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

Proposal Title: Online Mathematics Training Modules for the Biology Project

Institution: University of Arizona Dept./Unit: Biochemistry & Molecular Biophysics

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

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

List other participating agencies:

Briefly describe the program and the development plan.
Collaborative effort between the Department of Biochemistry & Molecular Biophysics, and the Interdisciplinary Program in Applied Mathematics to develop online mathematics training modules to complement the Biology Project website; and also to develop a more general learner centered on-line mathematics curriculum for biologists. The program will be developed by teams of faculty and students from both academic units with specific timelines and outcome objectives.

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

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

Authorizations
Project Director

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II.1 Abstract

The rapidly changing face of research in the life sciences requires a far higher level of quantitative skill for its practitioners than in the past -- necessitating a substantial change in the way we educate both undergraduates and graduate students in the life sciences. In tackling such an ambitious undertaking, there is one approach that we believe would be unique to the University of Arizona, namely a project to "quantify" the Biology Project (http://www.biology.arizona.edu), an award-winning interactive online resource for learning biology developed by University of Arizona faculty based in the Department of Biochemistry and Molecular Biophysics. It was created for biology students at the college level, but is also useful for medical students, physicians, science writers, high school students, and all types of interested people. The Biology Project takes full advantage of the interactivity of the Web to give students direct control of their learning. The non-linear presentation, requiring the active participation of the users, is designed to help maintain student attention, promote interest in learning, and enhance the retention of the learned material. The project is based on problem sets with tutorials, case studies, and laboratory simulations. All are richly illustrated and tested by thousands of students. The Biology Project was created and is maintained by an experienced team of faculty content experts, a senior instruction specialist, a graphic artist, and systems analysts/programmers/technologists. The Biology Project has become one of the most highly used and important biology education sites on the Internet counting several hundred thousand user-sessions per month. The Project has been translated in part in Spanish, Portuguese and Italian. We also have a request for permission to translate it into German.

The long-term objective of this proposal is to develop a comprehensive suite of quantitative modules complimenting, and integrated with, the biological themes and topics in the Project. This effort would be coupled to the parallel development of a new learner-centered, on-line mathematics curriculum that would provide a basic resource for training in quantitative and statistical methodologies for undergraduate and graduate students in the life sciences. These long-term objectives will require significantly greater funding and more time than is allowed under the current LCE program. Accordingly we propose to use the LCE funding to develop a small number of pilot modules that will serve as preliminary results for a major proposal to the National Science Foundation to fund the building of the full program.

In addition to the uniqueness of the Project itself, we have available a unique personnel resource equipped to carry out this task: namely the faculty and students of the University of Arizona's renowned Interdisciplinary Program in Applied Mathematics. For over a decade the Program has promoted and fostered interdisciplinary research and education at the interface of the biological and mathematical sciences with the result that there is now a large cohort of graduate students and faculty, experienced in both pedagogy for, and interactions with, the life sciences community.

Our proposal calls for teams of faculty, graduate students, undergraduate students, and Biology Project Staff to develop a series of quantitative modules aimed at users with different levels of expertise for many of the major subject areas covered by the Biology Project, as well as the development of additional modules providing more general educational material to teach "Mathematics for the Biologist". Illustrative examples of such modules, which were developed several years ago for the annual Mathematics Awareness Week, and sponsored by the American Mathematical Society, can be found at http://math.arizona.edu/~maw1999/. Our efforts to develop these online resources nicely complement many other classroom-based educational initiatives underway at the University of Arizona to improve the quantitative skills of our student population.

II.2 Identification of Need

We are faced with a dual difficulty: biology is rapidly becoming more quantitative, while at the same time, incoming freshmen to the university are less well prepared in quantitative thinking than were their counterparts of only a decade ago. The problem exists at many levels: even within that sub-group of students (be they undergraduates or graduate students) who are well versed in the mechanics of using mathematical skills and thinking, many have serious difficulty in coupling observations in the real world, especially the biological world, with a simple mathematical concept. The purpose of this proposal is to secure funding to build an initial series of modules for the Biology Project aimed specifically at demonstrating the intimate relation between the observable world and the mathematical world. Based on the experience and materials that we will gather and develop during the course of this LCE funding cycle, we will be able to compete effectively for funding from the National Science Foundation to secure longer-term funding to build an extensive series of math-based modules that will be thoroughly integrated with the biological modules that comprise the current Biology Project.

