Learner-Centered Education Program
Arizona Board of Regents Attachment A

INSTITUTIONAL SUPPORT FORM

Proposal Title: "The Software Enterprise: Preparing Industry-ready Software Engineers"

Institution: Arizona State University East Dept/Unit: Division of Computing Studies

Multi-Campus/University Projects List other participating agencies:(check other campuses or universities participating)_ _ ASU Main ___ UA

__X_ ASU East ___ UA South

____ ASU West ___ NAU

Briefly describe the program and the development plan.
This proposal requests support for curriculum development and assessment of a practice-oriented multi-semester sequence dubbed the "Software Enterprise". The primary goal of the work described in this proposal is to develop the materials and the environment to implement an instructor-facilitated, learner-centric model for the Software Enterprise. Graduates should exhibit a higher degree of applied competencies in industry-relevant areas, and as an indirect measure, should have more success in career placement and advancement.

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

Professional Development	______	Program or Course Development/Modification	__P__
LCE Research	__S___	Improved Assessment of Learning Outcomes	

Authorizations

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The Software Enterprise: Preparing Industry-ready Software Engineers

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1. Abstract

This proposal requests support for curriculum development and assessment of a practice-oriented multi-semester sequence dubbed the Software Enterprise. The Software Enterprise is under construction to address national and local industry needs to produce industry-ready graduates in Software Engineering. The primary goal of the work described in this proposal is to develop the materials and the environment to implement an instructor-facilitated, learner-centric model for the Software Enterprise. To complete this work, support is also required to implement an assessment methodology that tracks competencies of new graduates as they complete the Enterprise and enter local industry. Graduates should exhibit a higher degree of applied competencies in industry-relevant areas, and as an indirect measure should have more success in career placement and advancement.

2. Identification of Need

The newly formed Division of Computing Studies (DCST) on the Arizona State University East campus is tasked with developing programs in the polytechnic model. Graduating students are expected to be “industry-ready.” In the model of a polytechnic, an increased emphasis is placed on hands-on practice over pure scientific study. DCST has responded by offering a new Bachelor of Applied Computer Science degree program that embodies the polytechnic spirit. Given the new emphasis of DCST and its programs, input from industrial advisors, and recent lessons learned from our one semester capstone project course, the capstone experience is undergoing a significant evolution. This evolution extends the scale and scope of the capstone experience from a one-semester, single-project course to a multi-semester, multi-project, and multi-year sequence. This proposal requests support for the Principal Investigators’ implementation of this planned evolution.

2.1 The Need to Develop Software Engineers

The Information Technology (IT) areas of software development and Software Engineering have a high impact on the national and Arizona economies. A recently released report from the ITAA maintains that computer programming remains the largest segment of the IT workforce, representing 20 percent, or over 2 million jobs[1]. ITAA Projections for future employment growth are strong as well, with programming ranked third out of nine IT categories[2]. The Bureau of Labor and Statistics forecasts 45 percent growth in Software Engineering opportunities from 2002-2012, representing over 310 thousand job opportunities. Software Engineering for applications ranks 8th and Software Engineering for Systems Software ranks 9th out of all career categories[3].

The impacts to the local Arizona economy are just as strong. Projections for Arizona show a 76 percent growth rate in Software Engineering for Applications and a 54 percent growth rate in Software Engineering for Systems Software (see Table 1). The expanding success of high-tech companies both large and small in Phoenix and the rest of the state leads to opportunities such as the one recently announced by General Dynamics[4].

