First Year Engineering Experience Initiative[1]

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Abstract

This project is one of nine projects supported by the Hewlett Foundation's Engineering Schools of the West Initiative. At the University of Nevada, Reno the College of Engineering and the College of Education are working together on the 5-year project: *The First Year Engineering Experience Initiative: A Bridge To and From Problem/Project/Team-Based Learning*. The collaboration stems from a unique view of the engineering pipeline and aims to improve the quality, quantity, and diversity of our graduates through a flexible, hands-on curriculum.

This paper describes the program's three main activities: the development of an integrated freshmen curriculum, a future scholars program, and a summer bridging program. Assessment has been integrated into all activities and is being performed by experts from the College of Education.

Currently, curriculum activity is focused on two freshmen courses. The first is a combined mechanical, electrical and civil engineering course where students work on interdisciplinary teams building digital scales. The second course is for mechanical engineering, material science engineering, and computer science students and focuses on structured programming through the use of robotics.

The future scholars program is the teaching analogy to a research post-doc. The future scholars work with faculty on the integrated freshmen courses while receiving training on learning and teaching styles.

The Hewlett Bridging into Engineering Program is aimed at students who are at high risk of dropping out based on historic data. The program is being followed up with periodic meetings between the participants and student mentors.

[1] This project was supported by a grant from the William and Flora Hewlett Foundation's Engineering Schools of the West Initiative (www.hewlett.org).

1. Introduction

The Engineering Schools of the West Initiative (ESWI) is a program supported by the William and Flora Hewlett Foundation. The program honors a statement made by the late William Hewlett indicating that the graduates of the western state schools were the backbone of HP's success. The overall goal of the ESWI program is to increase retention, recruitment, and student learning.

The program is supporting nine public colleges in nine western states: University of Nevada, Reno (UNR), Boise State University, Colorado School of Mines, Montana State University, New Mexico State University, Northern Arizona University, Oregon State University, University of Utah, and University of Wyoming.

When it comes to undergraduate engineering education, the metaphorical "pipeline" is often discussed. The pipeline is envisioned as a system that delivers students to our programs. The common belief is that if we could somehow increase the size of the pipeline or the "flow rate" through the pipeline, this would address a number of our retention and recruitment problems. However, we feel the pipeline is actually quite different than most people envision.

Our vision of the science, technology, engineering, and math (STEM) "pipeline" is shown in Figure 1. Students "flow" through the STEM pipeline from kindergarten to BS degree by passing through a series of pipes and tees with valves. The valves represent the teachers and classroom experiences and the pipes represent the students' personal goals and career objectives (i.e., where they are headed). At each tee-section a valve diverts some students out of the mainstream into the STEM flow path. As shown, the flow path from kindergarten to a STEM BS degree is far from straight. In fact, the path of least resistance delivers the overwhelming majority of the students into non-technical careers.

At first glance, it would seem to be most effective to concentrate on the K-12 valves since the first valve, elementary school, has the largest impact on the quantity of the output, the middle school valve has the second largest impact, and so forth. However, the valves over which we (the university) have control are at the university-level: first year experience, sophomore, junior and senior-level valves. Thus, from our standpoint, we achieve the largest impact by focusing on the first valve at the university-level: the First Year Experience (FYE).

However, we also recognize that the K-12 valves have far greater potential to affect the total flow rate. With this in mind, at UNR the College of Engineering is partnering with the College of Education on all aspects of this project. Thus, while we are focusing on the FYE in the short term, we are also focusing on affecting change at the K-12 level in the long term. Also, by including Ph.D. candidates and post-docs from top tier universities on the teaching team for our FYE courses, we will also affect the valves further along at the University level, both at the University of Nevada, Reno and at other institutions.

