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Moving Research Into the Classroom

Successful Adaptations at a Service Academy

By Erick Snellman, Jerry A. Krueger, and Edward T. Unangst

To promote research exposure for biology students, we developed a successful classroom-based research program in two elective courses. Students work in small groups mentored by faculty and allotted class time to conduct highly focused research projects. This program exposed 80% of biology graduates to research in various programs.

The benefits of research exposure for undergraduate students are well documented and strongly supported nationally (NRC 1996; Halaby 2001; NRC 2003). The most common benefits cited are close faculty-student relationships, promotion of critical thinking and inquiry, improved communication and problem-solving skills, increased confidence, and exposure to interdisciplinary and student-centered learning (NRC 1996; Halaby 2001; Killeen 2001; Lewis, Conley, and Horst 2003; Krueger, Noyd, and King 2005). Although we've seemed to reach a national consensus among college educators, implementation of undergraduate research programs, both inside and outside the classroom, is highly variable. This seems to run counter to the decade-long rise in interest and programs (NSF 1996; Boyer Commission 1998; Gonzalez 2001; NRC 2003). There are a host of common barriers to conducting successful undergraduate research programs, which include constraints in finance and facilities (Lewis, Conley, and Horst 2003); time and training commitments (Sundberg and Moncada 1994; Herreid 1998); conflicting faculty and administrative demands and rewards (Dimaculangan et al. 2000); and student naiveté, stress, and confusion over expectations (Thorton 1972; Herreid 1998; Switzer and Shriner 2000).

Our institution, the United States Air Force Academy (USAFA), attempts to encourage and foster research among its faculty and students. For example, in the past year 216 students and 327 faculty members participated in $16.4 mil-

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lion worth of externally funded research projects (Head 2004). As we are a military service academy, the expectation is that grants fund a broad range of undergraduate research programs designed to develop close working relationships between students and faculty while furthering mentoring opportunities for future Air Force officers (Dean of the Faculty 2005; Krueger, Noyd, and King 2005). Among the benefits our department wanted to achieve by implementing discovery-based learning were team-building skills, critical thinking, problem solving, and exposure to data analysis. Like all scientists who teach, we want our students to develop an appreciation for the scientific process and rigors that accompany it. To fulfill these desires within student time constraints, they must be accomplished without extra course load and with minimal commitment or responsibility outside the classroom. When we started the program, we also hoped that these courses would build students' confidence in performing research, and kindle increased participation in our other research programs.

A significant roadblock to performing undergraduate research at USAFA is securing the necessary time commitment for both faculty and students to successfully complete a project. By any standard, USAFA students have rigorous, time-demanding schedules in order to meet existing academic, military, and athletic requirements. In addition, both civilian and military faculty perform all teaching and laboratory requirements along with a wide range of administrative and mentoring duties unique to a military institution.

In this article, we describe the classroom-based research program we developed over the past five years in the Department of Biology. Our approach allows students to benefit from the investigative process while accommodating their rigorous daily schedules. At the same time, this program has fostered increased student participation in our other research programs and increased mentoring opportunities for our faculty.

Institutional background and challenge

USAFA trains and educates 4,000 young men and women annually in preparation for commissioning as second lieutenants in the U.S. Air Force. The undergraduate curriculum (there is no graduate program) includes required courses in basic sciences, engineering, humanities, social sciences, and military arts and sciences (USAFA 2006). Each student completes 112 semester hours of core curriculum. Students also select courses from 32 academic majors and 4 minors. For example, to earn a degree in biology, 36 semester hours (148 semester credit hours total) are necessary. In a typical graduating class of 930, there is an average of 60 biology majors. In addition to academics, USAFA emphasizes military training and athletic conditioning, all while developing students' integrity and character in preparation for military service (USAFA 2006; Dean of the Faculty 2005).

Academic activities are confined to weekday times between 7:30 a.m. and 4:00 p.m. Students also devote considerable time and effort to mandatory military training and athletic conditioning scheduled after classes each day until 6:00 p.m. and often on weekends (USAFA 2005). Study time is scheduled as formal academic call to quarters from 8:00 p.m. to 11:00 p.m. on weekday evenings. Although skilled in time management, our students' simultaneous pursuit of academics, military training, and athletics translates into a rigorous and challenging daily schedule of events. The "full plate" academic schedule consisting of both core and major classes precludes many from committing to faculty-mentored independent research study (Reed 2005). Further commitments to military training, professional development, and athletic conditioning lead some students to jealously guard their remaining free time. It's important to note that upon graduation most biology majors don't enter career fields requiring direct application of biological principles, but general application of science and mathematics. For example, 60% of biology majors become pilots, and an additional 30% serve in nonscientific career specialties in which broad exposure to math and sciences prove critical. This fact creates a challenge for faculty wishing to involve students in research: How do we describe the benefits of research when our students' career specialties do not require it?

