Learner-Centered Education Program
Arizona Board of Regents
INSTITUTIONAL SUPPORT FORM

Proposal Title: *Discovering Genetics*: A learner-centered undergraduate laboratory course

Institution: Northern Arizona University Dept/Unit Biological Sciences

Multi-Campus/University Projects
(check other campuses or universities participating)

___ ASU Main ___ UA
___ ASU East ___ UA South
___ ASU West ___ NAU

List other participating agencies:

Briefly describe the program and the development plan.

Modify, implement, and institutionalize a discovery-based undergraduate laboratory course in genetics. Students design, conduct, and report (written and oral) original genetic research using a simple microorganism. Funds are requested for production of a formal laboratory manual and associated website, and for development of tools for assessing student performance as well as the achievement of broader course objectives. The project will be disseminated to a national audience of practicing scientists, and will be published in a peer-reviewed educational journal. An on-campus workshop will be offered to introduce the project to diverse faculty and to discuss ways in which comparable learner-centered discovery-based laboratory courses could be developed in a variety of disciplines. The central theme is to use the scholarly/research expertise of faculty to engage students in original research/discovery in a teaching classroom/laboratory setting.

Funding Category

Indicate a primary (P) and, if applicable, secondary (S) funding category:

Professional Development _____ Program or Course Development/Modification __X____
LCE Research _____ Improved Assessment of Learning Outcomes _____

Authorizations

Project Director

Signature _____

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Signature _____

Official Authorized to Enter into Contractual Obligations

Signature _____

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Abstract
Discovering Genetics is a learner-centered laboratory course being piloted in the Department of Biological Sciences at Northern Arizona University. The course includes not only instructor-designed laboratory exercises to reinforce the central principles of genetics, but also student-designed, open-ended experimental work. The course addresses the need for students to feel more personally engaged and empowered in their learning. In addition, the students' involvement in true scientific discovery provides a more accurate picture of the way science is actually done, and allows students to experience directly the intellectual and personal rewards inherent in discovery. *Discovering Genetics* provides an avenue for testing the hypothesis that student involvement in original research leads to improved understanding of scientific principles and enhances the critical thinking skills of participants in ways that may extend across disciplines. This proposal seeks funding to further develop *Discovering Genetics* on the basis of feedback from a feasibility study conducted in Spring 2002 and a seconding piloting of the course scheduled for Spring 2004. Proposed activities include the production of a formal laboratory manual and website to accompany the course, implementation of course revisions based on performance measures and student evaluations, presentation of the project at the 2004 meeting of the American Society of Plant Biologists and/or National Council on Undergraduate Research and in a manuscript to be submitted to the Journal of College Science Teaching. We will also offer a one-day, on-campus workshop to facilitate the development of comparable learner-centered, discovery-based laboratory courses in other disciplines.

Identifying the Need
In 1997 Dr. Darrel English retired from the Department of Biological Sciences at Northern Arizona University. For many years, Dr. English had taught an elective laboratory course to complement the lecture course in genetics. Since Dr. English's retirement, we have lacked the resources (financial and personnel) to provide a genetics laboratory course. The loss of such a course limits the choices for our undergraduate majors who are required to take two advanced laboratory courses prior to graduation.

This proposal requests funding to support the further development and institutionalization of an elective undergraduate laboratory course (*Discovering Genetics*) focused on genetics, the science of inheritance. The new course differs significantly from most laboratory courses on campus in the following ways:

- The course includes not only instructor-designed exercises to reinforce the central concepts of genetics, but also student-designed, open-ended experimental work where techniques learned in structured exercises are applied to questions posed by the students themselves.

- The course, taught by a research-active scientist, takes advantage of the specific experience and expertise of the professor and adapts National Science Foundation-sponsored research to an undergraduate laboratory setting.

- Because the primary objective of the course is to guide the students in original research of their own design, the most appropriate means for evaluating student progress is the same as for practicing scientists: critical review (including peer review) of research papers and oral presentations authored/delivered by the students.

The development of this course addresses not only the programmatic needs of our department, but also several additional issues that are of growing concern:

- Many of our core courses now have 100 -200 students enrolled. Although in courses with mandatory laboratory components, the students have a chance to work in smaller groups under the supervision of a graduate student, we need to increase opportunities for small group experiences and close collaboration between research-active faculty and students.