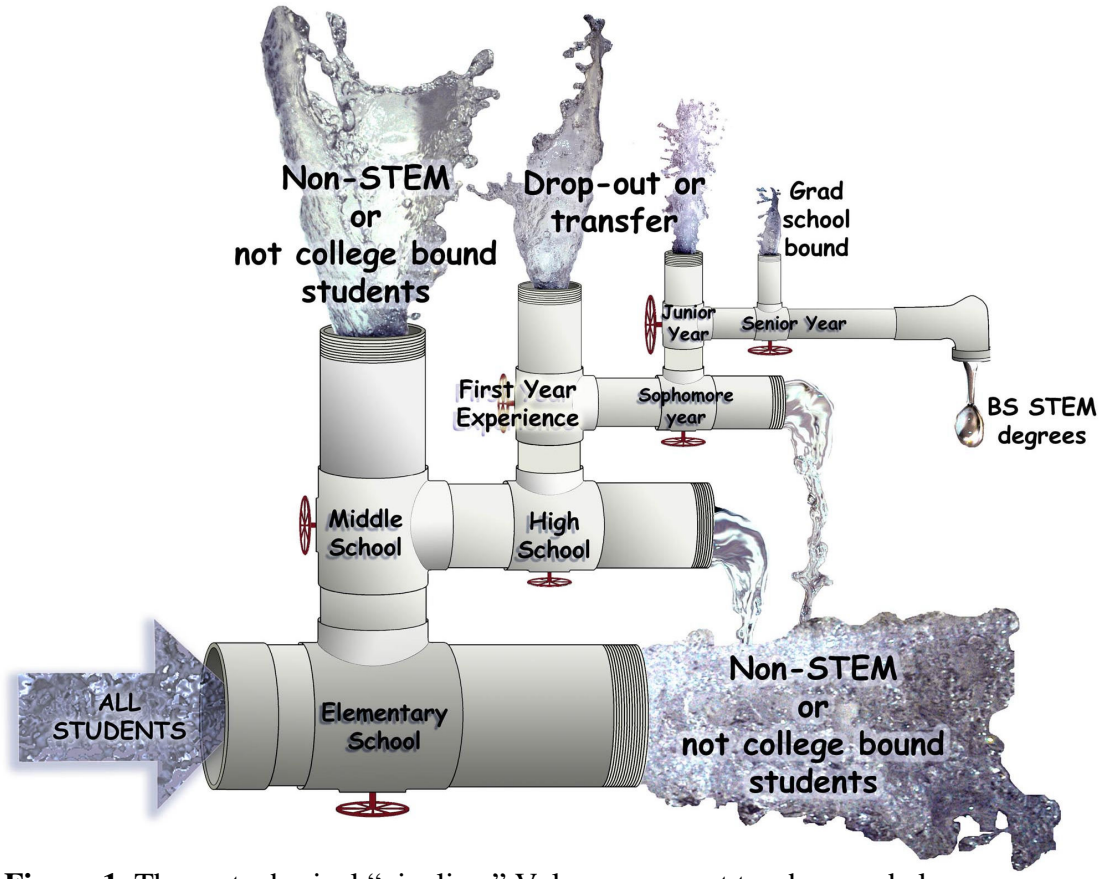

Figure 1. The metaphorical "pipeline." Valves represent teachers and classroom experiences. The path of least resistance is toward the non-STEM pool. STEM students must be constantly and purposely diverted away from the mainstream to stay on the path towards a STEM BS degree. The final output is the Quality, Quantity and Diversity of the STEM BS degrees.

2. Project Description

Our overall goal is to increase the *quality, quantity* and *diversity* of engineering graduates from the University of Nevada. To accomplish this goal, the College of Engineering and College of Education are collaborating on implementing three major activities:

1. ***Curriculum Reform of the First Year Experience:*** Based on our highly successful freshmen project based learning (PBL) courses, we are developing a **college-wide First Year Experience** (FYE). The hands-on team-based project-based introductory courses will be comprised of 1-3 credit modules representing the variety and complexity of the engineering disciplines at the university. This modular development will provide maximum flexibility for students in each discipline area, within the common methodology of a project-based, diverse introductory experience. This expansion on current programs will increase retention of freshmen engineering students by creating a more effective and motivating first course experience.

As an added multiplier, pre-service K-12 teachers are also being encouraged by the College of Education to enroll in the FYE courses to gain first hand knowledge about engineering. This focus has the ability to train pre-service K-12 teachers to affect change in the input to the engineering pipeline both locally and nationally. Responsibility for the development of a core program curriculum is a shared responsibility of the development team with representation from each department within the college.

