Using Student-Centered Investigative Modules to Teach a Multi-Disciplinary Scientific Methods Laboratory Course to Undergraduate Non-Science Major Students

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Dr. Usis is an associate professor in the Department of Biological Sciences. He has been teaching at Youngstown State University since 1986. He has been instrumental in developing and designing science laboratory experiences. His excellence in teaching has been recognized at YSU since the first class of Master Teachers was designated by the Dean of the College of Arts & Sciences in 1994. The curriculum developed by John integrates an inquiry investigative approach that students use to explore the life cycle of yeasts and the scientific method. He has combined his research interests with classroom instruction and developed modules that teach the scientific method by presenting problems in the fermentation process. He is the Institutional Representative to the Ohio Plant Biotechnology Consortium and an active member of the Ohio Biological Survey.

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The recently adopted Youngstown State University "new" GER (General Education Requirements) model established several out-come based goals for the Natural Sciences. Shown in Table 1 are the specific goals 13, 7, and 6 that directly affected course design in the Departments of Biological Sciences, Chemistry, Physics & Astronomy, Geology, Physical

Geography, and Center for Environmental Studies. The mandate that "one course must have a laboratory component" required the departments to evaluate their facilities and staff.

Table 1. General Education Requirements (Goals) in the Natural Science Domain approved by the YSU Academic Senate, March 4, 1998, for adoption in the Fall 2000.

Minimum of 2, no more than 3, courses that address goal 13:
13. Understand and appreciate the natural environmental and the processes that shape it.

And in addition, goal 6 or 7.
6. Understand the scientific method; forming and testing hypotheses as well as evaluating results.
7. Realize the evolving interrelationships among science, technology, and society.

One course must have a laboratory component.

Under the "old" GER requirements no laboratory experience was required or had been designed for the non-science major except in several health-related programs. Thus, the addition of a science laboratory experience for the general student required a shifting of resources within the University. It was felt that a shared, coordinated approach that combined resources would be more efficient; rather than having each department independently developing its own GER laboratory course. Faculty limitations and facility restrictions (Table 2) presented the greatest difficulties to be overcome. Only the Departments of Biological Sciences and Chemistry have facilities able to accommodate the scheduling of concurrent sections. With an anticipated enrollment expected to exceed 600 students per semester and the need to have laboratory sizes manageable (maximum 25 students) dictated that as many as 25 sections needed to be offered and equitability distributed among the six departments and programs.

Table 2. Full Service Faculty and Laboratory Facilities available within the Natural Science Departments for instructing non-science undergraduates.

Department	**Faculty**	**Laboratory Rooms**
Biological Sciences	14	2
Chemistry	15	2
Geology	5	1
Physics & Astronomy	8	1
Physical Geography	1	1
Environmental Studies	1	0

To assist in the development, design, and preparation for this new course, science faculties submitted and were awarded an NSF Grant-Institutional Change (DUE 9850079) for a three-year period beginning Aug. 15, 1998. Funding from this grant resulted in the construction of a multi-disciplinary laboratory course specifically designed to promote the "new" GER goals.

Course description was development and submitted to the appropriate curriculum committees and review bodies of the University by late Fall 1998. In the process of this course's development, faculty further desired that students directly participate in the scientific process by investigations of natural phenomena and experience hypothesis formation and testing first hand. To maximize a student's exposure to the varied disciplines within the sciences, it was proposed and adopted that each discipline develop a set of five-week modules that would encourage students to ask questions, to pose hypotheses, and to make predictions about demonstrations or initial guided exercises that presented potential questions. Students would be required to test their hypotheses and synthesize new results that would allow them to draw conclusion about the observed phenomena. Over the semester, students would be exposed to three different disciplines. They would not move from one five-week module to the next in a pre-arranged order. Individual instructors teach their modules three times in a semester, instructing 25 students each time, for a total of 75 students per section. This approach not only maximizes student exposure; it also maximizes resource utilization. The final approved course description that appeared in the YSU Undergraduate Bulletin for Fall 2000 is shown in Table 3.

Table 3.	Undergraduate Bulletin course description for the science laboratory course designed to meet general education requirement and be taken by non-science majors.
Catalog Number:	A&S 2600 *Explorations in the Sciences*
Description:	Student investigations in the natural sciences using a variety of laboratory approaches focused on a single theme or concept; multidisciplinary study from three of the following science areas (biology, chemistry, physical geography, geology, physics, astronomy, environmental science) segmented into three five-week units (6 hrs/wk). This course is applicable to the University science laboratory requirement.

To ensure a diversity of modular couplings and an exposure to three different disciplines, a module matrix (Table 4) was developed. Faculty constraints limit the ability of several departments to offer more than one section per semester. As a consequence of both facilities and staffing, Biology and Chemistry appear coupled in most sections. However, no discipline teaches two modules to the same set of students. From the module matrix was developed the scheduling matrix (Table 5) used to designate class meeting times and dates. Two concurrent sections were scheduled at peak demand times, MWF 0800-0950 and MWF 1000-1150. In both cases Biology and Chemistry are the only departments with available laboratory space.