Seventy-five percent of our 530+ faculty consists of active duty Air Force officers, with the remaining being civilian professors. Additional military instructors from allied nations, officers from other U.S. Armed Forces branches, and distinguished visiting professors from around the nation contribute to the diversity of the USAFA faculty (Dean of Faculty 2006). For military officers, this is a three-year tour of duty. Approximately 50% hold doctorate degrees with a minimum of a master's degree required for faculty membership. Unlike most colleges, we have no graduate program with accompanying graduate students to perform as instructors, laboratory assistants, or research assistants. Thus, our faculty performs all teaching responsibilities, lab work, and varied administrative duties within their respective departments along with traditional military supervisory roles. Faculty appointments are considered 90% teaching, with 10% time allocated for research. As with our students, time is the most precious commodity for the faculty.

Research in the classroom: A service academy approach

We began the process of integrating focused, multidisciplinary research projects or investigative laboratories (Sundberg and Moncada 1994) in our Applied Ecology (Bio 481) course in 2000, and Molecular Biology Methods (Bio 464) in 2002. Each course is an elective within the

TABLE 1

Examples of student research projects from the past year.

Molecular Methods:

Subcloning a gene encoding a bacterial lipase

Cloning a gene encoding a novel thermostable esterase

Molecular-based identification of meadow voles using cytochrome b gene

Field Ecology:

Plant moisture stress in *Pinus ponderosa, Abies concolor,* and *Pseudotsuga menziesii* in a similar habitat on the USAF Academy

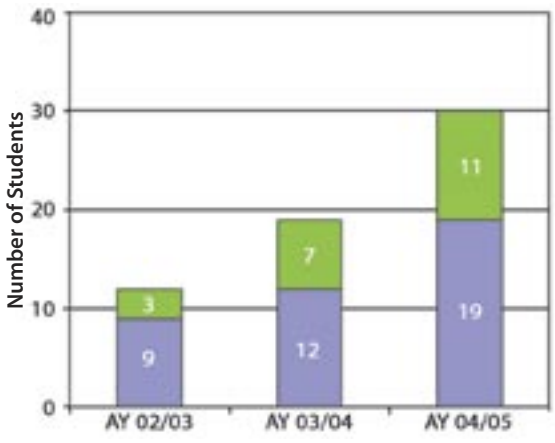
Effects of core body temperature and hydration on noninvasive estimates of body composition in bullfrogs *(Rana catesbeiana)*

The in situ thermal conductance in the bark of Ponderosa pine *(Pinus ponderosa)* on the USAFA campus

FIGURE 1

Increase in independent research enrollment attributed to the classroom research experience

Blue bars indicate independent research enrollment not related to classroom research, while green indicates those students who stated they enrolled because of previous classroom research work. AY indicates academic year.



biology major. Prior to this, each class devoted significant course work to fieldwork or hands-on approaches to instruction but lacked the application of data analysis in solving research questions. Enrollments average 10–12 students per course, the bulk of which are seniors. To enroll, students must have completed a series of prerequisites to ensure adequate preparation. In the semester prior to the class, potential research projects are developed and associate researchers on the faculty are recruited. During the first week of class, the range of potential research projects is presented to the students in class. Discussions and interactions are encouraged, often to the level of discussing the required skill sets for research projects students will be expected to master.

Students self-select into groups of two or three, based on their pooled interest in projects. In order for us to comply with the 105-hour level of effort for a 3-hour semester course, we carefully design each project to be completed within approximately 30 hours of individual effort (90 total for a three-person group) with data collection and analysis completed in a six-week time frame. For illustration, we've provided some examples of our projects in Table 1. In our 16-week semester, this allows for adequate literature review and preparation (3–5 weeks), data collection and analysis (6 weeks), and written and oral assessments (4–6 weeks). With interdisciplinary projects, students get to work with faculty members other than the primary instructor in the class. In our department, we've been fortunate to recruit a small core of faculty who participate each year. This provides more faculty-student interaction in addition to laying possible foundations for student involvement in future independent research programs.