- High enrollments in courses with required laboratory components necessitate multiple laboratory sections and the training of many graduate students (e.g., we offer 18 sections of the laboratory component associated with our first semester introductory biology course). It is often difficult to identify the needed pool of qualified graduate teaching assistants.

- With large enrollments and multiple laboratory sections, preparation of materials for each exercise becomes the equivalent of a factory production line. Lab exercises, despite the best intentions of those developing and writing them, become "cook book" in their approach and do not necessarily reflect how science is actually done.

- A significant number of the students enrolled in large classes with required laboratory sections are under-prepared or, worse yet, uninterested. This invariably lessens the quality of the experience for the other students, as it draws the attention and energy of the teaching assistant away from them and toward those students who are not self-motivated, and who are potentially disruptive. This is one of the strongest arguments in favor of *elective* laboratory courses.

- Throughout our culture and times, there is an increasing emphasis on (bio)technology. While the learning of techniques is critical to the training of modern biologists, there is an unfortunate trend toward introducing as many techniques as possible into a single laboratory course, as if the techniques themselves were the essence of science.

- The essence of science is *discovery*. Although many good laboratory courses attempt to include some sort of discovery, or "unknown", this usually involves the student discovering what the teacher already knows. That is not how science works. At the same time, truly open-ended laboratory work, where each student is free to attempt to discover whatever has aroused his or her curiosity is not feasible in courses with large student enrollments.

- There is an increasing emphasis on developing effective pedagogy for large classes, and for under-prepared students. This is laudable and crucial. However, we also need to pay attention to the "average" student who does not appear at risk but may graduate from college with a solid C average—without ever realizing his/her true (A?) potential.

As a research-active faculty member in a department with a strong PhD- granting graduate program, I am delighted that undergraduate involvement in research is also encouraged and rewarded at NAU. Professional scientists and educators have an obligation to these younger students—an obligation to instill in them not only a respect for the power of science, but also recognition of its limitations. Students need to realize that questioning rather than answering is the essence of science. Scientists who remain practicing scientists throughout their careers do so because they are addicted to "the joy of discovery". We should not keep this joy a secret from our students.

Technical Needs

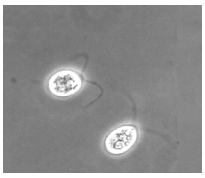
I am developing the laboratory materials using previously acquired computer hardware, software, and peripherals (Macintosh G4 computer, Nikon professional film and Canon print scanners, Canon PowerShot digital camera, Microsoft Word, Excel, Pagemaker, Powerpoint, Adobe Photoshop and Dreamweaver MX) purchased with former National Science Foundation grant funds and a supplemental Regents' Professor research stipend. The teaching laboratory is equipped for internet access for all students. I will be using a Macintosh G4 laptop computer and LCD projector (purchased with Howard Hughes Medical Institute grant funding) to assist students in finding relevant internet sites, and for accessing our library's on-line journal databases. I recently received on campus training in the use of Dreamweaver MX for website construction and will continue to seek the advice and expertise of our on-campus ITS staff, as well as Jeff Henrikson, a computer specialist in our department. The teaching laboratory has been fully equipped for the experimental work using prior National Science Foundation research funding as well as funds from a former Howard Hughes Medical Institute grant to NAU. However funds are requested for expendable/consumable supplies used by the students.

Work Plan

A genetics laboratory course (referred to hereafter as *Discovering Genetics*) was offered in Spring 2002 to test the feasibility of having undergraduates conduct meaningful original research in a single semester and in a classroom setting. This first offering of *Discovery Genetics* included 14 undergraduates ranging in

experience from second-semester freshmen to graduating seniors. At the completion of this pilot course, more than 90% of the students rated the course overall as "outstanding", or "very good". 83% of the students said that the course stimulated their interest in genetics.

Discovering Genetics was not offered in Spring 2003 because I was on sabbatical leave from NAU. However, based on the success of the original pilot course and the lessons we have learned from this first trial, I am now proposing to (a) offer a modified version of *Discovering Genetics* in Spring 2004, (b) institutionalize the course through the development of a laboratory manual and associated website, (c) disseminate the nature, goals and outcomes of the project at the national level, and (d) offer a summer workshop to encourage development of similar courses that take advantage of the unique research expertise of individual faculty. Before detailing our plans, a brief description of the course may be helpful to reviewers.