Table 4. Module Scheduling Matrix for A&S 2600 Explorations in the Sciences

First 5 Weeks	Second 5 Weeks	Third 5 Weeks
Biology Chemistry Geology	Biology Chemistry Geography	Biology Chemistry Environmental Science
Biology Chemistry Geology	Biology Chemistry Physics	Biology Chemistry Geology
Biology Geology Physics	Biology Chemistry Physics	Biology Chemistry Geology

The Scheduling Matrix represents the arrangement of the 27 modules to be offered in 9 sections for the Fall 2000. The Dean of Arts and Science and Registrars Office used this matrix to assign course codes to designate time, classroom, building, and instructor. These course offerings appear in Fall 2000 Schedule of Classes.

Table 5. Scheduling Matrix for A&S 2600 Explorations in the Sciences

Time and Days		Sect. No	B	C	Gl	Gr	P	E
0800-0950	MWF	1,2	2	2	1	1	0	0
0800-1050	T Th	3	1	1	0	0	0	1
1000-1150	MWF	4,5	2	2	1	0	1	0
1100-1350	T Th	6	1	1	1	0	0	0
1200-1350	MWF	7	1	0	1	0	1	0
6:00-7:50pm	MTTh	8	1	1	0	0	1	0
6:00-8:50pm	MW	9	1	1	1	0	0	0

(B) Biol. = 9; (C) Chem. = 9; (Gl) Geol. = 5; (Gr) Geog. = 1; (P) Phys. = 3; (E) Env. St = 1

A departmental version (Table 6) of the Scheduling matrix is used to assist in assignment of teaching positions by the chair and to coordinate the individual instructors between modules and between disciplines. Communication and coordination between module instructors within an individual section is essential. Each student receives three individual grades for their performance within each discipline's module. The establishment of a common set of goals and objects were already in place since this course was specifically designed to fulfill the science General Education requirement.

Table 6. Department of Biological Sciences, Scheduling Matrix for A&S2600 for Fall 2000

Sect. No.	Days	Time	Bldg	Rm	Faculty	With
0225	MWF	0800-0950	14	4060	Colapietro	C & Gl
0228	MWF	0800-0950	14	3030	Snyder	C & Gr
0231	T Th	0800-1050	14	4060	Usis	C & E
0234	MWF	1000-1150	14	4060	Usis	C & Gl
0237	MWF	1000-1150	14	3030	Zolla	C & P
0240	T Th	1100-1350	14	4060	Dripps	C & Gl
0243	MWF	1200-1350	14	4060	Kahn	Gl & P
0246	MTTh	6:00-7:50pm	14	4060	Lorimer	C & P
0249	MW	6:00-8:50pm	14	3030	Kassawat	C & Gl

The three faculty of each section collectively develop their individual expectations and grading system, and establish some joint evaluation mechanisms for determining the student's final grade in the laboratory course. Each module has, thus far, been equally weighted in the determination of an individual's final grade. The pilot sections that have been conducted have utilized a variety of evaluation tools. Laboratory reports, journals, notebooks, homework assignments, short answer tests have all been used to measure progress and success in student achievement of the GER goals.

A total of five pilot sections have been offered, one in the Spring 1999, one in the Fall 1999, one in the Winter 2000 and two during the Spring 2000. While the University at this time was still operating under a quarter rather than a semester academic calendar, the ten week interval per quarter allowed the pairing of two modules to test the movement of students from one discipline and laboratory setting to another. Module couplings have been conducted between Biology/Environmental Studies (S99), Biology/Chemistry (F99), Geology/Geography (W00), Biology/Chemistry (S00) and Geology/Physics (S00). Biology, Chemistry and Geology have developed and had the opportunity to test two different sets of modules. Faculty who taught these modules developed their own investigative exercises during the summer and were supported by the National Science Foundation (DUE 9850079).

Assessment of the success of the pilot courses has been measured using entry and exit surveys. Students on the first day of class are asked to describe in writing the scientific method; again on the last day students are asked to describe the scientific method. Their answers have

not been used in determining their final grade in the course. Results of the pre/post improvement in understanding science are shown in Table 7.

Table 7. Improvements in Understanding the Scientific Method by General Education non-science undergraduate students for pilots sections of A&S 2600 conducted in the quarters of S99, F99, W00, and S00.

Entry surveys:
- 20% entering students unable to offer any description of the scientific method; additional 15% provide completely incorrect descriptions.
- Majority of student descriptions follows no logical sequence or order. 60% and 50% use the terms hypothesis or experiment somewhere in their descriptions.
- 18% entering students provide descriptions that adequately describes scientific method. (Of this group; 80% were junior/seniors, 20% freshman.)

Exit surveys:
- 4% provide incorrect descriptions
- 20% provided correct but incomplete descriptions (i.e., missing steps) 89% utilize terms hypothesis and experiment
- 54% students provide correct descriptions of the scientific method.