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

Proposal Title: Developing and Promoting Learner-Centered Instruction Through Science and Engineering Based Projects in Precalculus and Introductory Calculus

Institution: Arizona State University DEPT/Unit: CRESMET

Multi-Campus/University Projects
(check other campuses or universities participating)
_X__ ASU Main ___ UA
_X__ ASU East ___ UA South
___ ASU West ___ NAU

List other participating agencies:

Briefly describe the program and the development plan.
Mathematics, Engineering and Science faculty will collaborate to develop learner centered modules for use in precalculus and beginning calculus, two large enrollment undergraduate courses at our state's and nation's universities and colleges. The modules will provide instructional support materials for teachers, problem-based activities for in-class group work, and take-home team design projects to promote students' further exploration and mathematical analysis of a problematic situation.

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

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

Authorizations

Project Director

Signature: _____

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_____
Signature

Official Authorized to Enter into Contractual Obligations

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Developing and Promoting Learner-Centered Instruction Through Science and Engineering Based Projects in Precalculus and Introductory Calculus

Marilyn Carlson, Steve Krause, Mike Oehrtman, and Chell Roberts

Mathematics, Engineering and Science faculty will collaborate to develop learner centered modules for use in precalculus and beginning calculus, two large enrollment undergraduate courses at our state's and nation's universities and colleges. The modules will provide instructional support materials for teachers, problem-based activities for in-class group work, and take-home team design projects to promote students' further exploration and mathematical analysis of a problematic situation. Drawing from the body of relevant research, each project will be designed to engage students in the scientific process, while also promoting their understanding of major concepts of calculus and effective uses of current technologies. The primary outcome of this work will be five learner centered modules for each course. The group activities, team projects, and teacher support materials will provide research-based materials and tools to assist teachers in promoting a learner centered instructional delivery for precalculus and beginning calculus. The modules will undergo multiple cycles of refinement by observing their effectiveness in sparking students' curiosity and interest in learning scientific processes and applying mathematical concepts. Other funding sources will be targeted to have a statewide workshop for the broad dissemination of the refined and validated modules.

Needs

The failure rate in precalculus and beginning calculus in our state and nation is unacceptably high, with our state reporting failure rates ranging from 40%-60% in these courses. Despite isolated efforts to improve the situation, it is widely reported that freshman mathematics courses continue to be the primary filter for students' continued study of engineering, science and mathematics (MAA, 2002).

Most precalculus and beginning mathematics textbooks are designed to build the skills and ideas needed for continued study of mathematics. Even though this is the intent, research has revealed that most students emerge from precalculus and beginning calculus with weak understandings of the major mathematical concepts of the course. Students have been shown to have particular difficulty in using their mathematical knowledge and tools to represent, analyze, and interpret dynamic real world events (Thompson, 1994; Carlson, 1998), a common way of using mathematics in the sciences and engineering. At the same time, there is a growing body of literature that suggests pre-college students, when provide an opportunity to construct their own understanding through student centered projects, can reason informally with concepts of rate of change, function and other fundamental concepts of calculus (Kaput, 1994). This data is particularly alarming when one considers that the majority of students who enroll in calculus around the nation (80% at ASU, with similar percentage reported at NAU and U of A) intend to major in engineering.

It is also widely reported that students are not finding calculus to be connected or useful for completing projects in engineering. Exit surveys from students who complete precalculus and beginning calculus reveals that these students, at the completion of these course, do not view the mathematics as relevant in solving science and engineering problems; nor do they understand how to use the mathematical concepts as tools to strengthen the quality of their scientific explorations. This is not surprising if one considers the focus and structure of current precalculus and calculus textbooks. Most make only a token effort to include some applied problems; these problems typically appear as isolated exercises with no effort made to promote students' broader exploration of a problematic situation. This project will respond by combining the expertise of mathematics education faculty, scientists and engineers to develop meaningful modules that promote students' engagement in the scientific process, while also promoting their understanding of engineering design principles and mathematical concepts central to precalculus and beginning calculus.

The modules that we propose to develop will build on the broad body of research related to scientific inquiry and problem based learning (Lawson, 2000; Lesh et al., 2002, Schoenfeld, 1995; Carlson, 1999). The design of the student tasks will encompass learner centered techniques and strategies (collaborative group learning both inside and outside of class, individual and collaborative student research, problem based learning, etc.) as defined by ABOR (2003). Each module will be further guided by the literature that describes the processes involved in learning the concept of precalculus or beginning calculus that is the focus of that module (Monk, 1992; Kaput, 1994; Thompson, 1994; Carlson, 1998; 2000, 2001, 2003; Oehrtman, 2002).