Chlamyd

Laboratory work in *Discovering Genetics* uses a single-celled microorganism, the green alga *Chlamydomonas*. *Chlamydomonas* is used extensively in research laboratories around the world (including my own) to address a wide variety of biological questions. Because it is a "modelsystem" there are many established professional websites highlighting *Chlamydomonas* research, as well as a massive literature database that students can access to enhance their laboratory experience.

Although part of the course involves instructor-designed experiments to illustrate basic principles of genetics, the most important and unique aspect of the course is the inclusion of student-designed, learner-centered projects. In model systems such as *Chlamydomonas*, where genetic approaches are possible, investigators often learn about a particular biological process by isolating mutants that are defective for that process. This may seem paradoxical, but figuring out exactly <u>why</u> a particular mutant cannot perform a specific function can provide great insight into how the process works in <u>normal</u> cells.

With this approach in mind, each *Discovering Genetics* research team (two students working together) decides upon a particular biological function of interest and a type of *Chlamydomonas* mutant that they could isolate that would be relevant to that function. Making this decision requires that they understand the basic biology of the organism as well as the types of questions that might be addressed by the isolation of a particular type of mutant. The student teams must (1) design experiments to create and select the mutants, (2) design and conduct experiments to further characterize the mutant once it is obtained, and (3) perform genetic crosses with their mutant to determine its pattern of inheritance.

Although the students work in pairs, we use class time to share ideas so that the insights of other students (as well as my own) can be incorporated into each project. It is critical that the students do not attempt mutant searches that I know are not feasible. I have worked with the organism for 30 years and know it well; I use that experience to guide their choices in ways that maximize the likelihood of success without necessarily forcing them to duplicate work that I (or others) have already done. In our first piloting of the course, the students obtained many new mutants that had not been previously described.

Our objectives, and the timetable (milestones) for our proposed work, are as follows:

- Offering *Discovering Genetics* for undergraduate enrollment in Spring 2004, modified on the basis of outcomes of our 2002 pilot course;
- Development of a pre-test/post-test for evaluation of student progress (January 2004);
- Development of rubrics for evaluating student performance in the following areas (January 2004)
  - Class participation
  - Preparedness for each week's activities
  - Maintenance of a laboratory notebook
  - Mastery of research techniques
  - Written presentation of research
  - Oral presentation of research
- Production of a formal laboratory manual (January – August 2004)
- Construction of a website to complement the course (August – December 2004)
- Presentation of the project at a national meeting of practicing scientists (American Society of Plant Biologists, July 2004)
- Submission of a manuscript (Journal of College Science Teaching) describing the project (June 2005)
- Offering an on-campus 1 day workshop to encourage the development of similar discovery-based laboratory courses in other disciplines (May or June 2005)

Graduate student Patricia Daniel, trained in my research laboratory, will act as my assistant. The laboratory exercises require preparation and testing of a wide variety of materials. The materials needed depend upon the students' experimental designs and thus cannot be predicted in advance. Although ideally we would like the students to do these preparations and preliminary tests themselves, this is not feasible within the weekly three-hour lab meeting. Thus, between class meetings, my assistant and I serve as technicians for the students as they design their experiments.

Based on our first piloting of *Discovering Genetics*, I now know which laboratory exercises worked well, and which did not; I know what types of mutant searches are the most successful; I know that I must spend more time helping students develop their writing skills; I know that I can spend less time (!) on helping students develop computer and presentation skills. Most importantly I know the students need an extensive laboratory manual that includes not only details of experimental procedures but also background information about *Chlamydomonas* written at their level. Patricia will devote approximately 10 hrs/wk (throughout the spring 2004 and 2005 semesters) to assisting me in preparing lab materials, helping students with their experimental work, and assisting me in the assessment of student learning/performance. She will devote an additional 10 hrs/wk to gathering materials for the laboratory manual, converting my oral instructions and outlines into text, creating and processing digital images for inclusion in the manual, and identifying appropriate resources and links for the *Discovering Genetics* website. We will also receive assistance in website construction from Jeff Henrikson who has been responsible for developing and maintaining websites for many of our biology faculty.