Title	2000	2010	Quantity Change	Average Annual	Percent Change
Computer Programmers Computer Software Engineers, Applications Computer Software Engineers, Systems	9770 5370 6530	10270 9460 10060	510 4090 3530	260 450 400	5 76 54

Table 1. State of Arizona Software Engineering Employment Growth Projections[5]

The perception that the dot-com bubble bust and recent outsourcing trends make these sectors unattractive career fields is inaccurate. Instead, these developments have reemphasized the need for highly trained software engineers over software programmers. DCST is moving rapidly to fulfill this need. The new Bachelor of Applied Computer Science (BACS), approved by ABOR in 2004, introduces a program emphasizing state of the art skillsets in technologies such as Sun’s J2EE/Java platform, Microsoft’s .NET platform, embedded systems, and Linux (a

[1] Information Technology Association of America. “Adding Value…Growing Careers: The Employment Outlook in Today’s IncreasinglyCompetitive IT Job Market”. Annual Workforce Development Survey, September 2004. Figure 3, page 8. [2] Ibid. Table 20, page 22.
[3] US Dept. of Labor, Bureau of Labor Statistics. “Tomorrow’s Jobs”, reprint section from the Occupational Outlook Handbook, 2004-2005.
[4] “General Dynamics needs 233 engineers, tech workers”, The Arizona Republic, October 5, 2004.
[5] Data collected from query on http://www.projectscentral.com

UNIX variant). However, emphasizing specific skillsets is not in itself sufficient to meet industry demands. The data cited above indicates that engineering competency is required. DCST meets with an Industrial Advisory Board (IAB) comprised of local industry leaders each semester. The IAB has also emphasized the need for engineers who can demonstrate applied competencies in software processes and not just in specific skillsets. To address this need, DCST recognizes the need to introduce stronger Software Engineering components into the BACS program. The Software Enterprise is considered central to these efforts.

2.2 The Software Enterprise: Motivation and Approach

The state of the software engineering profession is such that practitioners learn more through on the job experience than through traditional lecture-oriented approaches. In our efforts to address the difficulties encountered in our capstone project course, we asked ourselves how graduating students entering the marketplace gain the skills needed to become competent professionals. We identified some key characteristics then went about designing ways in which these characteristics could be incorporated into our project course.

The characteristics identified can be loosely categorized as relating to project management, professionalism, and process. Although junior software professionals do not need a high competency in project management, they do need an understanding of the space in which their project manager operates. Students often lack personal management skills such as estimating, tracking, and managing time and priorities that are required by junior professionals. Inexperience with these skills coupled with a “write-a-program-get-a-grade” mentality results in students that must be reconditioned in a professional environment. Students must evolve to a “follow-a-process-produce-a-deliverable” mentality (and eventually to “use-and-improve-processes-to-solve-customer-problems”). This evolution is often accomplished through formal and informal mentoring relationships in professional settings. Finally, students lack a “process” perspective. Junior professionals rarely, if ever, start out as Business Analysts. Therefore project-oriented coursework should not start by having teams define their own requirements. Generally, students may get exposure to multiple roles on a team-oriented project course, or may perform role playing, but often the most talented students dominate tasks across all roles in an effort to get the project done.

We considered these characteristics and went about defining pedagogical principles that our project course should incorporate to address these issues:

Continuous – Projects will be ongoing; students who enter the Enterprise will work with a software product line that already exists. They will be asked to extend, port, modify, and/or maintain this software product line.

“Real-world” – This term is used in the sense that students will be exposed to the full spectrum of forces affecting software projects. Teams will be asked to cope not only with technical but also with soft-skill issues.

Multi-semester – The Enterprise will be designed as a four-semester sequence. This sequence will expose students, in a specified order, to all phases and roles of the software process lifecycle.

Multi-project – Students will be expected to work through two projects instead of one during the Enterprise sequence. This will expose students to process phases in the proper order, and also not get too “honed in” on one particular project domain, thereby shortchanging process-related activities.

Multi-year – Students will work in teams, and will also work across course and academic year boundaries. Teams will also work colocated with other Enterprise teams. For example, students in the last semester of the Experience sequence will mentor and manage students in the second semester.

These principles are being incorporated into the redesign of our capstone project course, now dubbed the Software Enterprise. By the conclusion of the Enterprise sequence, students will have an appreciation for software process, the challenges of software maintenance, the impact of open source, the pros and cons of off-the-shelf software integration, business considerations in building software, and other practical aspects of software development. Though several of these principles are not unique to the Enterprise, some of them are, and the combined application of these principles also contributes to its innovation. In searching for the right “mix of ingredients” to make up project coursework, we believe a multi-year, multi-semester, and multi-project sequence that presents the process lifecycle in a sequence a new professional encounters them is the best approach.

