IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Annual Report – Year Five

E2020 Scholars: Advancing the NAE Vision

Report Period: July 2012 – June 2013

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E2020 SCHOLARS PROGRAM

College of Engineering
Iowa State University
Ames, IA 50011

E2020 is supported by a grant from the National Science Foundation

http://www.engineering.iastate.edu/e2020

Participants

Team Members and Collaborators

PI: Diane Rover
Co-PIs: Steve Mickelson, Mack Shelley, Monica Bruning
Engineering faculty leaders: Beth Hartmann, Doug Jacobson, Amy Kaleita, Chris Rehmann
Evaluator: Andy Ryder (RISE)
College staff: Joel Johnson, Paul Castleberry, Tina Prouty, Jane Stowe
Other engineering faculty collaborators: Tom Brumm
Graduate assistant instructors: Mark Laingen, Maggie Mishler
Undergraduate peer mentors: Lauren Nelson, Kurt Lundeen, Elizabeth Mally, Caitlin O'Loughlin, Mark Sanocki
Department staff: Virginia Anderson
Communications consultant: Sandy Jennings-Hammond
Collaborators: College of Engineering Learning Community Task Team

Activities

Overview of Project

The E2020 Scholars Program has provided scholarships for cohorts of undergraduate engineering students within the college's established learning community infrastructure, giving specific attention to the aspirations and attributes of the National Academy of Engineering's (NAE) vision for the engineer of 2020. The project has outlined a set of student development and learning opportunities consistent with the NAE vision. Four E2020 outcomes were identified: leadership, global awareness and understanding, systems thinking, and innovation and entrepreneurship. These outcomes are being integrated into curricular and co-curricular activities. E2020 scholars participate in a learning community, and the four pillar areas of leadership, global awareness, systems thinking, and innovation are introduced in a one-semester first-year seminar and reinforced in a two-semester second-year seminar. These seminars supplement the regular program of study for engineering students. The scholarship program is promoting student engagement and development centered on the E2020 outcomes.

The E2020 Scholars Program is pursuing the goals of the S-STEM program through four objectives:

- Provide leadership development opportunities to greater numbers of students and create learning outcomes consistent with the E2020 vision.
- Engage students in new learning opportunities through cohorts and communities focusing on E2020 concepts.
- Use E2020 scholarships in coordination with programs developed in a related NSF STEP grant, i.e., the SEEC Project (www.engineering.iastate.edu/seec/).
- Use the E2020 focus in coordination with the NSF STEP grant to prepare more graduates to fulfill the NAE and college vision.

The E2020 Scholars Program was designed to leverage two effective programs in the College of Engineering at the time of the proposal: the Engineering Scholarship Program and the Engineering Leadership Program. The E2020 project has benefited from the application of successful, research-based practices, alignment with national recommendations, institutional and team strengths, and expert evaluation.

Three cohorts of scholars were selected, entering fall 2009, fall 2010, and fall 2011. A total of 73 E2020 scholars were named in these cohorts, including 31 transfer students, 25 women, and 12 underrepresented minority students.

Project Management

The project team met as needed to review progress and share information. The principal investigator team worked with college staff to administer the scholarship program. The PI and the associate dean for education communicated as needed regarding financial needs of the program. A graduate student assistant was supported with college funds during year 5. The team also includes an evaluator from ISU's Research Institute for Studies in Education (RISE).

Each pillar area is led by a faculty member outside of the PI team:

- Leadership: Beth Hartmann, Lecturer, Civil, Construction and Environmental Engineering
- Innovation/entrepreneurship: Doug Jacobson, University Professor, Electrical and Computer Engineering
- Systems thinking: Chris Rehmann, Professor, Civil, Construction and Environmental Engineering
- Global awareness: Amy Kaleita, Professor, Agricultural and Biosystems Engineering

The faculty leaders together with the PI, graduate assistant, and peer mentors form the instructional team for the seminar courses. A Blackboard Learn site is used for seminar course materials and assignments and for independent study project information and reporting.

The E2020 Program website, http://www.engineering.iastate.edu/e2020, has been maintained with various scholar and program information. The site will be updated to a final archival version in the coming year with assistance from a communications consultant.

The E2020 Scholars Program has been conducted alongside an NSF STEP-funded project, SEEC: http://www.eng.iastate.edu/seec/, which was in a no-cost extension during year 5 of the E2020 grant.

