CPATH CB - Computing and Undergraduate Engineering: A Collaborative Process to Align Computing Education with Engineering Workforce Needs

1 Vision, Goals, Objectives, Outcomes

1.1 Vision

To create a collaboratively-defined undergraduate computing education within the engineering and technology fields in alignment with the computational problem-solving abilities needed to transform mid-Michigan's economy and workforce.

The 2006 National Academy of Sciences report, *Rising Above the Gathering Storm*, highlights efforts at the federal level to improve the Science, Technology, Engineering and Mathematics (STEM) disciplines, noting the need to strengthen the science and technology enterprise of this country so it can "compete, prosper, and be secure in the global economy" (Committee on Science Engineering and Public Policy, 2006, p. 1).

Given the urgent need to strengthen the STEM disciplines, the National Science Foundation CPATH solicitation offers a unique opportunity to engage stakeholders from multiple sectors in the collaborative transformation of computing education within higher education institutions. Instead of a top-down approach, this community-building initiative brings together Michigan State University (MSU) in partnership with Lansing Community College (LCC), and the Corporation for a Skilled Workforce (CSW), in a process to transform undergraduate computing education within the engineering and technology fields. The project will engage community college and research university computer science and engineering faculty in collaboration with regional technology and engineering employers. Our goal is to develop a working dialog between industry and academia in mid-Michigan that will eventually yield a reexamination and reimplementation of the engineering curricula as relates to computational tools and problem-solving *that is driven by industry needs*.

CSW is a partner with the Mid-Michigan Innovation Team (MMIT), the organization spearheading Mid-Michigan's U.S. Department of Labor Workforce Innovation in Regional Economic Development (WIRED) initiative. MMIT, the network of community leaders representing education, business, and economic and workforce development that is organizing the WIRED initiative within Mid-Michigan, plays a critical role in this community-building effort. The MMIT represents a broad spectrum of interests within 13 counties (Bay, Clinton, Eaton, Genesee, Ingham, Huron, Lapeer, Livingston, Midland, Saginaw, Sanilac, Shiawassee and Tuscola) anchored by Flint, Lansing, Midland and Saginaw. MMIT has been brought in as a partner on this initiative because they seek to transform the region's largely-traditional manufacturing-based economy by fostering innovation, talent and collaboration. Their three (3) identified economic growth clusters - advanced manufacturing, alternative energy/bio-economy, and advanced construction - require educating employees that are highly skilled in STEM (and especially engineering)-dependent fields.

1.1.1 Background

Despite the growing need for higher level STEM skills, school-to-work education is too often focused primarily on K-12 education curriculum reform and improvement, with little attention given to post secondary education. For example, the Council for Excellence in Government held a series of town meetings in 2004-2005 on the future of American jobs. While high quality public schools were identified as critical to job creation and economic development, only 28% of the participants prioritized the need for the private sector to work with colleges and universities to improve the transition from school to work (Goldman Sachs, 2006, pp. 11 - 13).

In contrast, the project proposed here places primary emphasis on the *engagement* of higher education and higher education engineering and computer science faculty in the process of regional economic change and school-to-work education (Fear, Rosaen, Bawden, & Foster-Fishman, 2006). We will develop and implement a *process* by which a wide variety of stakeholders – business, community leaders and post secondary educators – collaborate to identify workforce computational skills, define how these skills can be integrated across curricula, and revise these curricula to integrate *computational problem-solving* across engineering departmental courses. Noting the strong computational demands of employers, our core goal is to better prepare graduates for the new economy being created in mid-Michigan.

We envision this approach as mirroring the process by which ABET accomplished a dramatic shift away from rigid accreditation criteria to evaluation criteria based on customer focus, continuous program improvement, and outcomes in student learning. The ABET reform process was driven by a strong and consistent message from leaders of American industry, forward-looking academicians, and professional societies. The apparent success of these new criteria (Lattuca, Terenzini, & Volkwein, 2006) for engineering education demonstrates the need for innovation and flexibility in curricular design based on constituency input and quality improvement principles.

However, as Colbeck (2002) notes, curriculum change in higher education is a slow process and only becomes institutionalized when perceived by faculty as integral to organizational functioning (p. 398). Colbeck studied engineering curriculum reform at seven schools that participated in the NSF-funded Engineering Coalition for Excellence in Education and Leadership (ECSEL) to promote active learning and team-based projects. She found that *cognitive institutionalization* – incorporating faculty beliefs about learning, teaching-practice reform, and reform adoption – had the strongest influence on faculty acceptance and participation in reform efforts. Colbeck concluded that faculty adopt curricular reform not because administrators (or other stakeholders) urge them to do so, but because they perceive it to be a norm accepted by other faculty (p. 416). Given that faculty are the key to higher education curricular reform, this initiative specifically involves faculty in reform efforts in ways that promote cognitive institutionalization.

