Learning Gains (SALG) survey, a student led peer review and finally an informal survey.

i) Pre and post CURE project survey

A pre/post survey conducted with the students before and after the CURE project showed positive trends in organization of data, scientific communication and confidence in the research project (**FIGURE 1**).

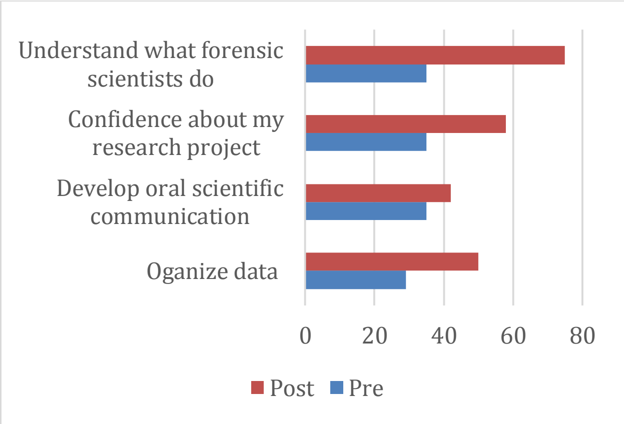

FIGURE 1 *Pre and post survey sata regarding CURE poster presentations*

The greatest improvement was seen in an understanding about what forensic scientists do in crime laboratories. However, students perceived least gains in developing their oral scientific communications. This is being addressed by providing students more opportunities to discuss scientific literature using journal articles related to their CURE projects before their final presentation. This will help familiarize the students with the scientific jargon and boost their confidence for the final presentations on their CURE projects.

ii) Student assessment of learning gains (SALG)

The Student Assessment of their Learning Gains (SALG) instrument was developed in 1997 by Elaine Seymour, an evaluator of pedagogy for undergraduate chemistry courses (16). The SALG instrument focuses exclusively on the degree to which a course has enabled student learning. Specifically, SALG asks students to assess and testify on their own learning, and on the degree to which specific aspects of the course have contributed to that learning. SALG is a web-based instrument consisting of statements about the degree of "gain" (on a five-point scale) which students perceive they have made in specific aspects of the course. Using SALG, students reported that they accomplished good to great gains in their ability to critically read journal articles as well as writing documents in discipline appropriate style and format and working on CURE research projects (**FIGURE 2**). To address the lower gains in the participation of discussions in the class, more time will be provided for students to first present their hypothesis to the class before undertaking the experimentation with a class discussion on the projects.

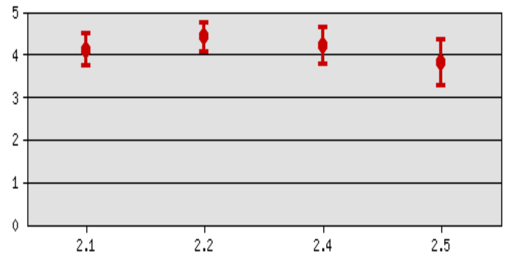

FIGURE 2 *Student assessment of their learning gains (SALG): class impact and attitudes.* The graph lists the mean and confidence interval (±3 times the standard error) for each item. 1:no gain, 2: little gain, 3: moderate gain, 4: good gain, 5: great gain

Questions asked included the following. As a result of your work in this class, what GAINS DID YOU MAKE in the following?
2.1 Critically reading of journal articles related to forensic science
2.2 Writing documents in discipline appropriate style and format
2.4 Working on a CURE project
2.5 Participating in discussion in class

iii) Peer review

Students were asked to perform a peer review during their final presentation and comment on each of the research projects (**Survey 1**). This provided the students with a process of self-assessment and evaluation. Student comments were positive and constructive recommending small but useful changes to research design and methodology as well as presentation styles. For the first question (which project they liked best and why?) students thought the concept, method, results, and presentations were interesting, related to their daily life, and were well organized. Student comments to the second question (criteria for which project they liked best) varied from interest in the project, depth of study, organization, clarity of data, confidence, and knowledgeable presentation. Students were also asked to grade the projects and suggest improvements to the projects.