Scholarship Administration

The College of Engineering scholarship office administers the E2020 scholarships for three E2020 cohorts and works with the university's financial aid office to make awards to students. The College of Engineering has committed to shared financial obligations for the 2009, 2010, and 2011 scholar cohorts.

Cohort and Community Development

The E2020 Program provides scholars an opportunity to develop a community of practice with other scholars, upper-class peer mentors, and engineering faculty who share a

common interest in developing competence related to the four pillars. During year 5, the 2011 cohort participated in the second-year seminar. The 2009 and 2010 cohorts were involved with independent study projects with faculty mentors. More information on the courses and projects is available in the Findings section of this report.

Curriculum Integration

One of the goals of the E2020 program is to identify ways to introduce the pillar topics to all engineering students, not only to E2020 scholars. The logical avenues are through the first-year experience and learning communities, using modules from the seminar courses; or via senior design, similar to the E2020 project-based learning experience.

We have been working with the learning community program coordinators, instructors and peer mentors in the college to share instructional materials for each of the pillars. The faculty leader for the leadership pillar (Hartmann) delivered a two-part workshop during spring 2012. The faculty leader for the systems thinking pillar (Rehmann) delivered a seminar at Iowa State's Learning Communities Mid-Year Institute and a workshop for the College of Engineering's Learning Community Task Team during spring 2013. There was interest in and outside of engineering to incorporate materials, including later in the curriculum.

Integrating E2020 pillar topics, resources and active learning experiences is an ongoing effort by E2020 faculty.

Dissemination and Networking

The E2020 Program was represented by team member Monica Bruning at the inaugural NSF S-STEM Projects Meeting in Washington D.C., October 14-16, 2012.

The following workshops were presented to Iowa State faculty and staff as part of sharing E2020 curriculum innovations and resources:

> C. Rehmann and D. Rover, "Introduction to Systems Thinking," workshop, Learning Communities Mid-Year Institute, Iowa State University, February 1, 2013.
>
> C. Rehmann and D. Rover, "Systems Thinking," workshop, Spring 2013 Learning Community Task Team Retreat, College of Engineering, Iowa State University, May 14, 2013.

The workshop materials will be made available through the E2020 website.

The following paper was submitted and is accepted for presentation at the Frontiers in Education Conference in October 2013:

D. Rover, S. Mickelson, B. Hartmann, C. Rehmann, D. Jacobson, A. Kaleita, M. Shelley, A. Ryder, M. Laingen, and M. Bruning, “Engineer of 2020 Outcomes and the Student Experience,” to appear, ASEE/IEEE Frontiers in Education Conference, October 2013.

Evaluation

Evaluation is led by co-PI Mack Shelley in coordination with Andy Ryder, a research and evaluation scientist from RISE. The evaluators facilitate all evaluation activities involving students as the primary contact with the Office for Responsible Research and the ISU Institutional Review Board.

Data entry at the NSF S-STEM Scholarship Reporting Site was in progress for 2012-13 at the time of this report. This additional reporting requirement is met by using project funds to support data collection and formatting by RISE and ISU’s Office of Institutional Research.

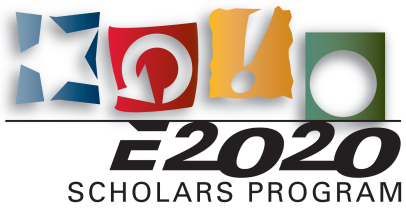
Each cohort is surveyed annually to obtain feedback on student experiences in the E2020 program. Additionally, an exit survey and interview protocols have been developed to collect data regarding program impacts from E2020 Scholars upon graduation from Iowa State University.

Findings

Outputs

E2020 Scholars Program Visual Identity

The E2020 Scholars Program graphical icon depicts the pillars of the program:



Star: leadership
Arrow: System thinking
Exclamation: Innovation
Circle: Global awareness

It continues to be used in program communications, giving the program and scholars a distinctive visual identity. Examples of use include student t-shirts, professional presentations, classroom presentations by students, workshop materials, and letterhead for the independent study project memos.

E2020 Scholar Cohorts

The first scholarships were awarded for a cohort entering fall 2009. A total of three rounds of scholarships have been awarded. The entering cohorts included both direct-from-high-school (DFHS) and community college (CC) transfer students. The statistics for each cohort are summarized below.