1.2 Goals

To promote the abilities of engineering graduates to perform problem solving with computer tools that are needed to transform mid-Michigan's economy and workforce, the project will

1. Bring together faculty and administrators from the College of Engineering at Michigan State University, Lansing Community College, and, through the Mid-Michigan Innovation Team

partners, leaders from business and industry, professional organizations, and key leaders in the Mid-Michigan WIRED region, who have an interest in transforming undergraduate computing education.

2. Create and institute a highly collaborative process to engage these participants in redesigning undergraduate computing curriculum. This process will be replicable in other engineering schools, in other STEM disciplines and in other WIRED communities state/nationwide.
3. Document and evaluate the efficacy of this approach to curriculum change and development.
4. Prepare a CPATH Transformation (T) grant proposal to complete and implement the redesign of computing education in the engineering programs at Michigan State University, Lansing Community College, and other mid-Michigan schools to serve as a test bed for national implementation.

1.3 Objectives

- Promote and support partnerships within and among academic institutions, business, industry professional engineering societies, and the workforce that have a stake in undergraduate computing education.
- Develop a process by which all partners understand each others' perspectives and feel ownership of both the process and outcomes to promote reform institutionalization.
- Integrate undergraduate computing education vertically through the engineering curricula.
- Identify and implement new models for undergraduate computing education in the engineering disciplines that are replicable across programs and institutions and that could be adopted at other institutions nationwide.
- Engage administrators and faculty across engineering disciplines in transforming undergraduate computing education based on identified needs in mid-Michigan.
- Promote organizational change in the participating academic institutions to ensure sustainability.
- Contribute to the development in mid-Michigan of a diverse, agile workforce with the computational problem-solving knowledge essential in a global context.
- Engage national leaders through CSAB, CAC and ABET to ensure a continuing focus on innovation within computing education consistent with accreditation criteria.

1.4 Anticipated Outcomes

- Develop a process for engaging higher education and community stakeholders to come together to explore common interests, share lessons learned and identify promising practices around computing knowledge and skills development and the application in terms of business and economic development.
- Devise a work plan that identifies stakeholders and outlines the process for engaging those stakeholders. Survey and interview instruments will be developed for determining stakeholder assessments of computational skills.

- Develop a list of employers and members of professional engineering societies who are interested in participating and willing to be interviewed and surveyed regarding their perceptions of the computational skills needs in their business sectors.
- Survey working engineers and members of professional engineering societies to understand their perceptions of workforce computational needs.
- Identify key computational problem solving skills in these business sectors.
- Abstract the computing principles and concepts and review them for alignment with the computational problem solving skills.
- Disseminate the findings and engage the stakeholders in dialogue through face-to-face forums, web sites, webinars, wikis and blogs to document the engagement process.
- Evaluate the project model and prepare reports of each phase of the activity.
- Engage a wider set of stakeholders in the preparation and submission of a full implantation CPATH Transformation (T) grant.

2 Implementation Plan

2.1 Transformation Model

The *Transformation Model* we propose is depicted in Figure 1. This is a cyclic model with feedback among the five major nodes. The primary focus of this CB project is on the *Identify Specific Workforce Computational Skills* node. Hence, we have shown a more detailed breakdown of the various stakeholders groups involved in that process. The node and processes that are shaded will not be addressed in this project; we will address these in the subsequent Transformation (T) proposal.

- The process begins by bringing together representatives from the various *Stakeholders* who come together to *Identify Specific Workforce Computational Skills*. We expect that these will vary widely by stakeholder sector and even within sector.
- The next step is to *Abstract Computational Problem-Solving Principles* from this list of discrete skills. These principles are then checked among the various stakeholders to confirm that they capture the important skills. Since the principles are intended to capture a wide range of skills, they should be broader and more generalizable than individual skills. This should allow stakeholders to see possible new connections that could help them fulfill their particular needs in new ways.
- Next, we *Align Principles with Computer Science Concepts* to map the problem-solving requirements onto the underlying computer science concepts that are the foundation of computer science curricula. This alignment is checked against the desired skills. This not only verifies that this abstraction is congruent with the desired skills, but the underlying concepts may suggest needs for future skills that are likely to emerge in the information-rich workplace of the future.
- From here we *Identify Opportunities for Curricular Integration* that fit between the computer science concepts and engineering curricula in other departments. The abstract

concepts begin to align with disciplinary problem-solving that addresses the eventual workforce needs.

- The final step in the cycle is to *Implement Computational Problem-Solving Revisions* in both computer science and other engineering curricula. We envision revising curricula across courses in multiple engineering departments to incorporate computational problem-solving tools within the various disciplinary contexts. From here, graduates enter the workforce, bringing the improved computational problem-solving knowledge and skills. Given the rapid pace of technical change, the transformation process would continue, with increasingly better integration across all phases of the model.