We will increase the variety of performance measures used to track student progress during the semester. We will develop and administer (on the first and last days of class) a pre-test/post-test that covers the most important concepts to be developed during the course and tests problem-solving and critical-thinking skills. The test will be given at both the first and last class meetings. Our goal is to see at least a 30% increase in post-test scores relative to pre-test scores. Prior to the first class meeting in January 2004 we will develop rubrics for evaluating student weekly preparedness (as was suggested by students completing our first pilot course), the quality and extent of student participation in class discussions, the quality of student generated research papers, the organization and completeness of laboratory notebooks, and the quality of oral presentations. These rubrics will be included in the course syllabus provided to students on the first day of class. We will develop a course/instructor evaluation form that is more specific to *Discovering Genetics* and is directed toward measuring the level of our success in reaching our objectives, as stated in the syllabus. The evaluation form will also ask students to evaluate the impact of the course on their perceived critically-thinking and technical skills, and on their perceptions of the nature of science.

For the Spring 2004 testing period we will ask students to maintain an anonymous journal describing their reaction to the each week's activities and assignments. We have found that students often forgot the early experiences of the semester when filling out evaluation forms on the last day of class. (In developing our freshman biology laboratory course several years ago, I found such journals to be one of the most useful evaluation tools for determining appropriate course revisions.) Finally, we will establish a data base on students completing the course that will allow us to maintain contact and track their progress in subsequent courses. We will query the students one year after completion of the course for their perception of any continuing impact on their academic progress and career decisions.

Key personnel

The key personnel for development of *Discovering Genetics* are (1) Karen VanWinkle-Swift, Regents' Professor, Department of Biological Sciences, NAU (Karen.VanWinkle-Swift@ nau.edu), (2) Patricia Daniel, graduate student, Department of Biological Sciences; pld@dana.ucc.nau.edu); and (3) Jeff Henrikson, Program Coordinator, Department of Biological Sciences, NAU (Jeff.Henrikson@nau.edu)

Expected Results and Outcomes

This project has a number of expected results and outcomes, which can also be viewed as goals or objectives: (a) Institutionalization of a discovery-based laboratory course in genetics; (b) Improved student academic performance and personal confidence that reflects student involvement in discovery; (c) improved student understanding of the process of scientific discovery; (d) Dissemination and scaling of the product within and beyond the parent department; and (e) Improved student retention.

Implementation of a discovery-based laboratory course and measuring its impact on student performance. The first milestone in this project was reached with the successful piloting of *Discovering Genetics*, January -May 2002. This effort verified that students were capable of conducting original research, and that the

available facilities were adequate for the work. We also determined that out-of class-time contributed by the instructor to facilitate student-designed experiments would be approximated 15-20 hrs./wk. Thus a graduate laboratory assistant would be essential. Our pilot course was focused on establishing feasibility. We are presently modifying the course content based on this experience and on student suggestions.

We hope to use *Discovering Genetics* to test the hypothesis that student involvement in original research and discovery leads to improved student understanding of scientific principles and enhances the critical thinking and problem solving skills of the participants. Performance measurements addressing these objectives will include comparing the performance of students enrolled in *Discovering Genetics* (BIO 343) on traditional multiple choice examinations and homework assignments in the accompanying lecture course (BIO 340) with that of students enrolled only in the traditional lecture course. We will also follow the academic performance (final grades and individual rankings in all courses) for students prior to and after their participation in *Discovering Genetics*.

Student critical thinking skills will also be demonstrated and assessed by student performance in the *Discovering Genetics* brainstorming sessions, the feasibility and completeness of their experimental designs, the outcomes of their experiments, and the written discussion and interpretation of their data as presented in their final research papers and oral presentations. As soon as the students have decided upon their individual projects, they will be asked to write a draft of the introduction to their final research paper. This should include relevant background about *Chlamydomonas*, why they have chosen to seek a particular type of mutant, and what they can learn from it. Additional writing assignments will follow as they proceed with their experimental work. I will edit and return the papers promptly so that so that they have feedback on most of the sections that are to comprise their final research paper. The quality of their final paper as compared to the earlier assignments will be a measure of their progress.