2.3 An Instructor-facilitated, Learner-centric Model

Traditional classroom-centered lectures by an instructor do not result in applied knowledge of engineering practices. The first Principal Investigator has taught the main Software Engineering course before; the experience suggests the best you can do is expose students to a spectrum of techniques and issues and relate anecdotes about how these apply in a commercial setting. While a foundation in best practices and engineering principles is needed, hands-on practice is the best vehicle for gaining applied knowledge.

Engineering programs nationwide realize this fact. Most programs adopt a design course (the “capstone” project course) near the end of the undergraduate program as a means to apply the principals learned in traditional lecture-oriented settings. We claim that a better methodology for evolving a student’s competencies from knowledge to comprehension to applied knowledge is to co-locate lectures, problem-centered learning, and complex process planning activities in time. In other words, disseminate information, immediately follow with problem-centered learning techniques, and then ask the student teams to apply the knowledge within an ongoing project instance that follows a specified process. The result is a highly iterative methodology for evolving the student’s competencies in a rapid fashion (see Figure 1).

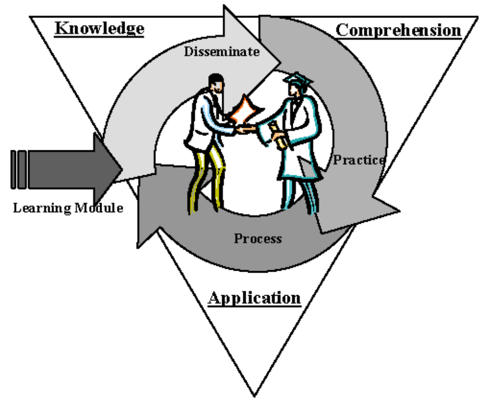

Figure 1. Iterative Instructor-facilitated Learner-centered Model

The traditional engineering instruction model asks students to first take a breadth-oriented survey-of-the-field style course that exposes them to a breadth of engineering practices and processes but typically lacks depth in any given area. The results are students who can recite the basic principles, but who lack the comprehension to apply them. These types of courses are then followed by courses that delve into a specific process topic in significant depth, for example a Software Design or a Software Quality Assurance course. These courses focus on deep skills development within the narrow process area. Students then complete the program with the capstone project, which asks them to apply this knowledge in a full semester project. This approach suffers from what we call the "toy problem effect". Many students do not get exposure to the full engineering process spectrum in a manner that allows them to apply the deeper skillsets they may have developed in a particular area. The results are students who can claim knowledge of a particular skill, but lack the context in which to apply this knowledge. A typical conversation an interviewer might have with a graduating student might be "well, yes I did a few use cases in my Software Requirements class, but no I have not done one of that size nor do I understand how to use that model to drive analysis and test planning."

We believe the coupling of disseminated knowledge to skills practice to incorporated process tasks will lead to quicker comprehension and better applied knowledge than the traditional model. We refer to this model as an "Iterative Instructor-facilitated, Learner-centered" model. Learners are responsible for individual study readings and exercises, for working individually or in small teams on problem-centered learning exercises, and for participating in complex projects under specified process roles (role playing). Instructors are responsible for disseminating knowledge via lectures and as a filter for reference content (research articles, industry publications, online searches, etc.). Instructors are responsible for crafting scripted exercises that allow for practice of specific skills. Instructors are also responsible for "coaching" teams and providing a context for projects. For example, the instructor serves the external roles of Senior Management, Customer, and Technical Consultant for the current set of projects.

Supporting such a highly iterative teaching and learning methodology places a great burden on instructors-as-facilitators to lead students down the right path. Knowledge from disparate sources must be both filtered and aggregated; it must also be packaged for digestion in a practice-oriented, collaborative learning environment. Structured, hands-on exercises for problem-centered learning must be constructed. Facilitators must determine the correct amount of guidance and support to provide team projects that enable learning without causing projects to degenerate into a "thrashing" state, alienating students from finding the right path.