One might ask why our incoming freshmen are so poorly prepared in mathematics and mathematical evaluation of real

world observations, but it is probably more productive to think of processes and procedures to cure the problem. Research is conclusive that students learn best when actively engaged with new information and interesting tasks, and that they achieve higher standards when they are given the opportunity to function as independent learners who take responsibility for their own learning. The faculty of the Department of Biochemistry and Molecular Biophysics (BMB) has employed these principles with enormous success since the early 1990s, and the Biology Project has been designed and implemented with LCE principles as core elements. Our proposed augmentation of the Biology Project is focused on student achievement, recognizes the fact that students learn best by different processes, engages the student as an individual in the discovery process, and allows students the flexibility to learn without the traditional classroom constraints of time and place.

An example of the kind of instructional biomathematics module that will be developed can be found at http://www.biology.arizona.edu/biomath/intro.html. We find that many students have difficulty with exponents, logarithms, significant figures, estimation, and scientific notation. The example shown at this web site presents basic information regarding use of scientific notation to work with large and small numbers, and how logarithms are used to deal with exponents. For example, to tie the concepts of exponents, logarithms, and bases together, we employ the biologically relevant example of bacterial cell division. Since cells divide to yield two daughter cells, the process of division can be quantified in terms of logarithms to the base 2. The number of cell divisions (the logarithm of the number of cells) is the exponent, namely the power to which the base, 2, is raised to yield the number of cells following the specified number of divisions. Following presentation of the basic information, the student is afforded an opportunity to answer a series of questions to determine whether or not they grasp the information that has just been presented to them. This pattern of information presentation, followed by examination to solidify the knowledge, is a common theme throughout the Biology Project.

This module will be greatly expanded to include much more information on exponents and logarithms and use of these tools, as well as biological examples of exponential processes. The exponential nature of chemical kinetics, enzyme kinetics, pH and other biological topics will be tied to this site. As we continue to expand the biomathematical components of the Biology Project, each of these sites will be tied to each other, and to the corresponding biology-based modules. The Biology Project has effectively utilized the principles of Learner-Centered Education for a decade. These principles have been incorporated into the core lecture courses in biochemistry, including the undergraduate majors courses, the honors courses, the non-majors courses, and the graduate courses, with enormous success. Mathematics has also utilized LCE principles very effectively. The proposed program will allow, for the first time, a functional integration of LCE experience of the faculties of BMB and Applied Mathematics. The results promise to be most exciting and productive.

Following completion of the activities proposed here, specifically building of a series of basic mathematics modules to address the fundamentals of scientific notation, the skills of approximation, dealing with exponents and logarithms, and the relationship between these mathematical principles and biological observables, we will develop a major proposal and submit it to the National Science Foundation for longer term funding of this initiative. The NSF initiative NSF 04-546 has as its mission "…to enhance undergraduate education and training at the intersection of the biological and mathematical sciences…" and, furthermore "…. The goal of the Undergraduate Biology and Mathematics (UBM) activity is to enhance undergraduate education and training at the intersection of the biological and mathematical sciences and to better prepare undergraduate biology or mathematics students to pursue graduate study and careers in fields that integrate the mathematical and biological sciences." The objectives articulated by the NSF are precisely in accord with our objectives. We have been successful for two decades in maintaining NSF support of the Undergraduate Biology Research Program (UBRP): the longest running Research Experiences for Undergraduates program in the country. We will build upon the exceptional record of the UBRP program to develop a complementary program in Mathematical Biology for Undergraduates.

The program proposed here will integrate the skills of the Department of Biochemistry and Molecular Biophysics and the Applied Mathematics Program to form a strong collaborative initiative. The principals in this proposal have been discussing details of this proposal for roughly one year, and the current proposal will enable the first phase of a long-term collaboration between these two groups of faculty. Students at the University of Arizona are fortunate to have the internationally recognized Applied Mathematics Program. The faculty in this interdisciplinary Program are world-class mathematicians, well versed in the applications of mathematics to biology and other areas, and strongly committed to undergraduate education in mathematics. Collaboration between these mathematicians and the nationally recognized faculty of Biochemistry and Molecular Biology will lead to an enhanced level of education for our students in the broad area of mathematical biology.

