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ABSTRACT

At most research universities, a major divide separates the world of the undergraduate student and the world of research. The standard model of undergraduate research is the apprenticeship model in which students are transported across this divide with little cognitive or practical preparation. Sinking or swimming, the student is then presented with a problem or project, shown the basics of how to solve the problem, and allowed to give it his/her best shot. This effort frequently takes place under the guidance of graduate students and/or research associates who themselves have little cognitive or practical preparation for this role. This research experience most often takes place late in the student's course of study and is usually pedagogically and epistemologically distinct from his/her course of study. Thus the degree of ownership in the work by the student varies widely, and interestingly, rarely does the experience lead to scholarship outside the home institution. Without questioning the intrinsic merits or approach of this model, it is nonetheless clear that universities and their faculty do not have the resources nor the will to make this experience a regular part of the academic life of a large majority of undergraduates. In this contribution we present an alternative model based on a case study of a team-based, student-directed research effort in the area of marine environmental science. From our research, we believe that team-based research by undergraduates holds the promise of meeting the educational, intellectual, and emotional needs of an increasingly diverse population of undergraduates and an ever-changing world/work place. Research-Based Learning (RBL) provides the structural strategy for linking this new undergraduate research model to both the classroom and the curriculum.

INTRODUCTION

Because of the nature of their mission (to create new knowledge), research universities have the potential to engage undergraduates in inquiry-based learning. The Boyer Commission (1997), however, concluded that "nevertheless, the research universities have too often failed, and continue to fail, their undergraduate populations." The "blueprint" report concluded with the challenge that "the research universities need to be able to give to their students a dimension of experience and capability they cannot get in any other setting" (Boyer Commission, 1997). Left unanswered were several questions: How can the challenge of providing meaningful and authentic research experience for undergraduates be achieved?

Almost in parallel with the Boyer Commission, the South Carolina Honors College, a liberal arts college imbedded within a research university, has developed a strategy to address the "How?" mentioned above: Research-Based Learning (RBL), an approach to undergraduate education that merges research activity, instruction, and the curricular offerings (Fig. 1) (Eddins et al., 1997; Eddins and Williams, 1997a,b). RBL encompasses a variety of initiatives to expand opportunities for undergraduate research, develop new curricula, reinvigorate existing curricula, and support innovation within the existing course structure. The RBL strategy brings together collaborative teams of students and faculty with shared interests, thus striving to elevate the level of student/faculty interactions in and out of the classroom and empowering students to participate actively in their learning and to develop lifelong learning and professional skills.

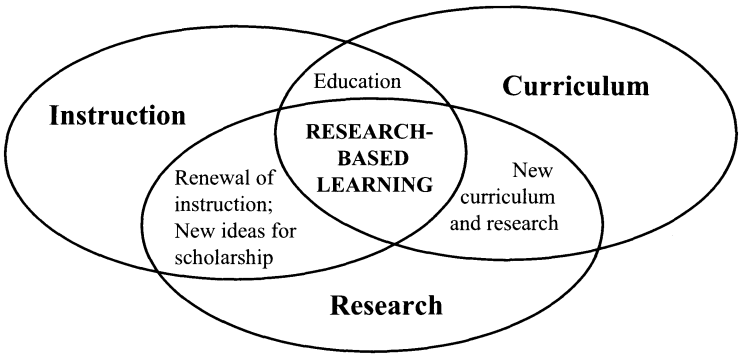

Figure 1.
RBL merges the university's most vital missions, research and instruction, with an educational structure, the curriculum. Ideally, new and exciting results appear at the interfaces between academic missions and structures whose fusion represents RBL (Eddins and Williams, 1997a)

HOW RBL FUNCTIONS

Besides the team approach, a unique element of RBL is a series of "critical connections" courses that help bridge the divide between the world of the classroom and that of research. In the natural sciences, we have developed the "Fundamentals of Scientific Inquiry," the "Design of Inquiry," and the "Implementation of Inquiry" which engage students as early as the freshman year in the process, ethics, social fabric, and psychology of the world of research and the creative process. These critical connections courses can then be linked to the usual independent study (399) and directed independent research (499) opportunities or be the launching pad for the formation of an assembly of self-selected students who choose to work together as a team. Of course the most crucial part of an RBL team is its focus, its research theme, and how the individual student-scientists engage themselves in working to solve the common research agenda. Ideally, faculty mentors guide the RBL activities but do not exert direction except when safety, legal, or potentially erroneous procedures are involved, especially in regard to data collection, interpretation, and preservation (archival). Faculty-scientists support the student-scientists through all of the following: (a) their presence at various activities, (b) advice, (mostly when asked for), (c) training, (d) funding for research activities and for scientific meetings, (e) negotiations with other faculty about time and expertise when needed for the students' research momentum, and (f) explanation of RBL as a model for team-based, undergraduate research.