The four Co-PI's on this project have extensive background in developing learner-centered STEM curriculum in their respective disciplines. This expertise will be critical in assuring that the leaner-centered modules that emerge from this work will be of the quality that is necessary to assure that they are broadly embraced by mathematicians, engineers and scientists, and that they are effectively disseminated and implemented in all freshman precalculus and beginning calculus courses at ASU main and ASU East. This project will support the design, development and refinement of 10 modules. The products of this work will provide a solid foundation for our longer term plan to seek other funding sources to provide workshops to make these modules available to our colleagues at ASU West, NAU and U of A.

Our research on the effectiveness of these modules should also serve to advance our understanding of effective means for promoting learner centered STEM instruction. We expect to gain insights about specific design principles for learner-centered curriculum, and specific information about the appropriate science and engineering contexts for promoting strong mathematical understandings in precalculus and beginning calculus students. The teacher support materials that emerge from this work will include videos of effective implementation of Learner Centered techniques for each module, relevant information on the understandings and behaviors that are targeted in each module, and tools to assess the effectiveness of the modules for improving student learning. These materials and tools will be used in professional development for the instructional faculty for these two courses.

Technical Needs

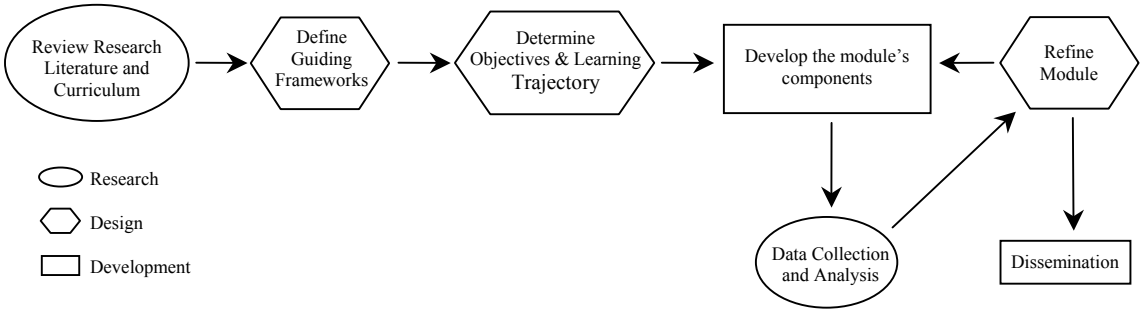
A digital camera and video editing software will be needed to produce the videos of the effective implementation of the modules. This equipment and software has been previously acquired with funds from an NSF research grant.

Work Plan

The work for this project will involve four faculty and two graduate students in developing 10 learner centered STEM integrated modules, 5 for use in precalculus and 5 for use in beginning calculus. Under support of a separate NSF research grant, the graduate students will begin work during the spring semester of 2003 to identify and compile related projects/materials that may provide useful knowledge for the development of the curricular modules. During this time, these students will also work with faculty to develop literature reviews and conceptual frameworks for the module topics. During the summer of 2004, faculty will work for two months (June and July) to develop modules that focus on the following concepts of precalculus and calculus that are regularly used in engineering design and scientific explorations. The precalculus concepts are: i) rate-of-change; ii) functions and formulas; iii) asymptotes and limiting behaviors; iv) exponential growth; and v) trigonometric functions. The beginning calculus concepts are: i) functions as models of covariational situations; ii) limit; iii) instantaneous rate of change (derivative); iv) accumulation (definite integration); and iv) The Fundamental Theorem of Calculus.

The work for this project will be accomplished by two cross-disciplinary teams. The *Precalculus Research and Development Team* (composed of one mathematics education faculty, one engineer/scientist, one education graduate student, and one curriculum development specialist) will design, develop, evaluate and refine the five modules for precalculus. Similarly, the *Calculus Research and Development Team* (also composed of one mathematics education faculty, one engineer/scientist, one education graduate student and a curriculum development specialist) will design, develop, evaluate and refine the five modules for beginning calculus (see Figure 1) . The two cross disciplinary teams will meet in CRESMET (the ASU Center for Research on Learning Science, Mathematics, Engineering and Technology) office space to carry out their research and development activities.

Figure 1. Module Research and Development Cycle



The development cycle for each module will involve each team in collaborations to initially determine the modules' overarching objectives; these will guide their definition of the learning trajectory for each module (the projected path for moving students toward the desired understandings and behaviors). These trajectories will also be guided by the research literature relative to learning the engineering, science and mathematics principles and concepts, and will serve as the framework for the module's design. The research and design process for supplementary materials (the learner-centered activity for in-class group work, the team design project, and the instructional support materials for precalculus and calculus teachers) will follow similar development cycles.

The development cycle for each of the five modules will span 7-10 days. Once each component of the module is developed, the graduate students will conduct clinical interviews with students as they work through the activities of the modules. The interviews will be transcribed and analyzed using Strauss and Corbin (1999) open, axial, and selective coding techniques, collecting additional data where needed. All members of the Research and Development Team will participate in the analysis and interpretation of the data. The results that emerge from this analysis will provide information for refining the problem-based activities and team design project for each module. The instructional support materials for teachers, will be refined by asking four precalculus and four beginning calculus teachers who are scheduled to teach the course during the Fall semester (2004) to read and provide specific comments for improving the instructional support materials. During the final week of the project (week 9) two precalculus faculty will be asked to lead the module implementation with four students. The instructional sessions will be video taped. The data that is collected will be analyzed and the results that emerge will guide the final refinement of the modules' components.