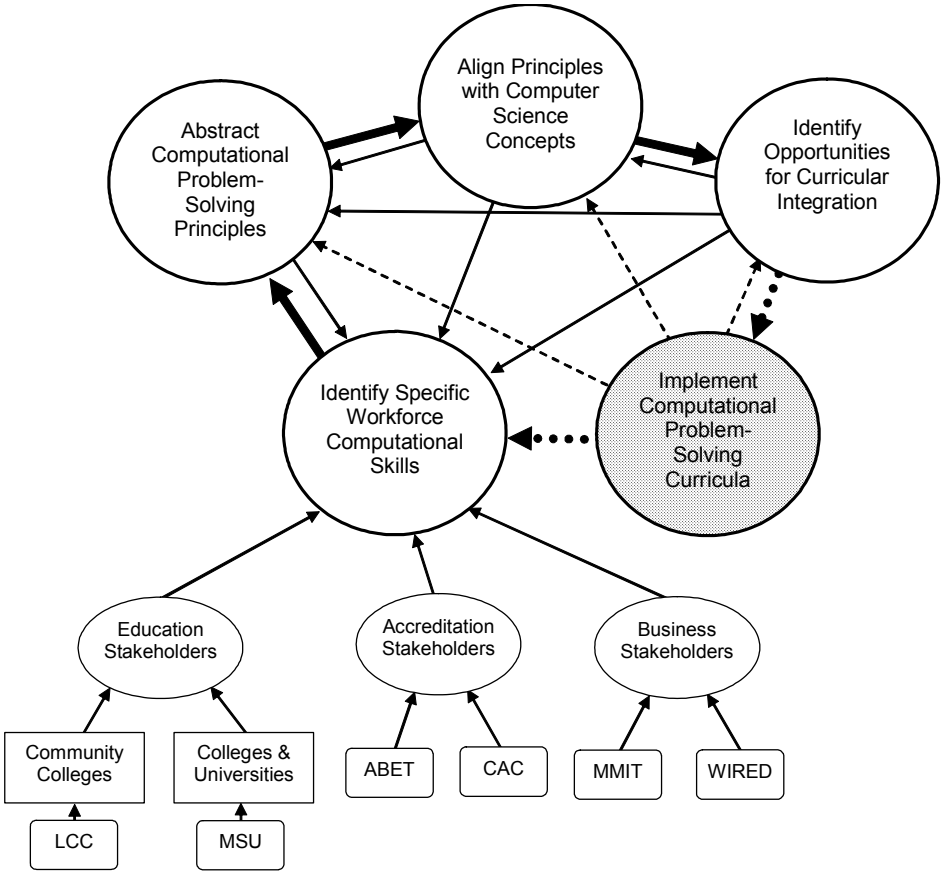

Figure 1: Transformation Model

The Transformation Model provides a framework that allows all stakeholders to see the interrelationships among what have, up to now, been discrete activities. The goal is to help each of the stakeholders view their needs in the context of this larger framework and to find ways to better engage all stakeholders in the entire process. For example, employers will understand that faculty design curriculum based on the underlying principles and concepts of a discipline, not simply to fill a workforce need. Faculty will view workforce skill requirements in the context of computer science principles and concepts and identify opportunities to integrate these principles into other disciplines to support computational problem-solving.

2.1.1 Current Practice in the Context of the Transformation Model

How does this Transformation Model compare with current practice? Current practice often isolates specific nodes of the process, ignoring the realities – and even the existence – of the other nodes. For example, reports on workforce development may *Identify Specific Workforce Computational Skills* needed by the workforce. These may be generalized to "improved STEM education" (e.g., National Center on Education and the Economy, 2007) but they have no connection to the reality of how curriculum is developed in higher education.

Computer science (CS) curricula are driven by *computer science concepts* as identified by CS faculty. For example, the current curriculum recommendations for computer science start with principles; identify the core CS body of knowledge; move to curricular models; and then lay out a set of courses to address the curriculum (IEEE Computer Society & Association for Computing Machinery, 2001). The first principle for curriculum design defined in this document is "the curriculum must reflect the integrity and character of computer science as an independent discipline" (p. 75). Nowhere in the curriculum design principles is it suggested that the CS curriculum address particular, or even general, workforce needs.

As for integrating computing principles and concepts into other engineering disciplines, this often takes the form of requiring computer science courses for students in other engineering disciplines. There is little interaction between the faculty teaching these computing courses and the faculty from other departments who teach the courses in which students are expected to apply what they know about computing in the context of other disciplines.

2.2 Expertise and Capacity of the Proposing Team

We have assembled a team with the breadth and depth of expertise necessary to address these shortcomings and find innovative approaches to transforming the engineering workforce in mid-Michigan. The partners in this project represent the major stakeholders and have the experience and established relationships necessary to successfully implement this project.

2.2.1 Michigan State University

As the only land-grant institution in the state, Michigan State University is committed to providing equal educational opportunity, extending knowledge to all people in the state, melding professional and technical instruction with quality liberal education, expanding knowledge as an end in itself as well as on behalf of society, emphasizing the applications of information and contributing to the understanding and the solution of significant societal problems. Moving beyond outreach to community engagement is a touchstone of the university's *Boldness by Design* initiative. MSU is represented in the project by the following team members.

