Establishing a Distributed Community of Educators

Project Summary

We propose to establish a research process around an existing unique and potentially transformative learning experiment. Within this process, we are seeking to answer the following questions:

**Q1:** Does early-curriculum authentic engineering practice enable greater development for engineering students, independent of prior indicators of academic success? **Q2:** Do engineering students who begin college education with such a learning experience, subsequently succeed as well as students in traditional engineering learning settings? **Q3:** How do faculty who practice the integration of first-, second- and third-person research change as educators?

The center of the research activity is an emergent Cal Poly initiative of action research with freshmen that aligns with the growing consensus on the type of education that engineers need: early exposure to practice-based learning; learning settings that cut across disciplines; projects in service to authentic societal needs; collaborative learning with a broad base of stakeholders; focus on self-directed learning. The learning experiment in question is funded separately from this request. We are requesting funding in this proposal to take advantage of this existing research activity setting for answering the questions outlined above and setting up a distributed community of external stakeholders as an interactive body to the research. These stakeholders, expected to be educational practitioners, researchers, business interests, governmental representatives, and non-profit organizations, will be engaged in an on-going dialogue about the learning experiment; this dialogue will be made available in real-time via a web-based interface. In this way, the research observation network will function as a kind of feedback loop of information to the activity center and to the larger education community.

Intellectual Merit

The intellectual merit of the research questions that we are addressing is that they will answer critical questions about the educational efficacy of a learning setting that is largely regarded as effective for engineers, but not studied in depth: transdisciplinary settings involving early exposure to learning to engineer in context. We focus on the development of reflective judgment and changes in leadership profile in both students and faculty. These particular indicators have been shown to foster the habits of mind that are needed for adaptive expertise and service to society. The assessment instruments that we have chosen also enable a meta-analysis of statistical data from much larger populations of both students and educators.

The intellectual merit of creating the transparent research observation network is that it serves a role in engineering education that systems thinkers call “making the system aware of itself.” This approach serves to create a new model of integrating first-, second- and third-person educational research in a way that fosters lasting change at institutions outside of the research center.

Broader Impacts

The integration of research and education is the central theme of the proposed work. Through this practice-based discovery within the distributed network that is created, we hope to demonstrate a new path for systemic change in higher education in general and engineering education in particular. We are looking to demonstrate change in both faculty and students. We will make every effort to recruit students who embody a range of ethnicities and represent a balanced gender mix, as their diversity is critical to the experiment. The proposed research observation network potentially serves as a new type of infrastructure for the engineering education community.
Establishing a Distributed Community of Educators
To study a transformational education experiment

M any see a robust workforce of engineers as vital to the health of the US economy (Augustine 2005; Duderstadt et al. 2008; Moving Forward to Improve Engineering Education” 2007). From this viewpoint, thousands of U.S. educators contribute to the health of the nation by inculcating engineers who are well-prepared to address the technological challenges of the industrial era. However, there is widespread agreement that when we examine the present and possible future scenarios that engineers will encounter, the traditional engineering curricular experience does not sufficiently prepare engineers for the rapid rate of change or the complexity of societal challenges that they will encounter (Engineering 2004; 2020 2005; Board 2005; Sheppard et al. 2009). On top of a technologically-rigorous foundation, engineering graduates need to be creative, agile and self-directed learners, systems thinkers, broadly educated, global citizens who are ethically-grounded and able to work in transdisciplinary contexts (2020 2005). Engineers also must be able to account for the interconnectedness of human activity and the social and environmental systems in which it is embedded. Educating the twenty first century engineer is a tall order.

To address this challenge, Jamieson and Lohmann suggest engineering educators “adopt our time-tested model for scholarly and systematic technological innovations and adapt it to our education innovations.” (p. 4, Jamieson and Lohmann, 2009). Very importantly, they and other engineering education leaders encourage a rigorous research-based approach, “similar to the way in which research is performed and used in traditional engineering disciplines.” (p. 259, (Steering Committee 2006)). In traditional engineering research, one aims to capture a kind of mechanistic understanding that can then be generalized and beneficially applied to larger populations. This type of research seeks to describe phenomena without disturbing it. The researcher places themselves outside the phenomenon being studied. Dowd (Dowd 2010) uses the ideas of Kemmis and McTaggart (Kemmis and McTaggart 2000) to characterize this approach as “third-person research” for its objective positioning relative to the objects of study. It utilizes both quantitative and qualitative observations.

Third-Person research has greatly aided our understanding of how learning is influenced by many individual factors, such as the learners’ self-efficacy (Bandura 1977), motivation (Deci and Ryan 1985), and beliefs about learning (Mueller and Dweck 1998). It has also helped us to better understand how the ecological factors of the learning experience influence the learners’ performance (Assor et al. 2002; Deci and Ryan 1987; Noels et al. 1999; Pintrich 2003).

One of the underlying assumptions of third-person research is that measuring the system does not significantly alter the state of the system being measured. Indeed third-person research is designed to be descriptive. Consequently third-person engineering education research does not change engineering education--that is, the third-person research approach creates the condition that Area 2 of the IEECI request for proposals attempts to address: the inability of this type of research to bring about widespread change within the engineering education system.
The paradigm of “independent observer” in third-person research requires that we assume the observer (subject) and the observed phenomena (object) are causally disconnected. This is the fundamental basis for an empirical approach and third-person research and teaching. Whereas this approach is fitting and even necessary for technical procedures, it is not suited to working with the dynamics of a human system. We aim to equip all engineering students, regardless of year, engineering degree program, or institution, with the knowledge, skills, and personal networks to make creative contributions to the advancement of sustainability within the engineering discipline—professionals who are better able to serve humanity through a more holistic development and a stronger capacity to innovate.