Finally, and most importantly, instructors must rethink how learning is assessed, and how to assess the relative success of the Enterprise sequence. Our approach for addressing these important concerns is presented in Section 0.

3. Technical Needs

The Division of Computing Studies and the College of Technology and Applied Sciences (CTAS) have provided sufficient hardware, software, and laboratory space to perform the proposed work. The only needed resources to complete this project are the requested summer support allocations indicated in the attached budget.

4. Work Plan / Timeline

The project will proceed with four distinct tasks. Assessment (described in Section 0) will be implemented in three distinct phases. Problem-centered learning development will be implemented as one task. These tasks are spread across the summers of 2005 and 2006 as shown in Figure 2.

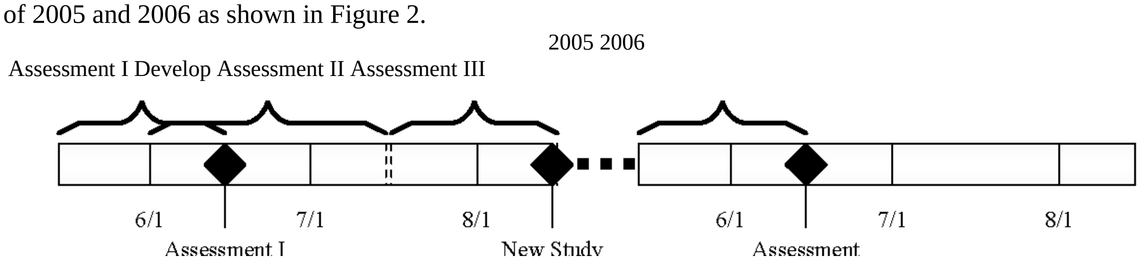

Figure 2. Proposed Project Timeline and Tasks

The task dates in Figure 2 assume each PI is working 50% time. Task descriptions are given in Table 2.

Task	Person	Description
Assessment I	Gary	This phase will construct and distribute an assessment based on the Lethbridge study as described in Section 0. The deliverable will be a report presenting and analyzing the data.
PCL Develop	Gary	This task will construct formal problem-centered learning modules and other artifacts for an iterative, instructor-facilitated, learner-centric model as described in Section 0.
Assessment II	Gannod	This phase evaluates and revises study categories to ensure maximum application to Software Enterprise stakeholders. The deliverable will be a new assessment study design.
Assessment III	Gannod	The final assessment will construct and distribute an assessment based on the revised study implementation in Assessment Phase II and produce a final report.

Table 2. Project Task Summary

5. Key Personnel

Principal Investigator 1: Kevin Gary, Ph.D. Assistant Professor, Division of Computing Studies, ASU East Dr. Gary joined the faculty of the Division of Computing Studies at Arizona State University East after spending four years in the private sector designing and developing software solutions for e-learning using portal and content management technologies. Dr. Gary had the opportunity to lead several software projects staffed primarily by software engineers with 0-7 years experience and various degrees. His belief that quality software is best constructed with a professional, process-oriented approach, coupled with his observations mentoring dozens of junior software engineers has led him to propose the Software Experience as a polytechnic learning model for ASU East. Principal Investigator 2: Barbara Gannod, Ph.D. Assistant Professor, Division of Computing Studies, ASU East Dr. Gannod joined the faculty of the eventual Division of Computing Studies in 2002. Dr. Gannod has significant interest in curriculum design and assessment. She is currently the chair of DCST's curriculum committee. In addition, she has been the chair of the curriculum committee for the Consortium for Embedded Systems (a consortium consisting of ASU, Intel, and Motorola that oversees research and education of embedded systems concepts) since Fall 2003. During the late Spring and Summer of 2004, Dr. Gannod led a "Gap Analysis" study that included an assessment of Embedded Systems Curriculum in the Computer Science and Engineering program (Tempe Campus) and Division of Computing Studies program (East Campus).