Thomas F. Wolff (PI), Associate Dean for Undergraduate Studies, College of Engineering, represents the college administration and will oversee the project. He will help build upon the existing partnerships between the College of Engineering faculty and engineering workforce stakeholders to extend stakeholder participation. Dr. Wolff is an award-winning teacher and experienced undergraduate administrator. He is a three-time winner of the Michigan State University College of Engineering's Withrow Teaching Excellence Award, and a Great Lakes Region winner of the Chi Epsilon Harold Robbins Teaching Award. He has been involved in curriculum development for over 18 years, with much service on the College of Engineering's

Curriculum Committee, both as Chairperson while a faculty member and as Secretary and Ad Hoc member while serving as Associate Dean. This included serving as Chairperson during the planning of the 1992 calendar conversion from quarters to semesters when the entire engineering curriculum was re-worked. He is presently leading an effort to develop a new and intensive first-year engineering program. His computing background spans from developing plotter graphics applications on 8K mainframes in FORTRAN II to developing applications for practicing engineers using advanced spreadsheets and Visual Basic. He has had a long interest in computing applications in teaching and practice, and is the author of Spreadsheet Applications in Geotechnical Engineering.

The **four co-PIs from Michigan State University** are an interdisciplinary group of faculty who are members of the *Engineering Pedagogy Research Group*. They have worked on a variety of cross-departmental efforts to integrate computational tools across the engineering disciplines (Briedis, Miller, Ofoli, Sticklen, & Urban-Lurain, 2006; Briedis, Urban-Lurain, Ofoli, Miller, & Sticklen, Accepted; Hinds, Sticklen, Urban-Lurain, Amey, & Eskil, 2005; Sticklen, Amey, Eskil, Hinds, & Urban-Lurain, 2004; Sticklen & Urban-Lurain, 2006; Sticklen, Urban-Lurain, Briedis, & Hinds, Accepted; Sticklen, Urban-Lurain, Hinds, Eskil, & Amey, 2005; Urban-Lurain, Amey, Sticklen, Hinds, & Eskil, 2004; Urban-Lurain, Sticklen, & Buch, 2006). The co-PIs will form the core group of MSU faculty for this project.

Daina Briedis (co-PI), a faculty member in the Department of Chemical Engineering and Materials Science, has been an AIChE program evaluator for chemical engineering programs since 1987, and served as an accreditation team chair (leader) from 1998 to 2003. In 1997, she was elected to the ABET Engineering Accreditation Commission (EAC), and later served on the Executive Committee of that body. As a member of the Executive Committee, she was appointed as Chair of the Training and Materials Development Committee. From 2003 to 2006 she served on the Board of Directors of ABET. She is a consultant for accreditation for engineering programs in the U.S., has consulted with the Japanese Accreditation Board for Engineering Education, and has also participated in accreditation training workshops internationally and around the U.S. She is currently serving ABET as Adjunct Director of Training. As part of the Engineering Pedagogy Group, Dr. Briedis is studying the effects of vertical integration of computational tools in the chemical engineering curriculum. She is also directly involved in the planning and implementation of a college "cornerstone/capstone" initiative for a novel freshman residency program at Michigan State.

Neeraj Buch, (co-PI), Associate Professor and a Researcher in the Pavement Research Center of Excellence, Civil and Environmental Engineering Department. Dr. Buch received his doctorate degree in Engineering from Texas A&M University in 1995. He has managed over $1,000,000 worth of concrete pavement research sponsored by MDOT, NCHRP and FHWA. Dr. Buch has over 12 years of industrial, research, teaching, outreach, and consulting experience. He is secretary on the ACI committee 325 (Rigid Pavements), force chairman of ACI committee 325-34 on Concrete Pavement Repair and Rehabilitation and a member of the TRB the committee on Pavement Rehabilitation. In the past three years Dr. Buch has taught several outreach classes in the area of pavement design, rehabilitation and management through the Highway Traffic and Safety Program (HTSP) (funded by partially by MSU and the State of Michigan. Dr. Buch has integrated computational tools into the introductory undergraduate CEE Statics courses.

Jon Sticklen (co-PI), is an Associate Professor in the Department of Computer Science and Engineering, College of Engineering, Michigan State University. His research in knowledge-

based systems has emphasized an articulation between applications development and needs-driven theory advancement, particularly in task-specific architectures and function-based reasoning. Applications areas have included troubleshooting for high performance aircraft, landscape level ecological modeling, and automated support for materials systems design and manufacturing planning of integrated structures made from polymer composites. More recently, Dr. Sticklen's major focus has been on pedagogical issues, and in particular on the pedagogy of first year engineering. Currently, Dr. Sticklen is one of the principles in efforts to plan and implement a "cornerstone/capstone" initiative with the MSU College of Engineering which may culminate in the establishment of a undergraduate residency program at Michigan State. Dr. Sticklen currently serves as a program evaluator (PEV) for CAC/ABET.