Proponents of third-person research approaches may counter argue that the insights provide a kind of direction for change. In other words, understanding the underlying mechanisms enables one to intervene toward predictable outcomes. This ability to manipulate/control the system is the value of mechanistic understandings that are generalizable and scalable to larger populations. However, humans and human systems do not function mechanistically. By way of analogy, one would not try to describe or predict the orbit of a celestial body by using the principles of quantum mechanics. Similarly, no additional application, improvement, knowledge, or quantity of a mechanistic approach to a human or living system, such as a classroom, community of educators or learners, or organization, will ever be sufficient to transform that same system.

As others have asserted (Torbert 1981; Greenwood and Levin 2005), third-person research is necessary to reveal a kind of situational evidence for change within learners (both students and faculty), yet it is insufficient as an agent of change within the education system. As recognized by social scientists (Dowd and Tong 2007; Reason and Torbert 2001; Boyce 2003), changing a human system comes through awareness of one’s own role in the system by way of an on-going critical self-reflection and experimentation situated in an authentic context. Dowd refers to this as first-person research (Dowd 2010) for its narrative involving the self. Organizational change comes about when members within the system reflectively dialogue around the conflicts that occur within dynamics of the social setting, i.e., through what constructivists call learning (Baxter-Magolda 1999; Wertsch 1985). The process of group learning or organizational learning, is considered second-person research (Dowd 2010), for the second-person narrative surrounding the inquiry. First-person and second-person research is called action research and is designed for the purpose of changing the system from within.

We are quick to point out that first-person and second-person research are also insufficient as agents of systemic transformation in education. We propose that the holistic integration of first-, second- and third-person research practiced in a lived setting of teaching and learning is what is needed to produce change within the engineering education system. Moreover, to address the question of adaptive expertise and the various scenarios considered in The Engineer of 2020, we suggest that the learning environment itself must be actively situated in a larger community setting of practice and action, rather than the abstracted and artificial settings of university classrooms alone.

learning in the research activity center
- favors self-directed learning;
- coached use of open-source learning materials
- addresses authentic needs through the project;
- situated in local community;
- requires multistakeholder, transdisciplinary collaboration and design

With the requested funds, we are proposing to establish a third-person assessment process to complement an internally-funded five-year, first- and second-person action research initiative on a particular transformational learning experiment at our polytechnic university. As depicted in Figure 1, Cal Poly’s learning experiment (commencing in September 2010) serves as the research activity center. It involves the situated practice of design in service to socially-relevant outcomes. It also considers students and faculty as research subjects and fully aware of their participation as such; student learners in the situated practice of transdisciplinary learning for socially-relevant ends and faculty learners in the situated practice of transdisciplinary learning and teaching for socially-relevant ends.
We are requesting funding to establish and support the research observation network depicted in Figure 1. The process we are proposing to create includes multimedia data capture and archival of the learning experience in the activity center. These data will be accessible by a research network of educators external to the Cal Poly initiative. Within this research observation network, individuals will be engaged in an on-going dialogue regarding what is taking place in the activity center. The individuals within the research network will provide real-time feedback into the learning initiative. As part of their participation in the proposed network, they themselves will be involved in action research (first-person and second-person reflection) about the learning experiment. We expect that they may enact change that is locally-situated in their own lives as a result of their participation.

The third-person research assessment process that is proposed serves to create the reference case and means for critical validation of the learning experience and also creates the basis for a larger community learning and transformation process. We believe our proposed structure of real-time dialogue within the network of practice (i.e., first- and second-person research) overcomes the barriers to pedagogical change typically encountered in third-person research.

The research questions that we are addressing in the proposed third-person assessment process are:

- **Q1:** Does early-curriculum authentic engineering practice enable greater development for engineering students, independent of prior indicators of academic success?
- **Q2:** Do engineering students who begin college education with such a learning experience, subsequently succeed as well as students in traditional engineering learning settings?
- **Q3:** How do faculty who practice the integration of first-, second- and third-person research change as educators?

We point out that these questions are not questions about traditional engineering technical competence or the ability to apply math and science, but questions about a type of development shown to be less robust in engineering students compared with other majors (Felder and Brent 2004a), yet critical to the development of learners (Felder and Brent 2004b; Lattuca et al. 2004; King 1994). Within the action research that is be-
ing studied, we are collecting data on facility with traditional engineering science content knowledge. That data will be available as a reference to the research observation network.

Obviously, the proposed research would not be valuable if the educational experiment that is being studied is not worth studying from an engineering education standpoint. In the following sections we provide detail on the experiment itself.

The research activity setting: a potentially transformational experiment

Recent discoveries provide insight on how the engineering learning experience could better serve the needs of today’s engineering graduates; both what and how engineering is learned are recognized as important (Jamieson and Lohmann 2009). Practice-based learning pedagogies, such as service learning and project-based learning, have shown promise as a means to enhancing students’ intrinsic motivation for learning and moral reasoning (Coyle et al. 2006; Slivovsky et al. 2003; Harding et al. 2007b). Some, however, are convinced that the magnitude of change required calls for transformational educational practices (Duderstadt et al. 2008; Sheppard et al. 2009).

A group of individuals, lead by the PI (Vanasupa), has been meeting regularly since September 9, 2009 to launch such a transformational education experiment. It is transformational in its integration of first-, second- and third-person research with teaching so that the actual educational research transforms the teaching. What is revolutionary about what we are doing is not any of the pedagogical techniques; it is the application of systems thinking for systemic change.