II.3 Technical Needs

The Biology Project development team is housed in Room 251 in the Biology Sciences West building. Room 251 is a 900 square foot facility divided into 7 furnished individual cubicles, a working space for computer maintenance, and a common area with computers and meeting tables. This facility was designed specifically to allow the kind of collaborative web-based educational activities envisaged in this proposal. The facility includes all the equipment required for successful completion of the proposed activities. Hardware includes 6 Macintosh computers, 3 Dell PCs, 2 flatbed scanners (Mac/PC) and a shared laser printer. Software used by the Biology Project development team consists mainly of Adobe Photoshop and Macromedia Studio MX suite. This suite includes Dreamweaver, Flash, Fireworks and Freehand. Additional software needs and licenses will be provided by the Department of Biochemistry and Molecular Biophysics. In summary, the existing facility has the necessary hardware and software to see this project through to completion.

II.4 Work Plan/Timeline

This project has been in development for approximately one year, with a group of faculty analyzing at length how to implement the quantification of the Biology Project. To begin this process, we will engage, as key individuals, two graduate students on the Ph.D. track, one in Applied Mathematics and one in Biochemistry and Molecular Biophysics, and one undergraduate student, a double major in Mathematics and Biochemistry and Molecular Biophysics. This team will work together with a group with four members of the faculty (Professors Michael Tabor and Joe Watkins in Applied Mathematics, and Michael Wells and Thomas Baldwin in Biochemistry and Molecular Biophysics), Educational Specialist Madeleine Lapointe, who is responsible for the format and structure of the material contained within the Biology Project, and Cheryl Ryan, a Graphic Artist who develops the captivating graphics of the Biology Project. Professors Bill Grimes and Rick Hallick are also key players. These last two individuals created the Biology Project as an adjunct to the freshman biology course, BIOC 181R, as well as the 181R course itself, and they have been the principle intellectual driving force behind both the Biology Project and the freshman biology course for many years. Professors Grimes and Hallick will work closely with the biomathematics developers to assure that the materials developed are appropriate for college freshmen.

This proposal seeks funding for the two graduate students only. Support of the undergraduate student comprises the 25% required match. The ICR for this project, together with support of the faculty and Biology Project Staff and commitment to supply the necessary software comprises additional cost sharing for this project.

Timeline:

10/12/04-4/1/05 Identify students to be involved in this project; refine topic areas for short-term goals.4/1/05-6/1/05 Together with the student team, focus the topic areas and establish a set of specific first-phase biomathematics modules. 6/1/05-8/15/05 Develop a refined listing of topics for which content will be required and build the beta version of the modules. 8/16/05-12/31/05 Test the beta version of the modules. 1/1/06-4/1/06 Refine the modules and develop materials for application in the classroom. 4/1/06-6/1/06 Test the “final product” with a small group of student volunteers. 6/1/06-8/15/06 Final tuning of the biomathematics modules.

In addition to these goals that are directly tied to the proposed project, we will submit a proposal to the National Science Foundation for the June 1, 2006 deadline to seek funding to commence in December of 2006 to continue and expand the work described in this proposal.

Task descriptions and assignments:

Professors Tabor and Baldwin will select the two graduate assistants to work on this project. We will select two accomplished individuals who have the capacity to speak to both biologists and mathematicians. We are fortunate to have a large cohort of students with an undergraduate education in one discipline and graduate education in the other, and have the capacity to talk with both groups and bring them to a common position. We also have a significant number of undergraduate students who are double majors in mathematics and biochemistry. Tabor and Baldwin will select from this large cohort of qualified students one individual who will serve to integrate the life sciences and mathematics, as seen from the perspective of the undergraduate student. This individual will be critical in assisting us in selecting the cohort of students to assess the products of this initiative.