2. ***Develop a Future Scholars Program for Ph.D. Candidates and Post-Docs:*** To support UNR faculty and provide a unique opportunity for Ph.D. candidates and post- docs, we are developing a residency-teaching program. This program is based on the NSF-funded New Century Scholars' Workshop held at Stanford. Ph.D. candidates in their last year of study and post-docs from other participating institutions will be invited to our campus to learn how to teach effectively, gain hands-on experience implementing PBL activities in our FYE curriculum, and learn how to balance their teaching and research duties. Students at other ESWI institutions are being targeted in our recruitment.

   The scholars will also cross-pollinate their research with the university since they will be from other institutions. We hope this experience will lay the groundwork for future collaborations in both research and teaching. The timing of the Ph.D. candidate/post-doc visit is unique and taps into a potent and sometimes unused resource. Ph.D. candidates who are writing their dissertation, or just finished with it are in transition from graduate school to a job and are at the leading edge technically. By giving them a short 3-6 month experience that taps into their research expertise and helps prepare them to communicate and teach, we will provide an excellent stepping stone to a productive career. We will build long term funding for this program, if judged successful, into our normal teaching budget through faculty research off-load.

3. ***Create a Pre-freshmen Bridging Program and Mentoring Network:*** The summer bridging program is aimed at improving the quality of the incoming students. Our data shows that up to 60% of our students need some remedial mathematics before entering our normal engineering sequence. This program provides a cadre of students who are willing to "go the extra mile prior to starting the freshman year" with experiences such as "survival skills for engineering pursuit", reinforcement of basic skills and project based experiences that make STEM fun and interesting. Participants develop the mathematical problem solving skills necessary to succeed in their freshman courses without spending several semesters in remedial courses. The program is advertised to the students as a pre-engineering experience and at no time is it referred to as remedial. Emphasis is placed on recruiting women and minorities to participate in the program whenever possible.

   It has been documented by many athletic programs as well as PBL studies at the University of Delaware that mentoring/tutoring and related support between the entering freshmen and their upper-class peer community eliminates the communication and comprehension gap that typically leads to high dropout rates [1]. Upper division students from both the College of Engineering and the College of Education will serve as STEM mentors for the First Year Experience and other freshman STEM courses (physics, math). In addition to the freshmen benefiting from the mentoring, the Education students will

see first-hand that math and science are tools used to solve engineering problems. In addition, targeted programs will be expanded to supplement the curriculum offerings to provide additional support and assistance to students identified as high risk for dropping out of the programs.

Outcomes: In addition to the aforementioned infrastructure changes, both the pre-service education majors and the Ph.D. candidates will disseminate the results of our efforts. In the long term, this will have a tremendous multiplier effect. One technology passionate teacher can have a huge impact on the number of students in the pre-university portion of the pipeline. The Ph.D. candidates and post-docs will not only learn to be better teachers, but they will also serve as a direct link between our research activities and activities at other institutions by bringing their research experience to the University of Nevada classroom and laboratory and by building relationships during their stay.

Assessment: Assessment will be a collaborative effort between the College of Engineering and College of Education and the Office of Institutional Analysis. The formative and summative evaluations will be both quantitative and qualitative in nature. Evaluations will include attitudinal questionnaires, student evaluations, enrollment databases, observations, personal interviews, and demographics. This mixed-method approach will allow both multivariate and descriptive analyses.

3. Activities and Progress

Curriculum Reform of the First Year Experience:
Based on an existing freshmen mechanical engineering course that used PBL extensively, a new course for freshmen mechanical, electrical and civil engineering students was prototyped. (Engineering 100A-Introduction to Engineering). In this course, students work on multidisciplinary design teams to design and build a digital scale, while learning about engineering and teamwork. This year, 10 civil engineering and electrical engineering students joined what used to be just a mechanical engineering course. In this first implementation, the course content was enhanced, checkpoints were implemented, and students were given a design space for the prototype development. It is proposed that by year 3 this course will service all ME, CE and EE freshmen.