According to systems theorists (Senge 1990), if repeated interventions in a system do not change the outcome, the interventions area occurring in the wrong part of the system. Engineering education systems are well-known to be resistant to change (Basken 2009; Sheppard et al. 2009, Duderstadt 2008, National Academies 2007), despite many local and national change initiatives since 1990. Although not universally so, many interventions are aimed at changes in content and mechanics. More recently, progressive voices advocate active, service or project-based modes of learning. Systems dynamics theory suggests, however, that for a high-leverage impact, our attention should be on the human part of the system.

The basic principles of dynamic human systems (Senge 1990) are:

- System structure creates behavior;
- We are not separate from the system;
- The problematized phenomena of the system (“symptoms”) are created by the system functioning through our own actions;
- The apparent components of the system dynamically interact.

Because humans are so integral to the behavior of the system (principles b. and c. above), a systemic process of change requires personal and group change—or in other words, first- and second-person action research. The first-person work and activities specifically relate to understanding and being responsible for the bias produced by the enactment of our own assumptions, frameworks, and mental models (Bowers 1990). Most third-person research endeavors operate within an objective paradigm which contains an associated set of fixed assumptions, frameworks, and mental models. Left fixed, the unintended consequences are attempts to solve a problem at the same level of thinking that created the problem.

Second-person research is dialectical, which naturally gives rise to conflict. These conflicts are emphasized and understood as the means for learning and growth. The second person process is therefore directly concerned with building the capacity to be aware of and productively work with such conflicts where they are present.

The pedagogy of the learning experiment is grounded firmly in the theories and practices espoused by John Dewey (Dewey 1938) and Paulo Freiri (Freiri 1968). In our modern-day version, open-source learning ma-
terials (e.g., calculus, physics, chemistry, environmental science) play core roles in students’ self-directed learning. Based on our successes and failures in pilot studies involving over 200 engineering and 30 non-engineering students within the past five years (Vanasupa et al. 2006b; Vanasupa et al. 2006a; Harding et al. 2007b; Savage et al. 2007; Vanasupa et al. 2007; Vanasupa et al. 2008c; Vanasupa et al. 2008a; Vanasupa et al. 2008d; Vanasupa et al. 2008e; Vanasupa and Granados 2008; Zhang et al. 2008; Widmann et al. 2008; Vanasupa et al. 2008; Vanasupa et al. 2009b; Vanasupa et al. 2009; Vanasupa et al. 2010a; Vanasupa et al. 2010b) and the underlying holistic, research-based pedagogy (Vanasupa et al. 2009a), we believe Cal Poly’s education experiment will better prepare students for the complexity and rapid rate of change they will encounter in society. Essentially, we believe the teaching model where a faculty acts as an authorized conduit of information (Figure 2, left) is giving way to the emergent learning model, where students have access to many different sources of information and faculty are co-learners in the context of authentic projects (Figure 2, right).

In Figure 3, we compare characteristics of the traditional engineering educational approaches and the transformational learning experience that is serving as the activity setting for this research. The proposed “emergent design model of education” builds on the PIs past success with a department-level reform grant in which 80% of the materials engineering courses were significantly restructured for design, project-based learning and alignment toward socially-relevant ends (Savage et al. 2007; Vanasupa et al. 2008a). We note that we are not requesting funding in this proposal for the actual learning experiment; we are requesting funding to set up a process to research it using third-person research approaches.

The intellectual merit of the third-person research questions that we are addressing is that they serve to reify the educational benefit of early exposure to learning to engineer in context—a learning mode that has been widely theorized as beneficial (see, for example, Sheppard, et al., 2008), but not systematically researched. Learning in interdisciplinary settings has also been theorized as beneficial (Ivanitskaya et al. 2002; Lattuca et al. 2004) and recommended for engineering (2020 2005). Indeed, interdisciplinary learning with students and faculty of the same epistemological traditions have shown accelerated development of reflective judgment within students (Ivanitskaya et al. 2002; Mansilla and Duraising 2007). To our knowledge, the developmental benefits of this mode of education have not been studied in a transdisciplinary learning context; in fact, those engaged in transdisciplinary research report on the conflicts that are experienced due to the difference in disciplinary cultures (Lele and Norgaard 2005).