- 2009 cohort:
  - 22 total, 14 DFHS students, 8 CC transfer students
  - 4 women and 5 minority students
  - 17 of 21 entering scholars remain in or completed the program.
  - 12 scholars graduated through spring 2013.
  - 86% 3rd year retention in engineering
  - 81% 4th year retention in engineering
  - One scholar changed to computer science; 2 scholars changed to non-STEM majors (economics, history).
  - 90% retention at ISU; two scholars left ISU, including one who transferred to a Colorado university in the same engineering major.
  - One scholar died in a car accident in fall 2010.
- 2010 cohort:
  - 26 total, 12 DFHS students, 14 CC transfer students
  - 12 women and 4 minority students
  - 24 of 26 entering scholars remain in or completed the program.

    - 10 scholars graduated through spring 2013; one scholar entered the concurrent BS/MBA program.
    - 92% 2nd year retention in engineering
    - 81% 3rd year retention in engineering
    - 92% 3rd year retention in STEM
    - 3 scholars changed to non-engineering STEM majors (biology, industrial design); 2 scholars changed to non-STEM majors (elementary education, psychology).
    - 100% retention at ISU
- 2011 cohort:
    - 25 total, 16 DFHS students, 9 CC transfer students
    - 11 women and 3 minority students
    - 24 of 25 entering scholars remain in the program.
    - One scholar graduated through spring 2013.
    - 96% 1st year retention in engineering
    - 88% 2nd year retention in engineering
    - 96% 2nd year retention in STEM
    - 2 scholars changed to non-engineering STEM majors (biology, math); one scholar changed to a non-STEM major (communication studies).
    - 100% retention at ISU

Overall, sixty-five of seventy-two scholars remain in or completed the program, giving an overall retention of over 90% in the program.

E2020 Seminar Courses

A one-credit seminar course, ENGR 110, is taken by scholars during the second semester of their first year in the program. It introduces students to each of the four pillars over twelve weeks. With three weeks per pillar, the first week introduces the students to knowledge related to the pillar; the second week focuses on developing basic skills through an active learning activity; and during the third week, students work in teams to demonstrate their ability to apply the new knowledge and skills to a real-world problem. Peer mentor sessions are interspersed with the class sessions.

Another one-credit seminar course, ENGR 210, is taken during fall and spring semesters of the second year, and provides more in-depth investigation into the pillars. The fall semester seminar is split into two seven-week periods, one for the leadership pillar and another for systems thinking. The spring semester seminar is split between the innovation and global awareness pillars. A faculty leader for each pillar has developed pillar-specific learning modules and assessment methods.

Leadership

The leadership seminars were designed to highlight that good leadership may be achieved differently by each leader. This concept must be understood and practiced. In the freshman seminar, the faculty leader concentrated on getting students to appreciate various aspects of these main topics: (1) knowing yourself, (2) teamwork, (3)

communication, and (4) self-discipline. The three weeks were focused on students leading themselves. By the end of the sophomore seminar, the students were expected to achieve the following learning objectives: For any given situation, students will (1) build and foster interpersonal relationships, (2) explain why engineers must effectively communicate thoughts and ideas in writing and orally, and (3) identify ways to effectively serve as a member of a team as a leader and/or follower.

Students in the freshman seminar took the *Keirsey Temperament Sorter-II*® and received classroom instruction on personality types and temperaments. Through this experience, students analyzed and described their personality and temperament preferences. Through written reflections, students performed metacognition to gain a deeper understanding of why knowing this information is important to becoming a leader. Next, students participated in a modified version of the "Stranded in the Desert" exercise from Johnson and Johnson's *Joining Together*. This exercise and the following discussion helped to highlight the importance of teamwork in solving a problem. Finally, the students worked in teams to build a tower made of various common office items. Each team member was given a specific "job" and asked to perform their role. Through this experience, students were able to appreciate the complexity of solving a problem through communication, collaboration, and coordination.

The freshman seminar created the framework and opportunity for students to view themselves as leaders. During the sophomore seminar, students were introduced to new topics and exercises to emphasize the importance of interpersonal relationships, communication skills, and teamwork. Nearly every class period was delivered with students sitting in a circle or at team tables to foster the sharing of thoughts and ideas. Students were able to practice their leadership skills by working together on a service learning project. Teams were charged with finding an activity to research, plan, and accomplish together to positively impact the lives of others. Students were encouraged to find a community interest item and devote one-two hours of their time to make a difference. Students practiced their communication skills by presenting their service learning project in either poster sessions or oral presentations.