Note that the work that we have proposed will be carried out by working half days for two months (see Timeline for Module Development—Table 4), rather than full days for one month. We believe that this approach will increase the productivity of our two research and development teams.

Table 4: Timeline of Module Development, Planned Accomplishments and Project Milestones

Week 1	Week 2	Week 3	Week 4	Weeks 5-8	Week 9
• Review literature and frameworks • Standardize module design • Determine module 1 objectives • Determine module 1 learning trajectory	• Develop module 1 • Begin module 1 data collection • Analyze module 1 data • Refine module 1 • Determine module 2 objectives • Determine module 2 learning trajectory	• Develop module 2 • Continue refining module 1 (as needed) • Begin colleting module 2 data	• Continue module 2 data collection • Analyze module 2 data • Refine module 2 • Begin development of module 3	Repeat cycles for modules 3, 4 and 5	• Continue to test modules with students (clinical interviews with students when completing the project.) • Acquire written feedback on support materials from precalculus and calculus teachers • Final refinement of all 10 modules

Key Personnel:

Marilyn Carlson is the project PI and will be a member of Research and Design Team. . She is a mathematics education faculty and has extensive experience in leading professional development for large enrollment courses. She has experience developing curriculum and has conducted research on knowing and learning concepts in precalculus and beginning calculus. She has taught undergraduate engineering courses and has completed graduate work in engineering. Contact information: marilyn.carlson@cox.net

Chell Roberts is a project Co-PI and will be a member of the Calculus Research Design Team. He is a scientist and engineer, is currently the Co-Director of the Integrated Manufacturing, Engineering Laboratory, and has recently been selected to lead the development of the new engineering degree program at ASU East. He has extensive experience developing learner centered projects for use in engineering design, and is currently in charge of developing the precalculus and calculus curriculum for ASU East.

Michael Oehrtman is a project Co-PI and will be a member of the Calculus Research Design Team. He is a mathematics educator who studies processes of learning and applying major concepts in beginning calculus. He has served as an instructor and trainer for a learner-centered calculus workshop at the University of Texas and has experience designing curriculum for graduate, undergraduate, and secondary mathematics.

Steve Krause is a project Co-PI and will be a member of the Precalculus Research Design Team. He is Associate Chair of Chemical and Materials Engineering and is a scientist and engineer who has extensive experience in developing engineering based projects for middle school students and undergraduate engineering courses at ASU.

Hillary Burns is a professional development specialist and will assist with the design, research and refinement of the professional support materials for teachers.

Graduate Students The graduate students in this project are ***Nicole Engelke*** and ***Vicki Lancaster***. They have strong backgrounds in the sciences (engineering and biology), are experienced in designing and conducting clinical interviews, and have an interest in studying the impact of learning mathematics in contextualized situations. They will assist with the literature surveys, data collection and data analysis component of this project.

Coordination with other course leaders for precalculus and calculus: Marilyn Carlson, the PI for this project, is assigned to be the class coordinator for beginning calculus at ASU during the 2004-2005 academic year. She will be leading the professional development and integration of these modules into the calculus I course (MAT 270) during the 2004-2005 academic year. She will also be working with the course coordinator for precalculus (MAT 170) (not yet determined) to assist with the professional development and implementation of these modules in precalculus. She is working with Matthias Kawski, the chair of the calculus committee, and Glenn Hurlbert, the Director of Undergraduate Mathematics at ASU to coordinate these efforts.

Expected Results, Outcomes and Sustainability

Ten research-designed and developed curricular modules will emerge from this work; five for precaclulus and five for beginning calculus. We expect that the implementation of these modules at ASU Main and ASU East will result in dramatic shifts in the problem solving behaviors, scientific methods, and conceptual understandings for all students in two large enrollment courses. Previously developed Concept Assessment Instruments for Precalculus and Beginning Calculus will be administered to assess this claim. We expect that more students will continue their study of STEM content, and that more students will view mathematics as a useful tool for engaging in real scientific investigations. Follow-up data will be collected during the 2004-2005 academic year. Findings will be reported in our summative report and will serve as useful data for our future work in this area. It is expected that this data will assure the institutionalization of the modules as regular components of these courses. Other funding sources will be targeted to hold a workshop during the summer of 2005 for professional development and dissemination of

the modules to our colleagues at state universities, community colleges and high schools who lead and teach precalculus and calculus. We expect that participants will acquire improved instructional abilities and understanding of learner centered approaches for which the modules will provide an initial curricular resource. We also anticipate that the research process will produce new knowledge for the further development of learner centered curricular modules.