The most crucial aspect of our classroom-based program is developing research questions that allow completion within a single semester. To accomplish this, our projects must be narrow in scope and employ proven laboratory methodologies (Table 1). While we understand that this limits student imagination in developing problem-solving strategies, we've found it is worth the trade-off by eliminating unnecessary complexity, course costs, and student confusion. We find this approach ensures a high probability of student success and results in a more rewarding research experience. By having students work in research groups of two to three students, it allows us to increase overall contact hours for research and promotes collaborative learning.

Commonly reported difficulties in performing undergraduate research (inside or outside the classroom) are miscommunication of expectations and lack of clearly defined outcomes (Krueger, Noyd, and King 2005). In this regard, we are in familiar territory with other colleges reporting similar problems over the past three decades (Thorton 1972; Herreid 1998; Switzer and Shriner 2000; Felzien and Cooper 2005). To overcome this, we've developed well-defined guidelines and explanations of our tactic to students early in the semester. To support student inquiry and creativity in problem solving, we explain the research projects are not "cookbook" laboratories, but activities in

which students must take greater responsibility for learning. In addition, we work hard to provide the necessary training and remediation within the first few weeks. Finally, we spend time in class discussing problems they may encounter, such as experimental failure or fixating on flawed strategies. We find that being upfront with our expectations eases most students' minds about how the semester will proceed and the importance of research toward student success in the course. However, despite our best efforts, many students remain confused and apprehensive about incorporating discovery-based learning into course content and its impact on their earned grade.

A common complaint made by our students is that they feel that time-intensive research projects are added to courses as requirements with little grade impact. To address this concern, we take care to schedule adequate classroom time for research efforts at the expense of actual course lectures, or other graded projects. It's critically important to us that students feel they have time to accomplish their project and see the projects as achievable within the semester. To aid them, researchers work with each group to produce a project timeline. This helps keep the groups on-task and may also appeal to their military spirit for having clearly defined objectives. Within the syllabus, we stress the importance of the projects by assigning them a significant point value (30–40%) and by allocating up to eight periods for research. We also assure our students that grades are not based on successful research findings but on level of effort and application of the scientific process.

Cadet involved in hands-on research at the academy.

Assessment

At the department level, we closely track the number of students involved in research. In addition to our classroom-based research courses, our students have the opportunity to participate in faculty-mentored independent study or summer research internships at various government research labs. In the past two years, we've exposed 60–81% of our students to various research programs. Many take part in more than one program. For example, adding the investigative laboratory research program to our Molecular Methods class has increased research opportunities 20% in the last two years. Figure 1 shows enrollment in our independent study program (faculty-mentored research) over the previous three academic years. It illustrates not only the growth of this program, but also growth that may be attributed to prior participation in our investigative laboratories courses. Classroom exposure to research directly resulted in nearly a three-fold increase in independent research enrollment (Figure 1).

To assess student performance within our classroom-based programs, we use a series of standard end-of-semester assessments that include written, manuscript-style papers and short oral presentations suitable for undergraduate symposia. Rather than assigning grades based on achieving a specific outcome, we assess the students' ability

to organize data and clearly present their findings. Group members are evaluated on their overall contribution to the project and input from their faculty mentor.

In addition to classroom presentations, we expect our students to participate in opportunities to communicate their research findings at regional conferences. Typically, our students showcase their work at a number of undergraduate conferences such as the Beta Beta Beta National Biological Association, American Association for the Advancement of Science/Southwest and Rocky Mountain Region, Colorado-Wyoming Academy of Science, and the USAFA/University of Colorado at Colorado Springs Undergraduate Symposium. In the past year alone we achieved a 50% increase in the number of student presentations at these venues at a very minimal cost. Eight of 10 students in Field Ecology, and 6 of 10 in Molecular Methods gave presentations at these conferences last year.

Summary

Military service academies face unique challenges integrating research into the undergraduate curriculum. Like other institutions we've worked hard to implement strategies designed to overcome a range of barriers to student participation in research by creating opportunities in the classroom.

This method has resulted in success, as evidenced in both student feedback and participation in independent studies and summer research internships. Each year students tell us that participating in this program was a highlight of their education. In addition, each year students relate that they've changed their career goals or graduate school plans based on this program.

By creating classes that focus on research, program limitations related to workload allocation, low budget allotments, and strict time constraints can be minimized. It does require motivated faculty willing to contribute time/effort and students willing to undertake these challenges. In addition, faculty must be willing to develop a course that sacrifices time allotted to classroom content teaching and transfers it to projects promoting student-based inquiry. Associating class-based research projects with ongoing faculty investigations and developing clearly defined projects that can be completed are critical to success. ■

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