6.0 Performance Measures

Despite the prevalence of software used in society today, Software Engineering is still considered an immature discipline. This immaturity is also a probable source for the lack of industry-readiness of our graduates. Only in the past few years has data come to light about the gaps between industry expectations and new graduate skills comprehension. In a widely referenced study, Lethbridge gathered the data shown in Figure 3 regarding learning rates of topics in the discipline and how that learning was acquired:

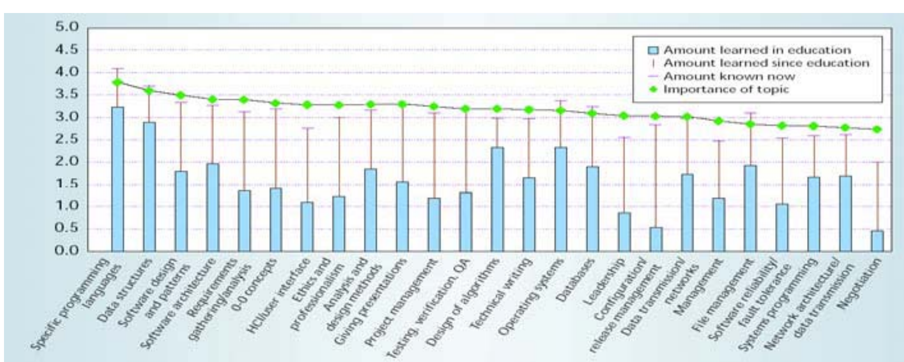

Figure 3. Learning Sources for the 25 Most Important Topics for Software Professionals[6]

Lethbridge notes that some of the largest gaps between topic importance and current knowledge occur in areas such as Negotiation, Leadership, Management, Cost Estimation, and Ethics and Professionalism. This reinforces the need to emphasize engineering practices. The Software Enterprise in the DCST at ASU's Polytechnic campus is addressing industry-stated needs for graduates who are better prepared for the workforce. The unique combination of project factors emphasizing both broad and deep practice of professional practices encountered by new professionals is our approach to satisfying these needs.

To determine whether the Enterprise is achieving the stated goal of industry-readiness for new graduates, we intend to use the model provided by Lethbridge as a starting point, but to augment it in two ways. First, we plan to reformulate the topic categories to allow the DCST constituents (students, alumni, faculty, and industry partners) to determine the topics most applicable to them. Second, we intend to collect and analyze additional data regarding student placement and career advancement for new and recent graduates.

We intend to use a three-phase assessment plan. In the first phase we gather information from new and recent graduates about acquired knowledge and industry-readiness in the knowledge areas identified by the Lethbridge study. In the second phase, we solicit information from DCST constituents about knowledge and skills that are necessary for success in the careers our graduates are expected to obtain. We anticipate that many of the topics will match those in the Lethbridge study. However, we may find that some topics are different and that their relative importance to the constituents differ as well. In the final phase we will gather information from students and recent graduates based on the topics identified by DCST constituents. The last phase will be our first opportunity to gather information from students that have been through the entire four-semester sequence of the Software Enterprise. We will compare the data obtained from this set of students with the data obtained during the first phase.

The results of our work will be disseminated in a variety of ways. We will work with our local industry partners on our IAB to advise them of our results to get both our feedback and to understand the characteristics of our new graduates. We will establish a web presence to disseminate our data to the engineering community. The Enterprise currently uses a collaborative portal site to coordinate class activities, and access to this site may be given to observers to “see” a running Enterprise sequence. The goal of the Enterprise is to produce open source software for teaching and learning applications in higher education, so completed and production-ready products will also be made available via the Web. Finally descriptions of our pedagogical approach and the assessment of our methods will be published in leading conferences and scholarly journals.

[6] Lethbridge, Timothy. “What Knowledge is Important to a Software Professional”, IEEE Computer, May 2000.

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Project Director

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Department Chair / Unit Director/ College Dean / Provost (may not be PD)

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