The graduate students and the undergraduate student will work as a team of three to develop the content. The fruit of their efforts will be critiqued by Professors Tabor, Wells, Watkins and Baldwin, and following approval, will be presented to Madeleine Lapointe and Cheryl Ryan who will render the necessary web sites to accomplish the specific goals. Following development of the initial phase modules, cohorts of undergraduates from a variety of courses will be recruited to evaluate the material. The dynamics of the process of critique-evaluation-modification-critique that has been so successfully used for the Biology Project in the past will be employed again for this project. Resource allocations:

The resources requested from ABOR will be used exclusively for support of two graduate research assistants, as described above. Support for the undergraduate student will be provided by matching funds from Applied Mathematics and the Department of Biochemistry and Molecular Biophysics, which will also support the Biology Project Staff and supply the necessary software and hardware required to successfully complete the proposed initiative.

Estimated task hours for each key personnel:

We will ask each of the two graduate students and the single undergraduate student to commit 20 hours per week to the proposed initiative for a period of 12 months. Following that time period, Applied Mathematics and BMB will cover the cost of these individuals for the remainder of the 18 months expected for this project. Madeleine Lapointe of the Biology Project will commit ca. 25% of her time to the proposed project, and Cheryl Ryan, Graphic Artist, will commit approximately 10% of her time. The four faculty will each commit an average of 2 hours per week to the project throughout the calendar year. Planned accomplishments including project milestones:

The projected accomplishments and milestones are outlined briefly in the Timeline, above. The critical milestones are to:

(1) focus the topic areas and establish a set of specific first-phase biomathematics modules—by 6/1/05;
(2) test the beta version of the modules—by 12/31/05;
(3) refine the modules and develop materials for application in the classroom—by 4/1/05.

Following these steps, the modules will be further refined and connected to the Biology Project. It should be noted that modules in the Biology Project are, in a sense, never really complete: as research moves ahead, augmentation of pedagogical material is essential, so that one should never really declare that a project is in truly final form.

II. 5 Key Personnel

The Program Director of this initiative is Prof. Thomas O. Baldwin, Professor and Head of Biochemistry and Molecular Biophysics. Prof. Baldwin assumes responsibility for successful completion of this project. Prof. Michael Tabor, Head of the Applied Mathematics Program, will share responsibility for direction of this initiative. Regents Professor Michael Wells designed the Undergraduate Biology Research Program ca. 20 years ago and continues today as its director, and Prof. Joe Watkins plays a key role in integrating the faculty of mathematics with the faculties of the biology departments. Together, these four faculty will assure that this project is successfully completed.

In addition to the above faculty, the Biology Project team, especially Education Specialist Madeleine Lapointe and Graphic Artist Cheryl Ryan, will render the essential web pages required for this project.

And finally, and most importantly, the 3 students, 2 graduate students and 1 undergraduate student, will play essential roles. These three students will develop the content that will be rendered by Madeleine Lapointe and Cheryl Ryan. The faculty will work closely with the student team to assure that the material supplied to the teaching and graphics specialists will achieve the desired objectives.

II. 6 Performance Measures

Evaluation of this project will be conducted on two levels, formative and summative. We will engage in substantial formative evaluation as the learner-centered online mathematics modules are created, tested, and revised at several junctures during the development of the curriculum. To identify design problems, we will recruit a group of 10 students to interact with the modules. Working with five students at a time we will monitor students' interactions with the learning materials from three different points of view:

1 Quantitative and qualitative learning: Based on the learning objectives and the proposed design, we will develop pre- and post-tests. These tests will provide a quantitative measure of the knowledge gained as well as qualitative data

about the learning process.
2 Usability study: We will observe students' use of the interface for possible errors in our design. After using the learning materials, students will be asked to evaluate the ease or difficulty in finding what they needed from the module.
3 Tracking students' use of the learning materials: Using WebTrends, a software package on our server, we will keep track of how students are using the modules, what documents they access and how long they use each document. These observations will allow us to tailor content and style to the needs of the users.

Following these observations, necessary modifications will be made before testing the other group of students based on already-established criteria.

Summative evaluation:

To evaluate the impact of the learning materials on learners, we will conduct a summative evaluation. At the beginning and the end of a semester, we will administer the pre- and post tests to 100 students taking an advanced biochemistry class. The following semester (or year) we will repeat the experiment, keeping the same course material and the same instructor, but this time adding the new learner-centered, online mathematics materials to the course. Results will be compared and we will write the report of our findings.

Presentation of findings:

The results of our findings will be presented to the LCE committee of ABOR upon completion. We will also publish the results on the Web and we will submit them for publication in an educational journal.