Biological and Environmental Sciences Department, Capital University, Columbus, OH 43209

CapitalUniversity

Classroom Learning and Undergraduate Research – Two Sides of the Coin

Kerry L. Cheesman, PhD, Robert M. Geist Jr. Chair and Distinguished Professor

ABSTRACT

Inquiry teaching (case studies, problem-based learning, teamwork, cooperative learning, flipped classrooms, etc) and undergraduate research (course based) are both known to be high impact practices in education. Yet they are often used in isolation by faculty who redesign courses, rather than allowing them to inform each other. Inquiry teaching should lead to additional questions that can be answered through course-based research projects. Encouraging students to find the answer to their own questions (with guidance) allows them the satisfaction of turning the coin over and discovering the beauty and uniqueness of the other side. When inquiry and research are employed together, students learn and retain more information.

INQUIRY TEACHING

Inquiry teaching has been demonstrated to be a high-impact practice in STEM for more than two decades. Inquiry methods include the use of case studies, problem-based learning, teamwork, cooperative learning, flipped classrooms, and more.

Most teachers that use inquiry methods begin with the 5E cycle (**e**ngage, **e**xplore, **e**xplain, **e**laborate, **e**valuate). Each stage (engage, explore, etc) can be achieved through the use of known methodology including case studies, problem-based learning, etc. The goals of inquiry teaching (regardless of methodology) include nurturing talents and passions, increasing motivation and excitement about a subject, fostering curiosity and excitement for learning, deepening understanding and going well beyond memorization, enabling students to take ownership of their own learning, and developing strong research skills. Together these goals lead to and tie into course-based research projects – the other side of the coin.

CUREs

'**Course-Based Undergraduate Research Experiences**' (CUREs) offer students hands-on experience doing original research, and offer faculty the opportunity to generate new information within their discipline. A CURE is a project that engages whole classes of students in addressing a research question or problem that is of interest to the scientific community.

Because CUREs are still relatively new in the undergraduate education landscape, there continues to be debate about what constitutes a CURE. Inquiry instruction has been the gold standard of science education for several decades, and involves many of the features of CUREs. Similar to CUREs, inquiry instruction involves students in asking and answering scientific questions, analyzing relevant data, and making and defending arguments. Both forms of instruction aim to develop students' scientific expertise, especially their ability to engage in scientific practices. In inquiry courses, students' work may be novel, but a stakeholder outside the classroom is unlikely to be interested in the results. CUREs are distinctive in offering students opportunities to make discoveries that are of interest to those outside the classroom.

Our CURE students have been coauthors on papers, have contributed results to national research data bases, and have made presentations at significant regional and national scientific meetings.

CUREs as PEDAGOGY

Research on undergraduate research experiences indicates that students who engage in research realize a range of positive outcomes, including more confidence in their ability to do science, greater identification as a scientist, and increased persistence in science, including taking additional science courses and completing a science major.

CUREs allow all students (rather than a select few) to engage in authentic research. CUREs require students to learn group and process skills, learn graphing and paper writing skills, and engage students in active learning throughout. Students from under-represented or under-served backgrounds (those least likely to get access to research internships or one-on-one research projects) are always included. Faculty members who teach CUREs are able to integrate their teaching and research responsibilities for the benefit of all students.

The unique potential of CUREs, and the growing body of research on their effectiveness, has piqued the interest of many faculty members and institutions across the country who are now integrating CUREs into their undergraduate curricula.

COMBINING INQUIRY and CUREs

For many years we have focused on making sure that all of our biology classes are taught using inquiry methodology. Both classroom portions and laboratory portions have been adapted to use more problem-based learning, case studies, and flipped classrooms. In recent years we have incorporated CURES into many of these courses to increase student engagement and student excitement about their learning.

The table below shows the vertical integration of CUREs into courses of the biological sciences curriculum at Capital University (all of which are taught using various inquiry classroom methodology).

Course Name	Course Level	Project	Disciplines Involved
Foundations of Biology	First Year *(3 weeks)*	Campus Trees *(Inquiry project)*	Botany/Ecology, Science Education
Genetics	Second Year *(5-6 weeks)*	**PARE - P**revalence of **A**ntibiotic **R**esistance in the **E**nvironment	Genetics, Microbiology, Environ. Science
Research Methods	Third Year *(10 weeks)*	Using the **NHANES** database from the USCDC **DNA Barcoding** of Fungi, Mice, and other species	Biochemistry, Nursing, Statistics Genetics, Zoology, Botany/Ecology,
Cell Biology	Fourth Year *(10 weeks)*	Effects of various drugs on cell proliferation	Cell Biology, Biochemistry, Pharmacology

INQUIRY and CUREs LEAD to ADDITIONAL OPPORTUNITIES

Because both inquiry classrooms and CUREs are active processes that engage students in creating novel data and taking ownership of their own learning, there is a desire on the part of many students to continue their research independently after the course project is completed. These projects can span an additional 1-4 semesters and involve up to four students per project.

Students that have continued their research (with any of the faculty involved in the original CURE) have been invited to present their work at a number of regional and national scientific meetings; these include the Ohio Academy of Science, the Ohio Physiological Society, the Ohio Wildlife Society, the National Conference on Undergraduate Research, the American Society for Nutrition, the American Association for the Advancement of Science, the American Society for Human Genetics, and the American Society for Biochemistry and Molecular Biology. Additionally, students have co-authored and published numerous papers at the conclusion of their projects.

Other students have become so excited about research in general that they have worked with faculty on separate, unique projects, some of which have been published as well. Finally, the overall rate of students deciding to go to graduate programs has increased since the advent of CUREs throughout the program.

CONCLUSIONS

CUREs are a vital form of / addition to inquiry teaching for science classes and labs. CUREs engage students in authentic research, exciting many students who may not have been passionate about research before being involved in an inquiry classroom that included a CURE. These projects are capable of reaching many more students than traditional undergraduate research experiences, thus preparing them for graduate programs as well as jobs in many fields.

When CUREs are planned and prepared by two or more faculty within a department or across departments, they help to break down silos and by example show students that science is almost always done in teams rather than in isolation. While CUREs are not the only form of undergraduate research that prepare students for presentations and publications, they are capable of increasing the percent of students who can, and will, have those opportunities.

A FEW REFERENCES

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