The broader impact of creating the proposed research network and associated supporting materials, is that it potentially serves as a new model for conducting third-person educational research in a way that effects change within the educational systems that the participant third-person researchers are embedded. It does so in part by enabling real-time feedback of the research where participants both influence the research and are changed by their participation. This dialogue and associated data will be readily available to any interested parties on a web interface (within the limits set by the Institutional Research Board for
<table>
<thead>
<tr>
<th></th>
<th>traditional model of education</th>
<th>emergent design model of education</th>
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<tbody>
<tr>
<td><strong>intent of education</strong></td>
<td>Learning for the sake of learning or in service to future employment</td>
<td>Learning in service to increased health, happiness and life within community</td>
</tr>
<tr>
<td><strong>learning model</strong></td>
<td>Mechanistic; knowledge built through acquiring subject knowledge in linear order; learning often abstracted from real context.</td>
<td>Relevant learning is best developed through integration of societal and human dimensions and situated in real context.</td>
</tr>
<tr>
<td><strong>learning process</strong></td>
<td>Learning objectives set by faculty for students; faculty design all particulars of coursework (assessment, timeline, class time activities)</td>
<td>Students and faculty establish shared learning goals for themselves within a framework of broad objectives; students and faculty co-create particulars of the learning experience; student, faculty and community members enact experiments for increased well-being.</td>
</tr>
<tr>
<td><strong>outcome</strong></td>
<td>Acquisition of knowledge as evidenced by graded exams or other student-produced products.</td>
<td>Personal agency and mastery as evidenced by living examples of co-created positive community change.</td>
</tr>
<tr>
<td><strong>consequence of learning model</strong></td>
<td>Siloed learning experiences and institutional structure.</td>
<td>Learning experiences that focus on addressing complex (or &quot;multifaceted&quot;), authentic challenges.</td>
</tr>
<tr>
<td><strong>presumed student condition</strong></td>
<td><strong>Deficient:</strong> Students must be directed or manipulated for their own good because they don’t know what is good for them.</td>
<td><strong>Sufficient:</strong> People's desire and ability to learn is innate; it flourishes best through self-direction in environments that support autonomy and where it is safe to “fail.”</td>
</tr>
<tr>
<td><strong>motivation model</strong></td>
<td>Students motivated externally through the threat or reward of grades or future employment opportunities.</td>
<td>Intrinsic motivation to learn fostered through self-selection of projects with personal meaning and relevance.</td>
</tr>
<tr>
<td><strong>faculty role</strong></td>
<td>Creating class particulars (lecture notes, handouts, homework), grading student work.</td>
<td>Locating resources, assisting in self-direction, creating environment where “failure” is a natural part of learning.</td>
</tr>
<tr>
<td><strong>student focus</strong></td>
<td>Re-producing knowledge administered by faculty or re-creating of arguments espoused by faculty.</td>
<td>Personal change and co-creating living examples of greater well-being, analysis of impact of living examples.</td>
</tr>
<tr>
<td><strong>culture</strong></td>
<td>Respect of “authority,” where authority comes with formal title</td>
<td>Mutual respect as cultural norm.</td>
</tr>
<tr>
<td><strong>relationships</strong></td>
<td>Students have a competitive relationship with one another, perpetuated through grading system; faculty have higher status than student; faculty to faculty relationships essentially non-existent</td>
<td>Students, faculty and community members have a collaborative, mutually-respectful relationship with one another</td>
</tr>
<tr>
<td><strong>knowledge</strong></td>
<td>Specialized disciplinary knowledge considered more valuable than “general” knowledge; quantitative data considered objective and more valid than qualitative data.</td>
<td>All ways of knowing, including indigenous ways, are valued; quantitative and qualitative data recognized as having different strengths and used with discernment.</td>
</tr>
<tr>
<td><strong>legitimacy of model</strong></td>
<td>Historical: Used in the past and presumed to provide adequate results.</td>
<td>Grounded in theoretical and empirical findings from a variety of researchers, dating back to John Dewey.</td>
</tr>
</tbody>
</table>

Figure 3. Comparison of traditional educational model and our emergent design model.
experimentation with human subjects). This transparent channel of information flow (i.e., feedback) to the higher education system embodies one of the higher-impact forms of systems intervention proposed by the leading systems thinker, Donella Meadows (Meadows 2008); changing the structure of who has access to what information.

Cal Poly is internally-funding the experiment because it strongly aligns with our strategic plan and we feel it is a valuable endeavor. The faculty/student structure of the experiment reflects a projected lower cost of total faculty salary expenditure per graduating student than the existing, traditional system, so it represents a financially sustainable solution for Cal Poly. We note that Cal Poly is a residential environment with over 90% full-time students. It is also in the lowest 1% for number of engineering faculty to graduating student ratio (~1:14) among the roughly 1500 US post-secondary engineering institutions, i.e., our engineering faculty salary expenditures per graduating students are small compared to 99% of US engineering institutions. Therefore, our new educational model has potential to be economically viable at many other institutions.

**The nuts and bolts of the learning experiment:** (Figure 1., “activity center”)

Table 1 summarizes the institutional context in which the learning experiment takes place. In terms of the structural details of the education experiment, funded and sustained within the existing university budget allocations and independent of this proposal, will annually involve a total of 100 freshmen students recruited from the majors of engineering, agriculture, architecture, liberal arts, science and math, and business college incoming student populations. We will seek to create a holistic balance of students representing different disciplines, ethnicities, and gender identities. While Cal Poly is among the top 10 institutions in the country for number of Hispanic engineers annually graduating, our population of Hispanic students on the whole is only about 20% of the roughly 19,500 students. Preference will be given to students who are underrepresented in their fields of study.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Size</th>
<th>Engineering Ranking</th>
<th>Average Profile</th>
<th>Demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Polytechnic State University</td>
<td>Total: 19,777</td>
<td>4th (among institutions whose highest degree is a bachelors or masters)</td>
<td>ACT: 28</td>
<td>57% male</td>
</tr>
<tr>
<td></td>
<td>Engineering:</td>
<td></td>
<td>SAT: 1275 (reading and math only)</td>
<td>43% female</td>
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<tr>
<td></td>
<td>5,304 (UG)</td>
<td></td>
<td></td>
<td>26% non-white</td>
</tr>
<tr>
<td></td>
<td>246 (grad)</td>
<td></td>
<td></td>
<td>74% white</td>
</tr>
</tbody>
</table>