Mark Urban-Lurain (co-PI), Director of Instructional Technology Research and Development, Division of Science and Mathematics Education, College of Natural Science. Dr. Urban-Lurain provides vision, direction, planning and implementation regarding the use of technology in instruction of mathematics and science. Prior to joining the DSME, he was in the Department of Computer Science and Engineering where he collaboratively developed several award-winning introductory computer science courses. He and his colleagues pioneered elements of the curriculum development process that would become the Transformation Model as part of the design of a large (4000 students/year) introductory computing course in which they interviewed the chairs of 67 departments across the MSU campus to understand the students' computing needs, then abstracted the computing principles and concepts identified in those interviews to create a course that gives students a broad overview of both the concepts and competencies of computing needed to solve problems, including "focal problems" integral to their major fields of study (Urban-Lurain, 2003; Urban-Lurain & Weinshank, 1999, 2000, 2001).

2.2.2 Lansing Community College

Lansing Community College (LCC) has a long history of partnering with private and public industries in Michigan. LCC actively seeks these relationships to serve student and community needs. Divisional missions provide students with the opportunity to actively shape the future, provide state-of-the-art education and training programs in technology, and provide individuals the opportunity to access and develop the knowledge and skills essential for transition to employment, and the opportunity for life-long training and retraining in a constantly changing job market.

Partnerships with industries are essential so that students can be properly prepared for the workplace of tomorrow. In 2005-2006, the faculty of the Mathematics/Computer Science Department, Liberal Studies Division, at LCC developed their strategic plan. One resulting goal states, "Activities will be developed and implemented to increase student confidence in and awareness of application of mathematical skills and workplace competencies in other courses and the workplace." LCC faculty believe that critical thinking and problem solving skills are essential in today's workplace and that they need to continually stay current relative to the needs of the future employers of both transfer students who obtain a four-year degree and those students earning associate degrees in technical areas. In addition, faculty in the LCC Technical Careers Division have experience piloting new programs such as the one involving alternative energy. All LCC students must be committed to life long learning as technology changes and the LCC faculty work to remain aware of these changes. Participating in this CPATH project allows Lansing Community College another opportunity to work collaboratively with Michigan State

University and new opportunities to work with Corporation for a Skilled Workforce and other businesses.

Louise Paquette, (LCC PI), is a professor at Lansing Community College in the Mathematics and Computer Science Department. Professor Paquette collaborates with the MSU co-PIs as part of the MSU Engineering Pedagogy Research Group. She has a long history of integrating technology into her courses: the graphing calculator and mathematical software in calculus courses; and Geometer's Sketchpad in a geometry course. Instructions for using the appropriate technology have been developed by Professor Paquette both independently, and in conjunction with other faculty. She has developed activities and group projects involving practical applications to promote collaborative learning. Goals of these projects/activities include increasing the students' abilities to use technology to solve problems, and development of their critical thinking skills. In 2006 she developed a new course to teach technical problem solving using MATLAB. Professor Paquette is the coordinator of the 2+2+2 Engineering Program, a collaborative effort between the Lansing Public School system, Lansing Community College, and Michigan State University involving students from the three Lansing High Schools. Her responsibilities include: ensuring they have a smooth transfer to MSU's College of Engineering; mentoring and advising the students while they are at LCC; and arranging tours of relevance at MSU, at LCC, and at local industries. She will be directly responsible for managing LCC portion of the project including the involvement of other LCC professors and coordinating with the other project leaders.

2.2.3 Corporation for a Skilled Workforce

Corporation for a Skilled Workforce's (CSW) mission is to re-imagine everything about work and learning in the global economy, for the prosperity of people, firms and communities. The CSW team brings over extensive experience leading workforce development change at the national, state, and local level. CSW has undertaken projects in 45 states and hundreds of communities across the country, helping to align workforce, community and economic development strategies.

Community engagement is one of the cornerstones of CSW's approach. As such, a large number of CSW's projects require skilled facilitation to aid various stakeholders in the understanding of each other's concerns and finding of common ground. As relevant to this proposal, CSW is supporting overall management of the Mid Michigan Innovation Team (MMIT)/ Workforce Innovations in Regional Economic Development (WIRED) initiative, with specific emphasis on governance, connecting new partners, communications and facilitation aimed at shared learning, public choice making, and structural transformation. We have included letters of support from several MMIT/WIRED partners in the supplementary documents.