The students were generally effective in achieving the learning objectives. After the sophomore seminar, most students were able to clearly articulate their strengths and contributions as a leader in their personal life and organizations within the university and their communities. Reflections from students indicated a greater appreciation and understanding for the importance of engineers to have strong interpersonal relationships, effective communication skills, and teamwork skills.

Systems Thinking

Many definitions of systems thinking have been proposed, but several features appear in most definitions: viewing a problem broadly and holistically; identifying interdependence and feedback; synthesizing as well as analyzing individual components; and accounting for dynamic (time-varying), nonlinear behavior. In the freshman seminar, the faculty leader focused on getting the students to appreciate the complexity arising from the interaction of

factors from inside and outside engineering—that is, to have students explain the importance of taking a broad view of a problem and considering feedback and dynamic behavior. By the end of the sophomore seminar, the students were expected to achieve the following learning objectives involving tools of systems thinking: For complex, ill-defined, dynamic problems involving engineering, social, ethical, cultural, environmental, business, and political issues, students will (1) identify connections between subsystems with rich pictures, (2) explain relationships with causal loop diagrams, and (3) sketch the behavior over time of key variables in the system.

Students in the freshman seminar worked in teams to draw a rich picture for a topic related either to a grand challenge problem or a successful team—in sports, school, music, work, etc. A rich picture uses pictures, cartoons, text, and sketches to depict connections between various elements of a systems or problem, including structures, processes, and concerns. The students then presented their work either in an oral presentation or a poster session. In the sophomore seminar students chose similar problems involving at least five of the seven issues stated in the learning objective and identified the key variable measuring success or failure. Then they applied three tools of systems thinking: rich pictures; causal-loop diagrams, which show relationships between elements; and behavior-over-time graphs, in which the behavior of the key variable is sketched as a function of time.

The students were mostly successful in achieving the outcomes. After the first offering of the freshman seminar, most students wrote that before the module, they did not know much about systems thinking. After the module, they knew much more and appreciated the number and diversity of issues that must be considered in a successful engineering project. In the sophomore seminar, students addressed the technical content adequately, though they struggled with identifying an appropriate key variable and sketching behavior over time. In particular, after carefully deriving a causal-loop diagram from a rich picture, many groups would mostly abandon their previous work and resort to mental models not reflected in their rich picture. Although the instructional activities can be adjusted to help students achieve the learning objectives more fully, most students demonstrated appreciation for the range of issues affecting an engineering problem and proficiency with the tools of systems thinking.

Innovation and Entrepreneurship

Innovation and entrepreneurship involve key skills and abilities for practicing engineers. While engineering programs offer numerous design courses throughout the curriculum, these often overlook thinking like an entrepreneur. One of the primary goals of this pillar is increase students' awareness that the skills of an entrepreneur will help them to be better engineers. In the freshman seminar, students were introduced to elements of entrepreneurship and explored what it means to approach problems from an entrepreneurial viewpoint. By the end of the sophomore seminar, students developed a business plan for a proposed company to solve some aspect of a grand challenge problem. The students then presented their work to a panel of judges to pitch their ideas.

The freshman seminar first introduced students to innovation by having them think about things (inventions, products, technologies, etc.) that have changed their lives. Students were then assigned to small groups, and each group selected a topic related to a grand challenge problem. The groups were asked to think more deeply about the problem and possible solutions. During the second week, students worked in their groups to refine their ideas and organize them into a presentation to the class. In the third week, groups presented their ideas, which were scored using a rubric that judges creativity of the solution as well as presentation skills. The freshman seminar concluded with feedback to the groups with an emphasis on innovation.

The sophomore seminar focused more on entrepreneurship, with the first week defining entrepreneurship and examining its relationship to engineering. The instructor again primed students on innovation, engaging them in a discussion of the greatest innovations of their time and drivers behind these innovations. These innovations were then placed in the context of grand challenge problems. Groups were formed, and each group was assigned a different grand challenge problem area. Groups were tasked to make a short "sales" pitch as to why their assigned problem area should be targeted by a company. The students then voted to select a single problem domain for their business plans the rest of the seminar. Students learned more about business plans and proceeded to work in groups to finalize their business plans. As in the freshman seminar, business plans were presented and judged. Given the same problem domain, the best plan was identified, adding an element of competition to the learning experience.