Each year, a transdisciplinary population of students stratified by SAT scores will be recruited to participate in the learning experience as the test cohort. We note that the learning experience is a kind of “immersion” experience, so that students and faculty coaches are not simultaneously fragmented in their attentions for traditional course demands external to the learning experience. Within the 100-student cohort, teams of various sizes and disciplinary mixes will work in collaboration with community members on local projects. After this freshmen-year immersion experience, students will return to existing curricula in their major. We chose the freshmen year for many reasons, among them is the critical role that early years play in setting the intellectual habits of learners. Another is that the first two years are the most vulnerable for engineering students in terms of attrition; Learning communities formed in the freshmen year aid academic resilience (Leigh Smith et al. 2004; Cress 2008). Figure 4 provides a graphical summary of this learning experience, which will commence in Fall 2010. In it, we are creating an interactive and dynamic learning environment and community, out of which the stakeholders will be engaged in a portfolio of service-based projects. Its faculty and community coaching structure follows the model of highly-effective business teams (Ancona et al. 2002) with two permanent core faculty mentors and one rotating core member and up to 15 different content experts as needed for individual projects. Other members of the mentoring team play different roles according to the needs of the projects.

One of the functional foci’s of these projects is applied sustainability. The execution of these projects will therefore require the direct application of scientific, mathematical and engineering rigor, effective team and community process, and the ability to actively reflect and learn in a self-directed way. The developmental challenges of the project, are consistent with the challenges expected for the 2020 engineer. In fact, many
1-Year of Emergent Design Learning Experience

100 student cohort
- >freshmen
- >multiple majors

faculty & community stakeholders
- >2 core, different colleges (e.g., liberal arts, science & math)
- >3 operational (e.g., statistics, engineering, chemistry)
- >3-15 outer net (e.g., economics, architecture, animal science...)
- >5-15 community partners

FALL
16 student credit units; 12 hours class time/week

WINTER
16 student credit units; 12 hours class time/week

SPRING
16 student credit units; 12 hours class time/week

48 units

Student Credit Units: 16 for personal development, 16 for personal development + collaborative design, 16 for collaborative design, experimentation

Focal Points:
- Foundational knowledge in mathematics, sciences, humanities, business, politics, psychology
- Application of reflexive practice, experimentation
- Learning how to learn, personal development of values, identity, information literacy, systems thinking

Roles:
- Faculty: ensure all are progressing toward established learning goals through interaction and assessment; bring needed intellectual breadth and/or depth to individual projects
- Community: ensure "real world" relevance of projects; participate as co-designers in projects; provide mature perspectives with open-mindedness; partner to locate needed resources
- Student: gain facilitation with open source learning materials; build capacity for self-directed learning

Personal Development (knowledge, skills, attitudes, identity, agency)
Community Collaborative Design (experiments, analysis, re-design)

Figure 4. Summary of the emergent design freshman learning experience.
dimensions of our learning experience align with calls for engineering education to move toward experiential learning, early-curricular engineering, service learning, socially-relevant applications, multidisciplinary team settings, and self-directed learning (Clough 2005; Sheppard et al. 2009; Jamieson and Lohmann 2009).

We acknowledge that engineering freshmen will be limited in their technical foundation. However, the challenges of complex human systems, collaboration in transdisciplinary settings, design for sustainability, and the rapid pace of change are not primarily concerned with either the reception or dissemination of technical material, but with the application of technical material in a lived, necessarily community, setting. Additionally, the PI has four years of experience in service-based freshmen engineering projects (see Vanasupa: Biographical Sketch); her experience is that clients’ needs are most often addressed through innovative designs that draw on freshmen-level understanding of technology. Additional campus expertise was sought when project solutions were outside the scope of students’ level of mastery.

Research Approach

The methodologies, practices and disciplines for the the first- and second-person action research that we will be using the transformational educational experiment are well known (Reason and Bradbury 2008). They are widely utilized in organizational change applied to educational institutions (Boyle 2003; Senge et al. 2000; Senge et al. 1999). Very briefly, for first-person research, one develops a practice of reflection and experimentation with personal change. These practices develop a personal sense of agency, or capacity for change (Popkewitz 2007). As one enters dialogue within a group (second-person research), the capacity for productive dialogue requires an awareness of one’s own mental models (Argyris 1997) and the ability to recognize the mental model of another. It also requires skill with productive dialogue (Bohm 1990) and healthy team dynamics (Ancona and Isaacs 2007).

We are requesting support for the assessment and monitoring process necessary to allow the first- and second-person research approach to be understood and considered at the scale of the 22,000 educators within the Engineering Education community in this country today. Within the limits of the boundaries set by the institutional research board for research on human subjects, we will make this experiment transparent via a web-based interface. This web-interface will function as a real-time dissemination path for research. (We will also disseminate results in traditional journal routes.)

The Research Observation Network: multistakeholders with many competencies

In setting up the Research Observation Network, our intent is to create a community that collectively represents different competencies (e.g., action research, education theory and practice, engineering pedagogy, change capacity). Through an on-going dialogue about the action research of the freshmen-year project, this group will serve as a kind of advisory board. This dialogue and associated data will be readily available to any interested parties on a web interface (within the limits set by the Institutional Research Board for experimentation with human subjects). Creating this transparent channel of information flow to the higher education system is among one of the higher-impact forms of systems intervention proposed by the leading systems thinker, Donella Meadows (Meadows 2008).

We will partner with practitioner researchers who are themselves not part of the core project at Cal Poly in order to assess and monitor the developmental progress of the teachers and students. These individuals will collectively represent a broad body of stakeholders which will include national and international partners. In choosing a broad range of stakeholders, we are following the principles of both sustainable design (Bell and Morse 2007; UNEP 1992) and collaboration for systemic change (Senge et al. 2007).