2.2.4 Accreditation

It would be counterproductive to propose curricular redesign without accreditation considerations, particularly given the relatively recent commitment of the Computing Sciences Accreditation Board (CSAB) to outcomes-based accreditation. **Albert Joseph Turner, Jr**. will be a consultant to this project to ensure alignment with the evolving CSAB/CAC criteria. Dr. Turner has served as the Chair, Computer Science Accreditation Commission (1988-90); President, Computing Sciences Accreditation Board (1991-93); Executive Committee Member and Training Chair, Computing Accreditation of ABET (2005-present); and Chair of 14

evaluation teams for ABET and CSAB. He has consulted on academic programs for Boeing Corporation and on 14 program evaluations for individual universities and seven for state higher-education agencies. The new CSAB/CAC criteria will not constrain the process in any way, but will allow some measure of filtering for the compatibility of the process outcomes with criteria requirements. It is important to note that the contribution from ABET to this project is only through faculty volunteers who have a particular interest in this project. Drs. Briedis and Turner's involvement in this project does not represent an endorsement of this work from ABET, but is included to maintain relevance and consistency in proposed curricular changes and their ability to fall within the constraints of the relevant accreditation criteria.

2.2.5 Science and Mathematics Program Improvement

Evaluation and assessment are crucial to understanding this project, for planning the full Transformation (T) proposal and to disseminate the results. A team from Science and Mathematics Program Improvement (SAMPI) at Western Michigan University will serve as external evaluators. **Mark Jenness**, SAMPI Director, will serve as lead evaluator. SAMPI has extensive experience evaluating STEM higher education and K-12 education projects, including those focused on engineering and technology. Current SAMPI projects include serving as evaluator for the Michigan Louis Stokes Alliance for Minority Participation (MI-LSAMP), a consortium of engineering faculty across four Michigan universities; an NSF STEP project focused on recruiting and retaining engineering students; and an NSF ITEST project fostering technology use in implementation of research projects by teams of high school students.

2.3 Results from Prior NSF Support

HRD-0503316: 05/2005 – 10/31/2010, $1,001,604 (to date), "Michigan Louis Stokes Alliance for Minority Participation." Mary Sue Coleman (PI), Levi Thompson (Co-PI), Ralph Kummler (Co-PI), Edmund Tsang (Co-PI), **Thomas Wolff** (Co-PI)

The University of Michigan, Western Michigan University, Michigan State University and Wayne State University were awarded funds to form the Michigan-Louis Stokes Alliances for Minority Participation (MI-LSAMP) in order to significantly increase the quantity and improve the quality of students earning science, technology, engineering and mathematics (STEM) baccalaureate degrees. The overall goals for the MI-LSAMP are to:

1. Significantly increase the number of URM students earning baccalaureate degrees from MI-LSAMP partners.
2. Institutionalize MI-LSAMP strategies and practices.
3. Contribute to a significant increase in the number of under-represented minority students earning baccalaureate degrees in the State of Michigan and nationally.
4. Increase the number of students pursuing advanced degrees in STEM fields.

To date, the project has engaged students on the four campuses in pre-first year summer bridge programs, tutoring, social networking, and is beginning to provide undergraduate research opportunities.

EEC-9872431: 9/15/1998 -9/14/2004, $300,000, "Multidisciplinary Bioprocessing Curriculum." R. Mark Worden (PI) and **Daina Briedis** (co-PI)

This project developed curricula to train senior undergraduate and graduate students from engineering and the biosciences to work together effectively in multidisciplinary teams on biotechnology-related projects. The goal of this program was to produce a diverse group of Ph.D. scientists and engineers having broad training relevant to the biobased-products industry. The objectives were (1) to develop a novel Multidisciplinary Bioprocessing Laboratory (MBL) course for senior undergraduates and beginning graduate students, and (2) to integrate the MBL course with existing course work to obtain specific curricula (e.g., options) in the participating departments relating to bioprocessing. Objective 1 was satisfied through the development of the MBL course, in which multidisciplinary student teams conduct a mentored semester-long research project in the lab of a faculty advisor. Objective 2 was satisfied through the development of a new Multidisciplinary Graduate Training Program in Technologies for a Biobased Economy (www.egr.msu.edu/bio/tbe.html). Fellowship support for the Program was recruited through a Department of Education GAANN grant and a Department of Energy BPI grant. In addition, the MBL course has been adopted as a required course for the M.S. Professional Degree in Microbiology, and fulfills a requirement for the Biochemical Engineering Option in the Chemical Engineering B.S. Program.

Resulting Publications: Over ten publications resulted from the grant.

DUE-0618501: 01/01/2007 – 12/31/2008, $418,984, "FIRST III - Faculty Institutes for Reforming Science Teaching: Developing the Scholarship of Scientific Teaching." Diane Ebert-May (PI) and **Mark Urban-Lurain** (co-PI).

The goal of this project is to develop a database for storing student assessment data to provide a data repository for faculty who wish to study student learning in undergraduate biology. During the project we intend to 1) establish a prototype assessment database for student learning outcomes from courses and curriculum in undergraduate biology and 2) develop an educational metadata language for assessment derived by a national pool of faculty. The project is just beginning at the time of this proposal submission, so results are not yet available.