Students developed a better understanding about entrepreneurial concepts and effectively communicating their ideas. They were introduced to skills that will enhance their work as a student as well as prepare them for the workforce.

Global Awareness

For engineers, global awareness has several possible meanings. In the E2020 project, global awareness is defined as being aware of and respectful of cultural and international differences in needs and values, understanding how regional and cultural differences affect the engineering design process and engineering business enterprise in general, and being able to work effectively with others from different cultures.

The freshman seminar introduced students to the impact of global and cultural differences on the engineering enterprise, through class discussions and brief case studies. The learning objective for the freshman seminar was that students would have a better understanding of the need for questioning and analyzing their own assumptions (about needs, values, constraints, criteria, resources, economics, etc.) when working on engineering projects.

In the sophomore seminar, the emphasis was on identifying cultural dimensions to an engineering project, with a two-pronged emphasis: one, that framing an engineering problem (and later, developing a solution) must consider the cultural and local norms and needs of the users or beneficiaries of the project, and two, that working with others from

different cultures presents challenges that one can to some degree prepare for. After discussion and readings on global awareness in engineering, technology, and business, students were asked to research one of the grand challenge problems, chosen at random for each team of 4-6 students, in the context of one country, also chosen at random for each team. Drawing on the skills gained in the Systems Thinking module, in the first half of this project they were to draw a rich picture describing aspects of the grand challenge problem in their assigned country. Then through discussion and further research, each team distilled their findings to a single engineering problem statement, including constraints and criteria. Ideally, this would be aided by their work in the Entrepreneurship model to frame and communicate an engineering problem. In the second half of the project, students were introduced to Hofstede's cultural dimensions, a classification of major cultural norms by country; this system is widely used in international business training. The students were then asked to review their problem statement and imagine that they were paired with a team of engineers native to their assigned country, and using Hofstede's cultural dimensions, explore how each country-team might approach the problem and its solution differently, and how cross-cultural dynamics might affect their work together.

E2020 Project-Based Independent Study

After completing the ENGR 110 and 210 seminar series, and beginning in the third year of the program, scholars continue to develop a deeper understanding of the pillars through individualized, capstone-like experiences using project-based learning. Students from the 2009 and 2010 cohorts are at various stages of independent study experiences with faculty mentors. The 2011 cohort begins projects next year.

A project-based learning (PjBL) approach was selected to facilitate independent learning and a deeper understanding of the material. Through their E2020 PjBL experience, scholars are expected to develop self-directed learning skills. As part of the assignment, scholars do the following:

- Complete a project under the guidance of a faculty mentor, selected by the scholar.
- Propose a project that meets certain criteria.
- Enroll in independent study credit to earn at least one credit per semester for the PjBL experience.
- Provide project updates, presentations, and a report to the E2020 Program.

Scholars can choose to work on projects oriented toward research, education or service. For a research project, a scholar takes an open-ended technical question, investigates it, and creates a solution. For an education project, a scholar may develop an innovation for a course that helps other students learn. For a service project, a scholar identifies a societal problem and approaches it through service learning, applying particular expertise to meet a need. A scholar is allowed to work as part of a group on a project. A scholar proposes a project in consultation with a faculty mentor and E2020 faculty. The scope and

pace of a project is individualized to a particular student's situation, such as timing with respect to other activities to be leveraged (such as a design competition, study abroad, undergraduate research experience, Honors Program project, etc.). A scholar is encouraged to create a PjBL experience that complements and leverages current coursework and/or co-curricular activities.

As part of project management and communications skills development, scholars report their progress several times during the year. A memorandum format for reporting progress was adopted. The memo is submitted by a student to the E2020 Blackboard site.

The following examples of individualized co-/extra-curricular learning experiences involving current and former E2020 scholars demonstrate their engagement with the E2020 pillars.

Brenda Klutzke, current E2020 Scholar, 2009 cohort, senior in mechanical engineering, former E2020 peer mentor: president of Iowa State University's chapter of Engineers Without Borders.

Kurt Lundeen, graduated E2020 Scholar and graduate student in mechanical engineering, 2010 cohort, E2020 peer mentor: member of Iowa State's Team LunaCY that won awards in NASA's annual Lunabotics Mining Competition.