A SPECIFIC OUTCOME OF RBL: MARE

The Marine and Aquatic Research Experience (MARE, *mare*, Latin for *sea*) is a model developed in cooperation with the Marine Science Program at the University of South Carolina for hands-on, team-based, science research and education for undergraduates by undergraduates. RBL is the philosophical underpinning of MARE. The overall goal of MARE is to enhance the learning opportunities for students aspiring to become scientists, for students to practice being scientists from conception, to planning, to execution of scientific tasks. MARE was originally conceived by undergraduates while taking two critical connections courses: "Design of Inquiry" and "Implementation of Inquiry." The student-scientists wanted MARE to be an opportunity to study the physical and chemical dynamics of a major estuary with potential impacts from industry (pulp and steel mills), agriculture (various cash crops), and development (residential, commercial, and recreational, especially golf courses and marinas). This adopted estuary (Winyah Bay) is part of one of the largest watersheds on the eastern seaboard. The idea of students' adopting such a major estuary, connected to such a complicated watershed, was both ambitious and naïve. For one reason, a complete understanding of this system is still beyond the reach of any individual student or even assemblage of student-scientists within the span of their time in college. And yet, after three years of effort, two generations of MARE leaders and over a dozen major expeditions, some involving up to 25 students and several observational platforms (boats and planes), MARE is thriving, not despite these challenges, but because of them.

MARE student-scientists have published nearly 20 abstracts, accompanied with poster and oral presentations at national and regional scientific meetings (for example, MARE, 2001). From this exercise at scholarship, including several senior theses, the current MARE members are moving to the next level of professionalism by writing manuscripts for publication and proposals for funding and launching an on-line, student-managed and reviewed, journal for the publication of undergraduate research in the marine sciences (*MarSci*) (Pickard et al., 2001).

MARE is different in other fundamental aspects from most undergraduate research experiences (MARE, 2001). MARE was not established as part of any professor's regular research program, but instead student-scientists recruited faculty participation from both inside and outside their home institution. MARE was not established to fulfill a degree program requirement but to bridge the gap between an academic curriculum in marine science and the practical world of practicing marine scientists. MARE is therefore connected to, and yet separate from, the students' normal course work. MARE is the students' own enrichment program, totally democratic and non-hierarchical. It is not a social club or scientific society with dues- paying members. It is a student-initiated, student-directed, student-managed research endeavor (Heincelman et al., this issue).

CONCLUDING REMARKS

Based on our five years of research developing Research-Based Learning and using MARE as an experimental RBL model in the natural sciences, we choose to end with remarks on four important considerations that space does not allow us to fully develop in this contribution: (a) the features that distinguish RBL from problem- and inquiry-based learning, (b) the potential for extending the MARE model into a laboratory-based scientific theme and into the social sciences and the humanities, (c) the biggest challenges to the adoption of RBL in research universities, and (d) the revolutionary nature of the MARE model.

First, RBL differs fundamentally and practically from problem- and inquiry-based learning by assuming their respective goals and premises while striving for scholarship, for authentic communications of the results of learning and discovery. RBL's focus is on the production of new knowledge and scholarship that does not lie dormant in term reports and even excellent but unpublished senior theses or capstone reports. The professional dissemination of the new knowledge gained from RBL activities ideally takes place outside the originating institution in order to present student-researchers with opportunities to learn networking and relational skills. For example, student-scientists of MARE have published nearly 20 abstracts and given related presentations at seven different regional and national conferences. RBL also provides opportunities for leadership--organizational and managerial development--as part of the learning process, intrinsic features not expressly sought in PBL or IBL experiences.

Second, the prospects are hopeful and encouraging for extending the MARE model into laboratory-based scientific themes and into the social sciences and the humanities. Although preliminary, the prognosis for the former is based on a fledgling initiative by pre-medical students to form a research team interested in problems in the neurosciences. For the latter goal, extending RBL from the natural into the social sciences and the humanities, we are encouraged by discussions with faculty interested in developing critical connections courses in the fundamentals of social inquiry and cultural inquiry as part of an 18-credit "minor of inquiry."

Third, in our five-year quest, the biggest challenges to realizing RBL in research universities is the entrenched reward structure and the culture of the faculty that is inherited from and perpetuated by that structure. Of course the internal university reward structure is reinforced by funding agencies that place premiums on productivity (numbers of publications and total grant dollars) over the impact of the sponsored research on the university's principal stakeholders, undergraduates. We believe that the MARE model presents evidence of the fact that, while principally structured for the benefit of students, the RBL model is really of mutual benefit to faculty and students alike. Ideally, an RBL research team

would include collaborating faculty, graduate students as pre-service faculty in training, **and** undergraduates (Eddins and Williams, in preparation).

Lastly, as exemplified by the MARE model, undergraduate research that is student-initiated and directed, with collaborative facilitation, not control, by faculty, may be nothing short of revolutionary. In fact, while there is ample room and need for both models, the RBL-MARE model is in reality diametrically opposite to that of the apprenticeship model in philosophy and operation. Furthermore, the conduct of research by students in the MARE model is very much like the ideal put forth for education (learning) by the noted writer-educator bell hooks in *Teaching to Trangress: Education as the Practice of Freedom.* The MARE student-scientists, driven by internal desires, dreams, and aspirations, are practicing freedom. They have willingly taken on the responsibility for the freedom to make decisions with regard to the conduct of their research, suffering the consequences of mistakes or benefiting from successes as their research unfolds and evolves. Their relationship with their research is intimate and personal as they learn in the process and as their knowledge and awareness grows about their science, themselves, and their profession. Another huge difference between the team-based model and the better-known apprenticeship model is the solitary nature of the latter experience. Students in the apprenticeship experience are rarely afforded the opportunity to practice and hone teamwork skills so necessary for the rapidly changing technological and scientific worlds.

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