2.4 Activities to be Undertaken in this Project

As this is a proposal for a Community Building grant, we will not implement the entire Transformation Model. Specifically, the activities in this project will address these nodes:

- Identifying Specific Workforce Computational Skills
- Abstracting Computational Problem-Solving Principles from those skills
- Checking the principles for alignment with Computer Science Concepts
- Identifying opportunities for curricular integration

This will lay the groundwork for a CPATH Transformation (T) Project proposal that will allow us to realize the full vision outlined in the Transformation Model.

We propose a model to build and engage a community of stakeholders around the issues of computing education to better prepare students for employment within engineering and

technology fields. The Project Timeline appears in the supplemental documents. The major activities will be:

2.4.1 Convene a Steering Committee

The first stage involves convening a steering committee charged with refining and implementing the process for involving a wider group in dialogue and community building. The steering committee will develop a work plan for engagement with a larger group of organizational representatives who have a stake in the future of computing skills within the engineering and technology fields. This committee will consist of 10-20 representatives from a cross-section of engineering and computing technology stakeholders, including academia (university and community colleges), engineering societies, business/employers and workforce and community/economic development experts. Examples include: Michigan State University, Lansing Community College, Corporation for a Skilled Workforce, Dow Chemical, General Motors, CSAB and other engineering societies within the Mid-Michigan region . The goal is to create a steering committee with knowledge of current computing practices and likely future needs within academic and professional settings.

This steering committee will have three primary tasks:

- Identify the persons to engage in the larger community building activities. Corporation for a Skilled Workforce will have suggestions for those persons and organizations that are affiliated with the WIRED initiative; the professional society representatives will be able to identify companies within the region that would be interested in participating; and the MSU and LCC faculty will be able to recommend other faculty to involve in the process.
- Devise processes to promote dialogue among this group of larger stakeholders. This process will build upon existing WIRED stakeholder engagement and be extended to directly include faculty participation.
- Develop protocols for interviewing stakeholders at engineering and technology companies in the region and developing the surveys for both employers and engineering/technical employees within the Mid-Michigan region. We will use alumni surveys developed by the MSU College of Engineering as part of the ABET process as a starting point.

2.4.2 Engage Engineering and Technology Stakeholders

The steering committee will coordinate the effort to identify and engage engineering and technology company executives and human resources professionals in this initiative. The committee will contact employers in the WIRED region to identify the computing needs for their employees. MSU and CSW will coordinate these efforts. The actual activities involved with this phase of the initiative will include phone calls, emails, and in-person meetings to discuss the purpose of the project and its goals. We will identify business stakeholders to interview as well as employers who will allow us to survey their employees regarding their computing education and preparation for the workplace.

Corporation for a Skilled Workforce will contact partners in the Mid-Michigan WIRED Initiative including other academic institutions (i.e. Saginaw Valley State University, Mott Community College, etc), employers (i.e. Dow Chemical), and organizations that are connected to employers in the region (i.e. chambers of commerce, Michigan Manufacturing Technology Center, and Center for Automotive Research). These organizations will be asked to act as intermediaries to

broaden the reach of this community-building effort. Since community engagement is a basic principle of the WIRED initiative, it makes sense to leverage these established connections.

We will work with engineering societies and their members to increase the number of engineering and technology companies involved in this initiative. Finally, the academic members of the steering committee will work with companies that employ their students and support their internship and cooperative education programs.

2.4.3 Survey Engineers and Members of Professional Engineering Societies

Workers are key stakeholders, and we want to understand what people working in engineering and technology feel are the strengths and weaknesses of their undergraduate computing education. We will conduct electronic surveys of 200-400 employees of participating companies as well as leaders and members of the professional engineering societies. This two-pronged approach will allow us broad reach into the field within the Mid-Michigan region. The surveys will

- Determine the extent to which current employees feel college prepared them for computational problem-solving needed on the job
- Identify educational experiences students found best prepared them for computational problem-solving
- Identify current and future computational problem-solving gaps based on employees views of future needs and trends
- Explore the relationship between higher education institutions, employers and students/employees in their efforts to promote improved computational problem-solving.

The process of conducting surveys and interviews will be iterative. We will use initial results of the surveys to help refine the interview protocols.

2.4.4 Interview Representatives of Engineering and Technology Companies

We will interview either the head executives or human resources executives (or both) to understand their employees' use of computer technology and the computational skills needed in their businesses. We will seek to understand whether they see the higher education institutions sufficiently preparing their employees to meet the computing challenges they face and what recommendations for improvements that might be made. Overall, we anticipate completing approximately 20-25 interviews.

2.4.5 Identify Key Computational Problem-Solving Skills

We will analyze the surveys and interviews to identify clusters of computational problem-solving skills that the various stakeholders see as crucial for engineering. A working group consisting of computer science and other engineering faculty along with representatives from employers, engineering societies, and the CAC of ABET will map the various skills identified in the surveys and interviews into clusters by employment sector and provide the foundation for abstracting computational problem-solving principles.