Survey 1 *CURE Research Projects (Peer review)*

Questions asked included the following.
1. Comment on which project you liked the best and why?
2. What criteria did you use to decide which project you liked the best?
3. Give the order of preference of the research projects from 1-5 (do not grade your project) (1 being the best)

4. What improvements can you suggest that the students could have done to improve their projects?

iv) Informal survey

At the end of the semester, students answered an informal survey where they mentioned their most enjoyable aspects of the project which included statements reflecting their personal preferences (**Survey 2**). They seemed to enjoy designing their own experiments rather than following a set procedure. They also admitted to the most frustrating parts of the project which included the several trials needed to get consistent data and unexpected results. They also wanted more time to complete their projects. Finally, students provided feedback on whether they thought that the CURE projects were useful. Most students admitted that CURE research projects helped them solve novel problems. They also thought that this experience should be introduced in other courses and that they learned a lot by doing the projects.

Survey 2 *CURE Research projects informal survey*

Questions asked and examples of responses are listed below.
1.What was the most enjoyable part about the CURE project projects?
"Being able to design our own project and learn"
"Our own investigation rather than follow a set procedure"
"Hearing about the challenges of the projects and what they would do differently"
"Doing research on a new idea and analyzing the results"

2. What was the most frustrating part about the CURE research projects?
"The several trials of the experiment to get consistent data"
"Unexpected results but also makes it more interesting"
"The same aspects that were enjoyable were also challenging"

3. What would you change about the CURE research projects
"More time to do the CURE projects"

4. Do you think CURE projects are useful for learning how to do research?
"Yes, researching our own topics helped us understand why research is so important and how to do it"
"Absolutely, more classes should have this experience"
"Yes, it challenges science students to solve novel problems with what we have learned"
"Yes, I learned more from the CURE research project"
"I learned a lot from the CURE research project"

Based on the results, we plan to incorporate these CURE research projects in other upper division forensic science courses. This study can also be used as an assessment tool by the department. Incorporating research projects in other courses will help provide students with opportunities to be innovative and learn important critical thinking skills for their future careers

References

1. Elliott MJ, Stewart KK, Lagowski JJ. The role of the laboratory in chemistry instruction. J Chem Educ 2008;85(1):145-149.
2. Domin DS. A review of laboratory instruction styles. J Chem Educ 1999;76;543-547.
3. Domin DS. Students' perception of when conceptual development occurs during laboratory instruction. Chem Educ Res Pract 2007;8(2): 232-254.
4. Murthy PPN, Thompson M, Hungwe K. Development of a semester-long, inquiry-based laboratory course in upper-level biochemistry and molecular biology. J Chem Educ 2014;91:1909-17.
5. Brownell SE, Kloser MJ, Fukami T, Shavelson R. Undergraduate biology lab courses: comparing the impact of traditionally based cookbook and authentic research based courses on student lab experiences. J Coll Sci Tech 2012;41(4):36-45.
6. Fox MA, Hackerman N. (Eds.) Evaluating and improving undergraduate teaching in science, technology, engineering and mathematics. National Research Council:Washington DC, 2003.
7. Caspers ML, Roberts-Kirchhoff E.S. An undergraduate biochemistry laboratory course with an emphasis on a research experience. Biochem Molecular Educ 2003;31(5): 303-307.
8. Hofstein A, Navon O, Kipnis M, Mamlok-Naaman R. Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. J Res Sci Teach 2005;42(7):791-806.
9. Craig PA. A project-oriented biochemistry laboratory course. J. Chem Educ 1999;76(8):1120-1136.
10. Russell SH, Hancock MPH, McCullough J. Benefits of undergraduate research experiences. Science 2007; 316(5824):548-49.
11. Lopatto D. Survey of undergraduate research experiences (SURE): first findings. Cell Bio Educ 2004;3:270-77.
12. Brownell SE, Kloser MJ. Towards a conceptual framework for measuring the effectiveness of course-based undergraduate research experiences in undergraduate biology. Stud High Education 2015; 40:525-544.
13. Mordacq JC, Drane DL, Swarat SL, Lo SM. Development of course-based undergraduate research

experiences using a design based approach. J Coll Sci Teach 2017;46(4):64-75.

14. Buck LB, Bretz SL, Town MH. Characterizing the level of inquiry in the undergraduate laboratory. J Coll Sci Teach 2008;38(1):52-58.
15. Weaver GC, Russell CB, Wink DJ. Inquiry based and research based laboratory pedagogies in undergraduate science. Nature Chem Bio 2008;4(10):577-80.
16. Seymour E, Wiese D, Hunter A, Daffinrud SM. Creating a better mousetrap: on-line student assessment of their learning gains. Paper presentation at the National Meeting of the American Chemical Society, San Francisco, CA. 2000.