

## Learner-Centered Education Grants

# 2004 Final Report

**1. Project Name and Project Director's Name. Include mailing address, phone and e-mail address.**

Project Name: Discovering Genetics: A learner-centered undergraduate laboratory course

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**2. Brief Description of Project:** *Discovering Genetics* is a laboratory course that integrates faculty research into the undergraduate curriculum. The single-celled organism, *Chlamydomonas monoica* is used as a model for introducing students to original research and discovery. Students use ultraviolet radiation to induce mutations and then screen the survivors for evidence of defects in sexual reproduction. Successful completion of the sexual life cycle of this alga requires the expression of more than one hundred different genes, any one of which may have been damaged by the radiation treatment. Once the mutants have been obtained, the students work to define the phenotypes of their mutants more precisely.

Although we use *Chlamydomonas*, our approach is applicable to many different experimental organisms, scientific disciplines, and technological approaches. The key ingredients for success are (a) instruction by research-active faculty whose years of experience can guide the students, (b) choice of an open-ended research problem where not even the instructor knows the precise outcomes in advance, and (c) willingness of the instructor to act as the students' assistant and research mentor outside of lab time.

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### 3. Goals, Outcomes and Assessments

- a. Goals and Primary Accomplishments: The major goals of the project were to
- Offer *Discovering Genetics* for undergraduate enrollment in Spring 2004, modified on the basis of outcomes of our 2002 pilot course;
  - Develop of a pre-test/post-test for evaluation of student progress
  - Develop rubrics for evaluating student performance
  - Produce a formal laboratory manual
  - Construct a website to complement the course
  - Present the project at a national meeting of practicing scientists
  - Submit a manuscript describing the project to an appropriate education journal
  - Offer an on-campus 1 day workshop to encourage the development of similar discovery-based laboratory courses in other disciplines

With regard to these goals, the primary accomplishments were the successful offerings of *Discovering Genetics* (BIO 343 at Northern Arizona University) in Spring 2004 (12 students) and again in Spring 2005 (10 students). Student response to the course was overwhelmingly positive. The formal laboratory manual was completed in Fall 2005 (a hard copy will be mailed under separate cover). The next offering of the course is scheduled for Fall 2006 and should be greatly enhanced by the completion of the lab manual. A descriptive website that will be used primarily as a means of recruiting students to the course has been designed and will be uploaded to the internet in early January 2006. The general theme of the course and the specific activities of the Spring 2005 class were presented on the NAU campus at the first annual College of Engineering and Natural Sciences Celebration of Undergraduate Research Day in April 2005. Two students were available to answer questions from visitors and evaluators [The poster won a \$50 prize!]. I offered a similar presentation of the course for the education division of the American Society of Plant Biologists' annual meeting in Seattle, WA in July 2005.

b. Outcomes and Assessment for each Goal:

Goal: *Offering Discovering Genetics for undergraduate enrollment in Spring 2004 and Spring 2005 modified on the basis of outcomes of our 2002 pilot course.* In Spring 2005 I made major revisions to the course (see previous progress report). By changing the nature of the types of mutants that were sought by the students, I was able to increase the opportunities for collaboration among students in the class. Although each research team obtained unique mutants, there were obvious similarities between the mutants; this helped to increase the students' interest in what others in the class were accomplishing. Students were also able to perform crosses between their mutants and those obtained by their colleagues and show, genetically, that different genes had been disrupted. The change in approach requires very efficient use of time throughout the semester, but the success of the Spring 2005 class (nearly two dozen unique mutants were obtained, and each student team was successful) confirmed the feasibility of the new approach. It was only at that point that the formal laboratory manual could be developed.

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Goal: *Development of a pre-test/post-test for evaluation of student progress.* A pretest had been developed for the earlier version of the course. With the revision described above, a new pre-test will need to be developed. We will do that before the Fall 2006 offering. However, because of the very open-ended nature of many of the activities, pre-test/post-test assessment may not be especially relevant. However, the course also includes a few pre-designed experiments to demonstrate central genetic concepts, and the pre-test could focus on those aspects of the course.

Goal: *Development of rubrics for evaluating student performance/learning.* Rubrics have been developed for each of the graded assignments and for the major research article that each student team prepares at the completion of the course. The rubrics are included in the laboratory manual and so will now be available to students at the beginning of the course. The rubrics have had two important positive effects: (a) evaluation of student learning is less subjective and standards upon which assignments are judged are uniform and known in advance; (b) with these well-defined guidelines available, the quality of student work has improved.