Dissemination and scaling of the product/concept within and beyond the parent department. The product to be developed is a formal laboratory manual and associated website. The concept, examples of student work, and sample pages of the laboratory manual will be presented at the annual meeting of the American Society of Plant Biologists in July 2004 and/or the national conference of the Council on Undergraduate Research in June 2004, where special sessions are devoted to educational projects. Our goal is to encourage practicing scientists to develop similar courses on their own campuses, bringing their own research expertise into the classroom. We will also organize and present (May 2005) a workshop for NAU faculty interested in developing similar courses in their areas of expertise.

It is important to recognize that while our laboratory manual could be adopted with little revision on any campus where a *Chlamydomona*s geneticist is on the faculty (including perhaps close to 100 campuses), the *concept* is even more broadly adaptable. ***Transferring the scholarly expertise of a faculty researcher to an undergraduate laboratory setting is feasible and desirable in many and perhaps all disciplines.*** Important outcomes are faculty promotion of student discovery, close faculty-student and student-student collaboration, and the establishment of a learner-centered educational environment. The close match between faculty expertise and course content will attract faculty to the task, and guarantee an enthusiastic, ideally qualified mentor. Such programs will also expand the audience exposed to federally funded research programs and help to blur, if not erase, the unfortunate distinction often made between teaching and research. Thus although each course may reach relatively few students, a variety of courses spanning disciplines could provide an exceptional learning environment for a large and diverse population of undergraduates. This is perhaps the most important objective of our proposed work.

Impact on student retention. Lack of a sense of strong personal involvement in course work, and lack of mentoring by faculty in the students' early years at the university, contribute to the withdrawal of students from university programs. Recent changes in requirements for the biology major at NAU should allow students to reach upper division courses, such as *Discovering Genetics*, more rapidly. The potential impact on retention is another compelling reason to encourage other research faculty to develop comparable discovery-based courses in their areas of expertise and to establish a close working relationship with a small group of students.

Budget Detail

1. Personnel:

Key:

K. VanWinkle-Swift: I am requesting $10,000 (1.5 months) of summer salary (June, July 2004) for (a) development of the laboratory manual, (b) construction of the website to accompany future offerings of *Discovering Genetics,* and (c) preparation of materials for presentation at the annual meeting of the American Society of Plant Biologists and/or other appropriate national venues in summer 2004.

Graduate:

Patricia Daniel: I am requesting a one semester graduate teaching assistantship to support Patricia's help in working with students during the laboratory sessions, helping students outside of class, assisting in preparation and testing of laboratory materials, and gathering written materials, references, and images for inclusion in the laboratory manual. The Department of Biological Sciences will provide half ($3,000) of the total sum ($6000) needed for this support.

Fringe Benefits:

Fringe benefits have been calculated as 16.65% of faculty summer salary, 1% of graduate student salary, and $625 for health insurance (1/2 time) for the graduate student.

3. Staff Travel: I am requesting $2,000 to support, in part, the travel of the Project Director and graduate assistant to the annual meeting of the national Council on Undergraduate Research in La Crosse, WI, June 2004 and/or the American Society of Plant Biologists in Orlando FL, July 2004. The latter society supports special sessions at its annual meeting that focus on curriculum development and innovative approaches to undergraduate teaching/learning.

6. Materials and Supplies: Although more than $20,000 of prior grant funding has provided the permanent equipment and non-disposable supplies needed to support work by each section of *Discovering Genetics* (12-24 students), expendable materials (chemicals and disposable plasticware) need to be purchased annually. I have requested $2,500 for this purpose to be provided by the Proposition 301 funding to NAU. (The student fee for the course is presently set at a nominal $25) I have requested an additional $2000 for purchase of paper, computer and printer supplies, film, and miscellaneous materials needed for production of the laboratory manual and for website and manuscript preparation. We will produce 50 paper and 50 electronic copies of the laboratory manual for use in 2005 and beyond.

8. Indirect costs: Indirect costs have been calculated as 47.8% of salary and wages (not including ERE).

Note: Continuation of *Discovering Genetics* beyond the funding period will require continuing support from the Department of Biological Sciences in the form of a 1/4 -time graduate teaching assistantship each year the course is offered. I expect to provide an additional 1/4 -time assistantship from my own future extramural research funding. In addition we will need approximately $2,500 in expendable supplies each year. At present a small proportion of Proposition 301 funds are used to support courses that provide training related to biotechnology. I expect this funding to continue for several years. The laboratory manual will be produced and sold on-campus and should "pay for itself" each time the course is offered.