Table 2 lists potential core members, most of whom are already engaged in the existing learning experiment as collaborators. We note that the network can grow over time. We are particularly interested in the possibility of growing the network with educators outside the core network because we believe the process of changing the larger education system requires growing an integrated, practice-based teaching/research that we are proposing.
Roger Burton (senior personnel) spent the previous 20 years as a high-level consultant to Fortune-20 multinational corporations. His area of expertise is transformational change in large human systems through building individual and collective capacity for learning. He has been working with the PI as a partner in this initiative since late 2008. Mr. Burton currently serves as an executive board member of the Society for Organizational Learning-China and has relocated to the San Luis Obispo area for the purpose of engaging in the five-year transformational education experiment which Cal Poly is launching in Fall 2010. He is also, separate from this initiative, creating a distributed global network of similar experiments by youth leaders, who will be invited as participants in the research network.

**Methodology: addressing the third-person questions**

In each year beginning Fall 2010, the 100 students who choose to be involved in the freshman-year learning experience that is the activity center of the proposed research will serve as the test cohort. One hundred, demographically similar students will be recruited from within the same incoming freshmen class as the “quasi-control” cohort. No interventions are planned for the quasi-control cohort. Students in the quasi-control will be enrolled in traditional curricula. However, we note that Cal Poly schedules incoming freshmen in blocks for the purpose of improving the chances that they will form strong learning communities. Therefore, the quasi-control cohort is likely to be scheduled within blocks. Over the course of the 5-year experiment, a minimum of 500 students are expected to be involved in test cohorts. Within the timeframe of the proposed work, we expect to engage a minimum of 400 students in test cohorts and 400 students in quasi-control cohorts. It is anticipated that a minimum of 100 will be engineering majors. We realize that the test cohort is relatively small and therefore have chosen our research instruments in a way that the results can be compared to larger data sets.

As stated earlier, we will be researching three questions which are re-stated in Table 3. Our assessment around these questions falls in two categories: direct assessment of individual developmental change, and the analysis of proxy measures of academic success longitudinally collected on test and cohort populations.

For the individual developmental change, our intent is to initially assess all students and teachers, engage in a reflective process with regard to the results of the assessment, and reassess each after a year (Reflective Judgment) or four years (Leadership Development Framework). The purpose of this process is to create some longitudinal findings. We will do this with all participants in the project and a control group of students in the ‘regular’ curriculum. Essentially what we are testing and monitoring is whether the active
addition of the 1st and 2nd person methodology as a core part of the curriculum enhances the student’s and teacher’s capacities in the areas of change, innovation, leadership, effective community contribution and the core capabilities of the 2020 Engineer. Table 3 summarizes that types of data that will be analyzed for each of the research questions.

Specifically, we will use the difference in pre- and post-tests scores on the Reasoning about Current Issues (RCI) instrument as an indicator for development after a year. This particular instrument is based on developmental stages of Reflective Judgment researched by King and Kitchener (King and Kitchener 2001). The model is based on John Dewey’s model of reflective thinking (Dewey, 1938) and measures the construct called “reflective judgment.” We chose this particular model because research shows correlations between growth in reflective judgment and growth in multicultural awareness, moral reasoning and tolerance for diversity (King 2000). Reflective judgment is also a core competency in the ability to solve unstructured problems (West 2004). Additionally, the King and Kitchener model has previously been applied in research with science and engineering college students (Felder and Brent 2004a) in larger-scale studies, enabling a meta-analysis of the data within the context of others’ findings. With this data for the test and quasi-control cohorts, we will analyze whether the mean change in score for the test cohort is significantly larger than the mean change of the quasi-control cohort.

A similar treatment will be used with the stages of development in the Leadership Development Profile (LDP). Torbert and others have used this model extensively in the past 20 years for research of adult development (Torbert 1994). Similar to the RCI, the LDP facilitates a meta-analysis of the data in this study against larger populations. However, this particular profile, does not present a simple linear positioning on a development scale, but looks at territories of experience within the development. It is our intent to partner directly with Dr. Torbert for this analysis; we have spoken with his associates and they have agreed to partner with us. However, the scope of the assessment is currently in negotiation. At minimum, the LDP assessment will include core members in the observational network and all engineering students in the test and quasi-control cohorts.

For Q1 and Q3, we would be using the change in development within the RCI instrument and the LDP. For Q1, we would also be looking at whether there were differences between the mean change scores for students within the test groups and within the quasi-control groups, blocked by SAT score ranges. Essentially, we would be asking if there are any differences in developmental change based on prior SAT score. The intent of this analysis is to determine if there is a statistically-significant difference in students’ development when analyzed by SAT score, which is a (biased) proxy measure of academic potential within traditional educational settings.

For Q3, we would look for changes in Reflective Judgment or Leadership Development Profile. The first- and second-person narratives that they would be engaged in would serve as further insight to the quality of any change experienced by the researcher observation participants.

### Table 3. Summary of third-person questions of the proposed research

<table>
<thead>
<tr>
<th>Question</th>
<th>Development of Early-Curriculum Authentic Engineering Practice</th>
<th>Development Instruments</th>
<th>Prior Indicators of Potential Academic Success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Does early-curriculum authentic engineering practice enable greater development for engineering students, independent of prior indicators of academic success?</td>
<td>Reasoning about Current Issues; Leadership Development Profile</td>
<td>SAT scores</td>
</tr>
<tr>
<td>Q2</td>
<td>Do engineering students who begin college education with such a learning experience, subsequently succeed as well as students in traditional engineering learning settings?</td>
<td></td>
<td>Longitudinal retention rate, graduation rate, major GPA</td>
</tr>
<tr>
<td>Q3</td>
<td>How do faculty who practice the integration of first-, second- and third-person research change as educators?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

development instruments: Reasoning about Current Issues; Leadership Development Profile

prior indicators of potential academic success: SAT scores

indicators of academic success: longitudinal retention rate, graduation rate, major GPA
For Q2, we would collect longitudinal data for students in test and quasi-control groups. The data for Q2 will be analyzed in the aggregate for the groups, analyzing mean values between the groups for differences. Dr. Liz Schlemer (co-PI) will oversee the analysis of the quantitative data.