- http://news.engineering.iastate.edu/2013/05/29/team-lunacy-wins-nasa-competition/
- http://www.news.iastate.edu/news/2013/05/20/lunabot13
- http://www.nasa.gov/offices/education/centers/kennedy/technology/lunabotics.html

Moses Bomett, former E2020 Scholar who changed his major to economics, 2009 cohort, ISU graduate: founder of Hope 4 Africa, Inc.

- http://www.iastate.edu/stories/2013/06/grad

Evaluation Findings

A survey is administered to the cohorts each year to obtain feedback on their experiences in the program. Quantitative and qualitative data analysis methodologies are used to analyze the survey data. Statistical evaluation of data includes descriptives and frequencies of survey responses. Open-ended questions are coded for common themes. The year 5 cohort survey is in progress. Results of previous surveys are available in reports and publications.

Training and Professional Development

The E2020 scholars have participated in program activities to advance their academic and professional development. The students have completed course modules to develop their knowledge, skills and abilities in the four pillar areas. Undergraduate peer mentors have been introduced to the NAE's vision for the engineer of 2020 and have facilitated scholar understanding and development. The seminar course instructor, faculty leaders, and project team members have developed materials to support curriculum and assessment of the four pillar areas of the program. Information is being shared with others, such as faculty and staff involved with learning communities in the college, leading to expanding the awareness and knowledge base of team members and collaborators.

Dissemination to Communities of Interest

During year 5, the systems thinking pillar was presented to university-wide and college-level audiences outside of the project team. Non-engineering faculty and staff commented on the potential value of using it with their students. The faculty leader has also been invited to present a systems thinking workshop for the IINSPIRE LSAMP minority undergraduate students involved with summer research and bridge programs at Iowa State in July 2013.

Plans for No-Cost Extension Year

The cohorts of scholarship students continue to be served by the program. In particular, the 2011 cohort will be starting the project-based part of the program in fall 2013, which will be guided by faculty and peer mentors involved with the program.

Identifying opportunities and sharing pillar curricular materials for wider use in the college by all engineering students will continue.

With assistance from RISE, the following S-STEM program goals will be evaluated for the E2020 Program in the coming year:

1. Improved educational opportunities for students:
   To what extent did students demonstrate progress on E2020 learning outcomes?

2. Increased retention of students to degree achievement:
   Did scholarship support, E2020 relevance to students, and learning community engagement increase retention?
3. Improved student support programs at institutions of higher education:
   What was the benefit of complementary NSF STEP grant activities?
4. Increased numbers of well-educated and skilled employees in technical areas of national need:
   What was the result of the E2020 focus and the concurrent goal of the NSF STEP grant to increase the number of engineering graduates?

Products

Website

The E2020 website, http://www.engineering.iastate.edu/e2020, provides an overview of the project intended to inform prospective students as well as interested persons inside and outside the university.

Publications and Presentations

The following workshops were presented to Iowa State faculty and staff as part of sharing E2020 curriculum innovations and resources:

C. Rehmann and D. Rover, “Introduction to Systems Thinking,” workshop, Learning Communities Mid-Year Institute, Iowa State University, February 1, 2013.

C. Rehmann and D. Rover, “Systems Thinking,” workshop, Spring 2013 Learning Community Task Team Retreat, College of Engineering, Iowa State University, May 14, 2013.

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Impacts

Impact on STEM Disciplines

Resources and materials have been identified, collected, and developed to teach students about engineering leadership, innovation and entrepreneurship, systems thinking, and global awareness. Instructional materials for two undergraduate seminar courses were developed. An intranet repository has been created for internal use by faculty and staff in engineering. Resources are also being made available to other engineering educators.

The curriculum integration approach of the E2020 Program is consistent with a recent national study that concluded:

- Engineering program chairs and faculty subscribe to most of the goals of The Engineer of 2020.
- Faculty and chairs give less attention to professional topics than to technical ones, despite the emphasis on professional skills in the NAE report and ABET criteria.
- Professional topics are typically emphasized in first-year design and capstone courses rather than integrated throughout the curriculum. (McHale et al., FIE, 2010)

Impact on Other Disciplines

The curriculum and assessment resources will use and contribute to the larger body of knowledge in the four pillar areas. There are various leadership programs and initiatives on campus and in the education community. There is an entrepreneurship program in the College of Business and various activities across colleges. Global awareness and systems thinking are also important areas across disciplines.