A second multidisciplinary course, Engineering 100B, is currently being developed for implementation in the Spring 2004. The course will combine freshmen mechanical engineering, material science engineering, and computer science students. The objective of the course is to teach students both structured programming and creative thinking. The course utilizes LEGO Mindstorms robots as the instructional medium. To program the robots, students start with Robolab, a graphical programming environment [2, 3]. The advantage of Robolab is that we can teach the concepts of structured programming without being encumbered by syntax. In the last third of the course, students will move onto NQC, a text-based language similar to C [4].

Pre-freshmen Bridging Program
The 2003 Hewlett Bridging into Engineering pilot program was held for a week and a half immediately prior to the start of the academic year. This program proved highly successful,

creating connections to engineering programs, and to the engineering community for students who are at higher risk of dropping out of our programs based on historical data.

This program was the first step in a multi-phased effort to enhance the success rates for our engineering programs. Each student in the program received a TI 85 calculator that is used in their calculus and engineering classes, a notebook with resources for the program that they keep as a reference in the future, and a protractor and compass.

More importantly, they spent a week with upperclassmen, spending time exploring the campus and resources available to them, and "learning the ropes" before school started. This is intended to make their transition to the campus life in engineering more successful. The activities for the program as delivered were modeled after a similar program at Northern Arizona University both in content and duration [5]. There were two notable exceptions to this: 1) the duration of the program was more compact whereas NAU holds the similar activities over a two month period and 2) we did not offer course credit and participation in formal courses with our program whereas NAU does.

Future Scholars Program for Ph.D. Candidates and Post-Docs

A sabbatical leave has delayed the implementation of a formal training course for the future scholars. Nonetheless, there are currently two participants in the future scholars program, the teaching analogy to a research post-doc. The future scholars are working with three faculty members on an integrated freshmen course.

A workshop is currently being developed for the summer 2004 through the Excellence in Teaching Program at UNR. This course will provide necessary training and support for the teaching scholars in residence. The course is based on the NSF New Century Scholars workshop [6]. Faculty at University of Nevada, Reno, who participated in the NCS workshops are being funded to assist with development and delivery of this program. We plan to replicate this NCS experience insofar as possible, using the same PBL-methodology for this educational program. Our version of the NCS workshop will include: balancing teaching/service/research, knowing the learner, assessment strategies, active/PBL activities, and practice lectures. This workshop will also be taken by our graduate teaching assistants and undergraduate coaches. This experience will be directly applicable to the PBL course delivery for which they are subsequently responsible.

4. Assessment

Eight of the nine ESWI grantees agreed to participate in a cross-institutional evaluation plan based on a set of research questions developed at the Assessment Subcommittee planning meetings. The purpose of such an evaluation would be to determine how well the collection of projects fulfilled the Hewlett Foundation's goals and objectives for the Engineering Schools of the West Initiative (ESWI). This will be done through the collection and analysis of baseline data compared with end of project data.

The evaluation plan proposed for this project is adapted from several sources [7-9], which includes criteria for utility, feasibility, propriety, and accuracy. The project evaluation will

provide a formative component, which will inform the ongoing development of the Hewlett project, and a summative component, which will determine the project's effectiveness.

The formative evaluation will include implementation and process evaluations to aid in the project structure. The summative evaluation will include outcome or impact evaluations to aid in determining what the project actually accomplished in terms of the stated goals.

The majority of the data collection will take place through information provided in annual reports from each institution. To facilitate the collection of data from so many sources, an online data collection system is being developed. The online data acquisition system will include a secure web-based application that will provide real time access to reports and analysis tools. This application will utilize many data sources (e.g. data from various SQL compliant databases, web-based data entry, Scantron surveys, etc.). The database will be developed to reduce reporting requirements through the implementation of a user interface that is efficient and provides the end-user with effective reporting, management, and decision-making tools. Security, privacy, and data integrity are expected to be of the highest order.

The data will be both quantitative and qualitative in nature, and will include, at the minimum, surveys, existing databases, observations, interviews, and focus groups. This mixed-method approach will allow both multivariate and descriptive analyses.

5. Acknowledgments

This work was sponsored by the Hewlett Foundation Engineering Schools of the West Initiative.