2.4.6 Abstract Computing Principles

Key to preparing students to integrate computing technology for problem-solving is to connect specific skills to the underlying computing principles and concepts of which they are instances. This is what distinguishes *training* on computer software, where each software change requires subsequent re-training, from education that prepares a workforce that can apply the underlying principles to connect new tools in new ways to solve new problems (Committee on Information Technology Literacy, 1999). Abstracting the skills identified in the previous step and mapping them to computing principles will allow the mapping of skills to principles to be checked among the various stakeholders to confirm that they represent the important competencies needed. This should allow stakeholders to see possible new connections that could help them fulfill their particular needs in new ways.

2.4.7 Disseminate the Findings and Engage Stakeholders in Dialogue

Sharing the experiences and outcomes of this project with the wider community of potential stakeholders will be crucial for engaging additional participants. Since this project will be articulating with the WIRED initiative, we will coordinate with other WIRED events to share the results of this project.

We will hold a forum with all of the higher education institutions in the Mid-Michigan region. Engineering faculty will be key participants in this forum, since faculty are crucial in any curricular reform efforts. Bringing together engineering faculty from the institutions that participated in this project along with those from other higher education institutions in mid-Michigan, will allow an exchange of ideas about how they can learn from the employers in the region and from one another, to enhance their curricula for computing education in engineering.

We plan to facilitate engagement opportunities that will allow employers to communicate with one another, members of the steering committee, faculty and other project stakeholders, about the outcomes of this project. These opportunities will also allow employers to engage with higher education institutions, promote faculty buy-in through cognitive institutionalization, and facilitate collaboration to improve undergraduate computing education.

We expect the development of a dynamic process to be a major outcome of this project and will capture the process by using collaborative, dynamic media, such as wikis and blogs, to document not only the final findings, but the process by which these findings emerged. These electronic artifacts will not only reflect the community from which they emerge, but will also act as a data source for research and evaluation of the process. We expect the analysis of these data to be crucial to developing a complete implementation plan and to engaging a wider stakeholder community.

2.4.8 Evaluate the Project Model and Outcomes

The purpose of the evaluation will be to 1) determine progress toward project goals; 2) document project activities, processes, and products; and 3) provide evaluative data to the project team for planning and project improvement. Additionally, evaluators will help prepare a comprehensive evaluation plan for future implementation grant proposals. The evaluation will be framed by the following key evaluation questions:

1. What have been the nature, extent, and effectiveness of the collaborative approach used in carrying out this planning grant? What are its strengths and limitations?

2. Do final curriculum plans reflect project objectives and anticipated outcomes for the various stakeholders—higher education institutions, faculty, students, business community, and professional organizations?
3. Have products, including implementation grant proposal, been prepared as intended?

Evaluation will be used to help strengthen the planning process by providing data to the coordinating staff and an external assessment of progress toward goals. The evaluation will document project activities and processes, gather information from stakeholders, and assess accomplishment of objectives. Both qualitative and quantitative data collection and analysis procedures will be used, including surveys and interviews of stakeholders, observation of project activities, and review of materials and products.

Evaluation will be a collaborative effort between project staff, key stakeholders, and external evaluators. Staff will be expected to provide evaluator access to project participants and stakeholders, maintain all project records, document activities, and provide access to program materials and products. Evaluators will prepare data collection instruments and procedures, gather and analyze data, participate in management team activities, observe selected planning sessions and other project activities, and review project materials. Evaluators will prepare reports and provide recommendations as needed. The evaluation team will also work with those developing the implementation grant proposal to prepare a comprehensive evaluation plan. The evaluation will be designed to meet the changing needs of project staff and stakeholders. A detailed task list will be prepared upon awarding of the planning grant.

2.4.9 Develop a CPATH Transformation (T) Proposal for Full Implementation

The final outcome of this initiative is the development of a Transformation (T) grant proposal to complete the remaining aspects of the Transformation Model. One indicator of success for this project will be expanding participation from all of the stakeholder groups to collaborate on the full implementation proposal.

2.5 Revitalization of Undergraduate Computing Education

For engineering education to prepare graduates to flourish in a new global economy, innovation and flexibility in curricular design based on constituency input and quality improvement principles is necessary (Lattuca, Terenzini, & Volkwein, 2006). However, curricular change in higher education requires faculty buy-in through *cognitive institutionalization* (Colbeck, 2002). Faculty must perceive the reforms as 1) consistent with the principles and concepts of their disciplines and 2) as part of the norms accepted by other faculty. Therefore, reform efforts must emphasize *engagement* of higher education and higher education engineering and computer science faculty in the process of regional economic change and school-to-work education (Fear, Rosaen, Bawden, & Foster-Fishman, 2006).

The *process* developed in this project will ensure that a wide variety of stakeholders – business, community leaders and post secondary educators – collaborate to identify workforce computational skills, define how these skills can be integrated across a curriculum, and develop revised curricula that integrates *computational problem-solving* across engineering departmental courses. By documenting, evaluating, and making the process explicit, it can serve as a model for national efforts to revitalize undergraduate computing education in engineering, and should be extensible to other computing education reform efforts.