### Timeline

The proposed research will take place in the larger context of the career work of the PIs and collaborators. We include a picture of the previous work here because we believe the success of any change initiative is dependent upon the historical context in which it is situated. In other words, we believe the kind of transformational learning experiment that is proposed requires those involved in the initiative to be an integral part of the existing system of change.

As shown below in Figure 5, the proposed research has its roots in activities dating back to 2003, a period of time when the PI, then department chair, sought to better align her materials engineering program toward societally-relevant ends (See Results from Prior NSF Support). The efforts from 2003 to the present served to build the personal and collective capacity for the current research. Another way of stating this is that the PI has encountered successes and failures within educational reform (Vanasupa 2009; Vanasupa et al. 2008; Vanasupa et al. 2008; Vanasupa and Granados 2008) which serve as learning experiences and contribute to the higher probability of success of the current initiative.

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**Figure 5.** Project timeline (light blue background starting in 2010) and past activities (grey background from 2003 to 2010) that support the proposed work.
Our experience with change in a human systems like the engineering education system is that it relies on both individual and collective capacity for change, as pointed out by organizational researchers (Boyce 2003; Senge et al. 1999). We have therefore endeavored to build this capacity within the educational system of change at Cal Poly within the core members of the change initiative, as indicated in Figure 5, prior to 2010. In the inset, we provide some background on the development of what is called “social fabric” that will contain the action research that is the object of the research proposed. Our purpose in providing this background is to enable the reviewers to better assess the relevance and value of studying the action research.

The initial tasks for the proposed research are to finalize the initial group of individuals within the observational network, set of the web-based interface that will serve as the research database and recruit the group of 100 incoming freshmen who are to serve as the quasi-control group.

During this time period, we will also establish protocols for collecting observational data in the classroom. This might be, for example, taking time-lapsed photography of classrooms for later observation. At first blush, this seems like an odd way to observe a class. However, the PI used this method in the past to reveal changed in classroom engagement dynamics.

Additionally, we will develop research protocols for ensuring ethical treatment of human subjects and anonymity with the data that is made transparent.

As indicated on the timeline, we will host monthly meetings and quarterly reviews via internet tools. Cal Poly has multi-media internet tools that can be used for the proposed work.

We also expect to hold face to face formative assessment workshops every other year at a central location.
Table 4. Collaborators and their affiliations.

<table>
<thead>
<tr>
<th>Community</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roger Burton*, Society for Organizational Learning-China, Board of Directors social enterprise</td>
<td>Sema Alptekin*, Honors Program and Industrial and Manufacturing Engineering</td>
</tr>
<tr>
<td>Jim Cole*, Transition Town-San Luis Obispo County non-profit</td>
<td>Craig Arseneaux, Political Science</td>
</tr>
<tr>
<td>Carolyn Eicher*, SLO-Grown Kids non-profit</td>
<td>Alypios Chatziioanou*, Civil and Environmental Engineering</td>
</tr>
<tr>
<td>Rick London*, CEO, United Way, San Luis Obispo non-profit</td>
<td>John Chen*, Mechanical Engineering</td>
</tr>
<tr>
<td>Jim Patterson*, San Luis Obispo County Board of Supervisors government</td>
<td>Adrienne Greve*, City and Regional Planning</td>
</tr>
<tr>
<td>Ruth Rominger*, Monterey Institute for Technology in Education non-profit</td>
<td>Kate Lancaster*, Accounting</td>
</tr>
<tr>
<td>Pamela Stein*, Transition Town-San Luis Obispo City non-profit</td>
<td>Jane Lehr*, Womens Studies-Ethnic Studies</td>
</tr>
<tr>
<td>Eric Veium*, Transition Town-San Luis Obispo City non-profit</td>
<td>Margot McDonald*, Architecture</td>
</tr>
<tr>
<td>Chad Worth*, Cal Poly Alumnus social enterprise</td>
<td>Neal McDougall*, Agribusiness</td>
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<td></td>
<td>Rob Rutherford*, Animal Science</td>
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<td></td>
<td>Liz Schlemmer*, Industrial Engineering</td>
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<td></td>
<td>Pete Schwartz*, Physics</td>
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<td></td>
<td>Sandy Stannard*, Architecture</td>
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<td></td>
<td>Lars Tomanek, Biology</td>
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<td></td>
<td>Nina Truch*, Communication</td>
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<td></td>
<td>Linda Vanasupa*, Materials Engineering</td>
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<td>Mary Whiteford*, Academic Programs</td>
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<td></td>
<td>Shanrou Ning Zhang*, Political Science</td>
</tr>
<tr>
<td></td>
<td>Also in attendance meetings and contributing ideas</td>
</tr>
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<td></td>
<td>Jeanne-Pierre Wolff, CEO, Wolff Wineries business</td>
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<tr>
<td></td>
<td>Dave Garth, CEO, San Luis Obispo Chamber of Commerce business</td>
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<td></td>
<td>George Work, Roots of Change business</td>
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<tr>
<td></td>
<td>Ermina Karim, San Luis Obispo Chamber of Commerce business</td>
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<tr>
<td></td>
<td>Brian Engleton, Nature School non-profit</td>
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<tr>
<td></td>
<td>Karen Merriam, Sierra Club non-profit</td>
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<td></td>
<td>William Tuclet, BFGC Architects business</td>
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<tr>
<td></td>
<td>Linda Halisky, Dean, College of Liberal Arts</td>
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<td></td>
<td>Phil Bailey, Dean, College of Science and Math</td>
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<td></td>
<td>Kevin Taylor, Kinesiology, California Polytechnic State University</td>
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<tr>
<td></td>
<td>Ann McDermott, Director, STRIDE (public health), California Polytechnic State University</td>
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<td></td>
<td>Mohammad Noori, Dean, College of Engineering, California Polytechnic State University</td>
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<td>Roberta Herter, Education, California Polytechnic State University</td>
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<td></td>
<td>Trevor Harding, Materials Engineering, California Polytechnic State University</td>
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<td></td>
<td>Katherine Chen, Materials Engineering, California Polytechnic State University</td>
</tr>
<tr>
<td></td>
<td>Lynne Slivovsky, Electrical Engineering, California Polytechnic State University</td>
</tr>
<tr>
<td></td>
<td>David Braun, Electrical Engineering, California Polytechnic State University</td>
</tr>
</tbody>
</table>