Goal: *Production of a formal laboratory manual.* Production of the laboratory manual has been the most labor-intensive of all the goals and the most central to the success of the course. Significant changes were made in the general scientific backbone of the course prior to the most recent offering in Spring 2005. As a consequence, completion of the manual was not possible until the relative success of the two alternative approaches was known. Although it is likely that further minor revisions will be made over the next 6-12 months, the laboratory manual is now in a very useable form. I expect to provide both spiral-bound hard copies and a CD for each student in Fall 2006.

Goal: *Construction of a website to complement the course.* Design of the website has occurred over the past few months. This site will be used primarily as a recruiting tool for students looking for an elective undergraduate laboratory course. Dr. Stephen Warburton, our departmental web-master, has helped me become comfortable with the Dreamweaver software used for site design. He will also help me "upload" the site in early January 2006. One page, "Additional Resources" remains under construction. This will include links to other useful websites, and a reference list. The "Additional Resources" page will be of use to students enrolled in the course. I also hope to add an additional page that provides highlights and images from previous offerings of the course. In the years ahead I will seek input from students as to any additional information they might like to see included in the website.

Goal: *Presentation of the project at a national meeting of practicing scientists,* *Discovering Genetics* was presented in the form of a poster at the annual meeting of the American Society of Plant Biologists in Seattle, WA (July 2005). A particular interest in the course was expressed by *Chlamydomonas* researchers from the University of Minnesota. In May 2006, the international *Chlamydomonas* research community will meet in Portland, Oregon. This will give me another excellent opportunity to discuss the general theme of incorporating faculty research into an undergraduate laboratory experience focused on original discovery.

Goal: *Submission of a manuscript describing the project.* In fall 2005, I offered to prepare an article describing the course for an upcoming issue of the CUR Quarterly (journal of the Council for Undergraduate Research). The issue is to be focused on the integration of faculty research into the undergraduate curriculum. The editors received 45 offers for articles, with space for only 5. Unfortunately, mine was not one of the chosen few. As described earlier, I am most interested in describing an approach that could be illustrated by several

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very different laboratory sections, each directed by faculty with diverse research interests. Thus, publication will be delayed until I find others willing to develop alternative discovery-based laboratory courses.

Goal: *Offering an on-campus 1 day workshop to encourage the development of similar discovery-based laboratory courses in other disciplines.* This goal has yet to be accomplished for reasons described in the subsequent sections.

**Problems or Issues Encountered:** The primary problems associated with the project have been the lack of release time for initial course development, and the very large input of effort required of the faculty member outside of class time (in a sense, serving as the students' technician). Unless the faculty member is able to acquire specific grant funding for course/curriculum development (such as the LCE award), this type of course offering may require some influx of funds from the faculty member's basic research grant(s). However, a small contribution from a principal investigator's research grant funds to stimulate undergraduate interest in basic research is not likely to be in conflict with the priorities of most funding agencies. Furthermore, because of the close association with specific faculty research expertise, and the enthusiastic response of the students, the extra hours of effort really can become a labor of love. The difficult part is convincing my colleagues to make the extra effort the *first* time.

I have not yet attempted to publish the general concept that underlies this course. The use of mutant searches in undergraduate genetics laboratory courses is not novel. What is novel is the use of a particular faculty members' own research area/expertise to direct the students efforts. Ideally the course would include several alternative sections, taught by different geneticists, each with its own unique theme. In my department, there is at least the potential to have two other sections of the course, one using the fruit fly, *Drosophila* and another using the yeast, *Saccharomyces* as the model systems. Sections could also differ in terms of the technical approaches used, e.g. classical genetics versus molecular genetics. Ultimately, I would like to see any publication of this concept illustrated with concrete, tested examples of how *different types of basic genetics research* can be adapted to a traditional once-a-week undergraduate laboratory format. Even more rewarding would be the inclusion of discovery-based "laboratory" courses in other disciplines—ideally *any* area of scholarly research might be used as the theme for learner-centered discovery.

- 4. Conclusions, Recommendations and Future Directions.** Development and implementation of the *Discovering Genetics* undergraduate laboratory course has provided students with the opportunity to conduct original research within the constraints of their very busy schedules. Based on student response to the course, I feel that the primary objectives have been achieved. However, I have found that the amount of preparatory work needed each week is still substantial and remains problematic in terms of convincing others to follow my lead. In my case, the co-assignment of a large lecture course in genetics that enrolls 80-100 students each semester and is also labor-intensive saps my energy. With an impending change in departmental leadership, I have arranged for a change in my teaching assignments for the next academic year. *Discovering Genetics* will now be offered in the Fall semester when I do not have the large lecture course to contend with simultaneously.