6. References

1. http://www.udel.edu/pbl/cte/spr96-tutor.html. Accessed 17 October 2002.
2. Portsmore, M., Cyr. M, and Rogers, C. "Integrating the Internet, LabVIEW, and Lego bricks into modular data acquisition and analysis software for K-college" proceedings of the ASEE Annual conference and exhibition, session 2320, 2000.
3. Wang, E., **Engineering with LEGO Bricks and Robolab**, College House Books, Knoxville, TN, 2002.
4. Knudsen, J., **The Unofficial Guide to LEGO MINDSTORMS Robots**, O'Reilly & Associates, Cambridge, MA, 1999.
5. http://www.cet.nau.edu/Support/MEP. Accessed 13 January 2004.
6. http://ncs.stanford.edu. Accessed 15 December 2003.
7. National Science Foundation's User-Friendly Handbook for Mixed Method Evaluation
8. User-Friendly Handbook for Project Evaluation: Science, Mathematics, Engineering and Technology Education
9. Joint Committee on Standards for Educational Evaluation, The Program Evaluation Standards: How to Assess Evaluations of Educational Programs

7. Biographical Information

ERIC L. WANG is an Associate Professor of Mechanical Engineering at the University of Nevada, Reno. Dr. Wang has won numerous awards including the Tibbitts Distinguished Teaching Award, UNR's most prestigious teaching award. In addition to his pedagogical activities, Dr. Wang conducts research on sports equipment, biomechanics, robotics, and intelligent materials.

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JESSE ADAMS, Assistant Professor of Mechanical Engineering at the University of Nevada Reno, received his Ph.D. at Stanford University. Jesse is currently doing research on high-speed scanning probe microscopy and has developed a microcantilever sensor platform that is also being investigated for explosive detection, chemical vapor detection, water quality sensing and viscosity sensing.

TED BATCHMAN has BS, MS, and PhD degrees from the Univ. of Kansas. After working at LTV Missiles and Space Division, he joined the Univ. of Queensland in Brisbane, Aus. He joined the Univ. of Virginia in 1975. In 1988, he joined the Univ. of Oklahoma as Director of the School of Electrical Engineering and Computer Science. In 1995, he joined the Univ. of Nevada, Reno as Dean of the College of Engineering. He is a Fellow of IEEE.

PAM CANTRELL is an assistant professor of science and mathematics education at the University of Nevada, Reno. She is the Director of the Raggio Science, Mathematics & Technology Center in the College of Education. The Raggio Center focuses on K-16 outreach activities in STEM education, grant work, research and evaluation, and dissemination of research related to STEM education best practices.

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JEFFREY C. LACOMBE is an Assistant Professor of Metallurgical and Materials Engineering at the University of Nevada, Reno. In addition to his education-oriented research activities, Dr. LaCombe's research lies in the areas of kinetic processes in materials (such as diffusion and solidification), nanoscale manufacturing methods, and remotely operated aerospace & satellite systems.

NANCY LATOURRETTE is a lecturer of Computer Science at the University of Nevada, Reno. Nancy received her BS degree in Mathematics and her MS degree in Computer Science. She teaches both programming and theoretical computer science courses. Ms. LaTourrette was the course coordinator for CS1 for several years and is the architect and coordinator for the *Women Discovering their Engineering Aptitude* initiative.

GARY NORRIS is a professor of Civil Engineering. Dr. Norris is chairman of the local Geotechnical/Geological Hazards Advisory Committee, chairman of the local Seismic Zoning subcommittee, past chairman of the Soil Properties Committee of the American Society of Civil Engineer and is a Cooperative Extension instructor to building officials and transportation department personnel.

WILLIAM SPARKMAN is a Professor and Dean of the College of Education at the University of Nevada, Reno. His research and teaching fields are public school finance and law. He has served on the planning committee for A Deans Summit on Education for a Technological World (2001) and Deans Summit II: Fostering Campus Collaborations (2003) sponsored by IEEE and NSF.

YAAKOV VAROL is a full professor and chair of the Computer Science Department, College of Engineering, at the University of Nevada, Reno. He has taught most undergraduate computer science courses and many graduate level courses in diverse fields including numerical techniques, algorithms, theory of computing, discrete simulation and parallel processing. He is a program evaluator of the Computing Accreditation Commission of ABET.