*Core member of learning experiment
Results from Prior NSF Support

**Triple Bottom Line Awareness in Design (TriAD): Diversifying the engineering profession of the 21st Century**
Department Level Reform Grant#EEC 0530760: September 1, 2005-August 31, 2009 (funding: $1 M)
Vanasaup (principal investigator), B. London, R. Savage, K. C. Chen
California Polytechnic State University, San Luis Obispo, California

This grant provided funds to transform the content and pedagogy of 80% of the major courses in an undergraduate materials engineering (MatE) program. The department-level reforms were aimed at bringing to the forefront the imperative for engineers to place society’s welfare above all other considerations through integrating considerations of social equity and the environment in the traditional engineering design process. There have been four main results from this work to date have been organizational transformation within the department; evidence accelerated student development; establishment of a new community of scholars across the university and with other institutions; and a spread of institutional transformation beyond the department into the Cal Poly College of Engineering. The five faculty involved in this initiative published over 25 manuscripts since 2006 involving this work, many of which are referenced within the text. Table 5 indicates the evidence surrounding the impact of this work. We note that Cal Poly is a primarily undergraduate institution without Ph.D. students.

Table 5. Summary of prior NSF support for L. Vanasupa.

<table>
<thead>
<tr>
<th>Impact</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>materials engineering department transformation</td>
<td>Increase in undergraduate student population from 128 (2005) to over 200 (2009); Use of learning science to convert traditional materials courses into project-based learning courses; Institutionalization of freshmen level design combined with service learning; Net influx of female students from freshman to sophomore years; Awarded Cal Poly President’s Community Service Award; Disseminated results in twelve publications to date (see bios for a brief listing).</td>
</tr>
<tr>
<td>accelerated student development</td>
<td>Significantly higher performance of test cohorts compared to quasi-control groups on a number of constructs shown to critically support self-directed learning, and design, such as intrinsic motivation (Vanasupa, et al., 2007), greater use of peers in the learning process, greater use of integrative cognitive learning strategies as well as content-rehearsal leamintzoral reasoning of the freshmen to that above an adult with a masters degree and slightly below that of an adult with a professional degree (Vanasupa, Harding, Hughes, &amp; Stolk, 2008).</td>
</tr>
<tr>
<td>new community of scholars</td>
<td>Established new research directions with Cal Poly faculty in psychology, ethnic studies, education, political science, history, and art and design; Established new research initiatives with colleagues at other institutions (UC-Berkeley; Carnegie Mellon; Stanford; Yale; MIT; University of South Florida; Michigan Tech).</td>
</tr>
<tr>
<td>wider institutional transformation</td>
<td>Influenced College of Engineering to adopt new vision and mission aligned with serving society through innovation &amp; engineering education; Established college-wide initiative with small groups of engineering faculty to pursue innovations in engineering education.</td>
</tr>
</tbody>
</table>

Collaborative Research: Civil and Environmental engineering Education (CEEE) Transformational Change: Sustainability Curriculum Development, Implementation, Dissemination and Assessment Course Curriculum and Laboratory Improvement, Phase II#DUE 0717428;#DUE0717556: October 1, 2007-October 1, 2011, Linda Vanasupa (PI); (funding $91K).

In this collaboration with Zimmerman (Yale University), Mihelcic and Zhang (Michigan Technological University), and Vanasupa (Cal Poly), the team is developing curricular materials for integrating sustainability concepts into civil and environmental engineering. Its unique feature is the use of Fink’s taxonomy of significant learning as a design guide for the materials and leveraging peer-to-peer networks for learning. The textbook was released in June 2009. They also conducted a workshop for the first two curricular learning suites on Systems Thinking and Sustainability in July 2009 at the Association of Environmental Engineering and Science Professionals Annual Conference. The materials were designed for integration into existing courses. Eighteen of the 20 workshop participants indicated that they were very likely to use the materials in the engineering courses.
References
Duderstadt, J., University of Michigan, and Millennium Project. 2008. Engineering for a Changing World:
A Roadmap to the Future of Engineering Practice, Research, and Education.