Impact on Human Resources Development

The goal of this project is human resource development. Scholarships have supported cohorts of undergraduate student scholars, including transfer students and students underrepresented in engineering. Peer mentors were trained, and along with the scholars, gained new knowledge, skills and abilities in the four pillar areas of the E2020 program. Faculty and staff also acquired new information about student development.

Impact on Institutional Resources that Form Infrastructure

Based on E2020 materials and findings, project team members have contributed to university and college workshops in support of undergraduate education at Iowa State.

Impact on Information Resources that Form Infrastructure

Information resources are under development to support teaching, learning and assessment in the four pillar areas of the project.

The E2020 program, though developed independently, is similar to a number of initiatives motivated across the U.S. in response to the NAE's report. One of the earliest was the University of Wisconsin's introductory course on the engineering grand challenges. Since then, Purdue University and other universities have implemented engineer of 2020 programs. The Grand Challenge Scholars Program (GCSP), a collaboration of Duke University, Olin College of Engineering, and the University of Southern California, is an NAE-sponsored version of Iowa State's NSF-funded E2020 Scholars Program. Several universities have established programs affiliated with GCSP.

E2020 faculty have not yet formalized assessment of the pillars through well-defined student learning outcomes and instruments. Several rubrics and surveys have been used to assess aspects of the program and student learning. Previous work by E2020 faculty with the Engineering Leadership Program piloted a competency-based leadership model closely aligned with ABET student outcomes. In the ELP model, there were eight learning outcomes that described the knowledge and skills achieved by an ELP scholar through participation in the program. Five of the outcomes were from ABET Criterion 3; three of the outcomes reflected additional skills attained through the program. These additional learning outcomes included an ability to create a vision, an ability to innovate, and an ability to value diversity and create an inclusive environment. Associated with these outcomes, ELP identified nineteen competencies and specific key actions for each competency. This competency-based approach was based on a framework developed for the College of Engineering by Brumm, Hanneman, and Mickelson.

In the college's framework, student outcomes are multi-dimensional and represent some collection of workplace competencies necessary for the practice of engineering at the professional level. Fifteen competencies are measured within this framework: Analysis and Judgment, Communication, Continuous Learning, Cultural Adaptability, Customer Focus, Engineering Knowledge, General Knowledge, Initiative, Innovation, Integrity, Planning, Professional Impact, Quality Orientation, Safety Awareness, Teamwork. Each competency is uniquely defined with is a set of observable and measurable key actions that a student may take that demonstrates their development of that competency. For example, the Initiative competency has the following definition and key actions.

> Initiative: Taking prompt action to accomplish objectives; taking action to achieve goals beyond what is required; being proactive.

Key Actions:

> Responds quickly. Takes immediate action when confronted with a problem or when made aware of a situation.
>
> Takes independent action. Implements new ideas or potential solutions without prompting; does not wait for others to take action or to request action.
>
> Goes above and beyond. Takes action that goes beyond job requirements in order to achieve objectives.

An assessment of the student's demonstration of competencies asks the following question for each of the key actions: "When given the opportunity, how often does the student perform the key action?" The response uses a Likert scale: 5 = always or almost always; 4 = often; 3 = usually; 2 = sometimes; and 1 = never or almost never. There is a mapping of the competencies to the ABET (a-k) student outcomes.

It would be possible to follow the ELP assessment approach for each of the E2020 pillars, resulting in a set of competencies and key actions for each pillar. This would align with and leverage the college's assessment framework. The identification of competencies appropriate for each pillar would draw from emerging engineering education research on assessment of leadership, critical thinking, entrepreneurship, and cross-cultural skills.

Impact on Society beyond Science and Technology

Several scholars who started in the E2020 Program changed to non-STEM majors, and these students and graduates are better prepared for interdisciplinary work due to their awareness about engineering and the E2020 pillars. An understanding of the E2020 pillars gives engineering students and graduates a stronger set of skills to collaborate with others outside of STEM.

The E2020 Program created a student-centered, inclusive learning environment that is attractive to diverse students. The E2020 cohorts have a higher percentage of students underrepresented in engineering compared to the percentage in the College of Engineering as a whole, thus broadening participation in engineering and diversifying the future STEM workforce.