I will continue my efforts to convince others to offer similar courses, however I will focus on a more individualized effort directed toward those whom I perceive as most likely to be responsive. The availability of LCE funds for this project has been essential. Summer salary for course development may be sufficient incentive to encourage faculty to increase

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their workload in a subsequent semester. However the majority of my colleagues are already overburdened. Departments need to carefully consider priorities and find creative ways to provide incentives and opportunities for innovative curricular reform.

My colleagues at other institutions have commented that most curricular reform programs focus on projects that impact very large numbers of students. The LCE award has been unique in allowing me to provide an important educational opportunity to a small group of students. A larger award that supported development of five or six such laboratory sections, each with a unique research emphasis, would be one way to impact more students while still retaining the small, intimate learning environment that *Discovering Genetics* has provided.

**6. Has this project led to sustainable change in your department/college? Yes. Describe:**

The course *Discovering Genetics* and been offered three times since 2002; I am scheduled to continue to offer this course once each academic year for the foreseeable future. I will continue my efforts to encourage fellow geneticists in my department to offer their own sections of BIO 343, based on their own areas of research expertise. However, I am not likely to be successful until the department/institution can offer some incentive/reward for what is presently a voluntary but significant increase in workload.

**7. Impact:**

a. Have other faculty been affected by this project?  Yes  No. If so, describe:

b. Number of courses affected/involved. One

c. Number of students affected. 35 (10-14 for each of three semesters)

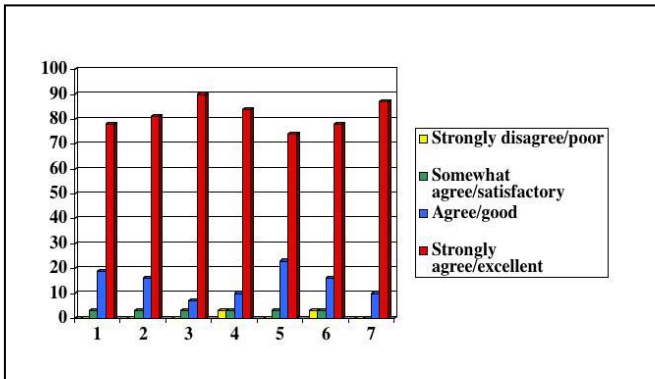
**8. Significant Outcome:**

What was the most significant outcome based on learner-centered principles that occurred through your project?

The most significant outcome from the offering of *Discovering Genetics* has been the positive response of the students.

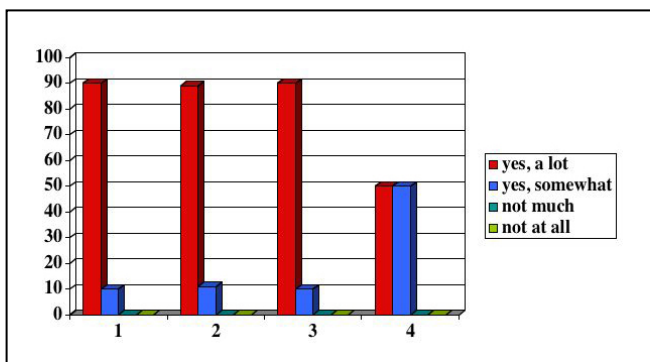
The graphs on the following page summarize student evaluations of *Discovering Genetics* for the first three offerings of the course (Spring Semesters 2002, 2004, and 2005). The first graph shows the responses to the university-wide questions that are used for all course evaluations at Northern Arizona University. The second graph shows the response to additional questions generated by the instructor that were specific to *Discovering Genetics*.

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Questions:

1. Objectives were made clear
2. Objectives were accomplished
3. Instructor genuinely concerned with student progress
4. My interest in subject was stimulated
5. The course was intellectually challenging
6. My general estimate of this course
7. My general estimate of this instructor



Questions:

1. The lab increased my understanding of basic genetics principles
2. The lab reinforced concepts presented in lecture
3. The lab seemed more like "real science" than most typical lab courses I've taken
4. The lab increased my confidence in my ability to think critically and reach my own conclusions