THE FOUNDATION COALITION: AN AGENT IN CHANGING ENGINEERING EDUCATION

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Abstract *¾ The Foundation Coalition (FC), one of eight engineering coalitions funded by the National Science Foundation, was established as an agent of systemic renewal for the engineering educational community. Arizona State University, Rose-Hulman Institute of Technology, Texas A&M University, University of Alabama, University of Massachusetts Dartmouth, and University of Wisconsin are the partner institutions that have focused on major curricular restructuring in the first two years of the engineering curriculum with downstream changes motivated by this restructuring. Restructuring has been guided by seven ideas that are informed by a number of theories about learning and change (for example, social learning theory and constructivist learning theory). The seven ideas, referred to as FC core competencies, are (1) active/cooperative learning, (2) student teams in engineering, (3) curriculum integration, (4) technology-enabled learning, (5) increasing participation of women and underrepresented minorities in engineering, (6) individual and organizational change, and (7) continuous improvement through assessment, evaluation, and feedback. The fundamental proposition on which the FC was created is that engineering curricula restructured to be consonant with the core competencies would improve retention and graduation rates, especially for women and underrepresented minorities, and improve the quality of engineering graduates, as defined by the characteristics preferred by employers of these graduates. The paper presents data-based narratives that help explore the extent to which the proposition has been demonstrated.*

Index Terms ¾ first-year learning communities, curricular change, unified engineering science framework, assessment

INTRODUCTION

Initially funded in 1993, the Foundation Coalition (FC) is the fifth in the series of engineering education coalitions (EECs) to be supported by the National Science Foundation (NSF). EECs were intended to catalyze systemic change across the engineering education community by developing and demonstrating the efficacy of new curricular models. Across the FC, partner institutions were mobilized by the underlying assumption that if they reimagined, restructured, and implemented their engineering curricula using specific pedagogical and change theories, both the quality of engineering education and the number of degrees awarded in engineering, especially for women and underrepresented minorities, would increase. Initially, FC partners developed pilot curricula based on the core competencies, i.e., active/cooperative learning, student teams, technology-enabled learning, and curriculum integration, and offered the pilot curricula to volunteer students. Retention and performance of the students in the pilot curricula, as compared to students in carefully matched groups, was very promising. Comparisons showed increased retention (especially for the targeted groups), higher performance on nationally normed examinations, improved attitudes toward the core competencies, and greater success in subsequent courses. However, improved retention and performance were insufficient to motivate adoption of the pilot curricula as the required curricula for entire colleges of engineering. Instead, considerable attention needed to be paid to concepts of organizational change, especially ideas related to responses to resistance. The experiences of partner institutions in offering the pilot curricula and moving through institutionalization are being captured in a set of case studies developed through qualitative research methodology. The focus of the current paper is to examine data-based narratives that explore the question of whether the pilot and institutionalized curricula positively impacted performance and retention of students.

FIRST-YEAR CURRICULA

In 1988, engineering curricula were viewed as three-year degree programs with first-year filters that focused on prerequisites in calculus, physics and chemistry. Today, first-year students across the FC, as well as other engineering education coalitions and institutions beyond the coalitions, learn engineering within a connected intellectual and social context. As FC partners developed and implemented pilot curricula that incorporated the core competencies, they remodeled or added classrooms to provide routine access to computer technology including computer algebra systems, e.g., Maple, Mathematica; spreadsheets, e.g., Excel; computer-aided design, e.g., AutoCAD, SolidWorks; and data acquisition software, e.g., Lab VIEW. Each partner developed real-world projects, for example, designing better cup holders for pickup trucks,

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building robots that mimic insects, building tools that help physically challenged individuals, and working along with nursing students in patient care, on which students would apply their knowledge of mathematics, science, and engineering design. Working and learning in teams helped students confront the difficulties as well as learn about the advantages of participating on teams. They learn why engineers need to learn physics, economics, mathematics, ethics, chemistry, and social implications of technology and they make better connections between these subjects and the practice of engineering. Taking two or more of the first-year courses with the same students builds community and social support that are vital as they take a challenging curriculum. However, curricular innovations raise a fundamental question: In what ways have these new programs affected student performance and retention? The following snapshots are intended to address this question.

IMPULSE – University of Massachusetts Dartmouth

The University of Massachusetts Dartmouth (UMD) began a successful, integrated, first-year engineering curriculum (Integrated Mathematics Physics Undergraduate Laboratory Science and Engineering – IMPULSE) in September 1998. This new program dramatically changed the freshman year as the college of engineering built classrooms for 48 students that provided a studio environment modeled after the RPI approach [1]. Faculty members restructured classes in engineering, physics, and calculus to help students link topics across the courses. More information about the program can be found in [2-6]. Two stories are presented to illustrate effects of the program.

First-year physics and calculus are challenging courses for many engineering students. Disappointing performance in either course often encourages students to consider transferring out of engineering. As shown in Figure 1 students who participated in IMPULSE completed both first-year courses at a significantly higher rate than students in the year before the program was implemented. The data for IMPULSE I (1998-99) are for students in the pilot implementation while the data for IMPULSE II (1999-2000) is for data once the program had been implemented across the college of engineering.

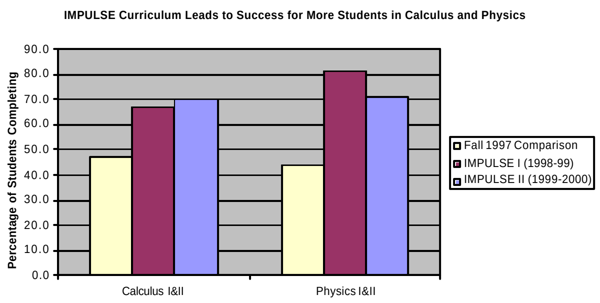

FIGURE 1
PERCENTAGE OF IMPULSE STUDENTS COMPLETING FIRST-YEAR PHYSICS AND CALCULUS (ADAPTED FROM [7])

The college has also examined the performance of the students. Figure 2 shows the performance of students in the first semester calculus course. A higher percentage of the students in the both IMPULSE I and IMPULSE II stayed with the calculus course to take the final examination. Further, these students scored higher than a comparable group of students in a traditional calculus class. IMPULSE led to more students completing first semester calculus as well as doing better on the final examination.

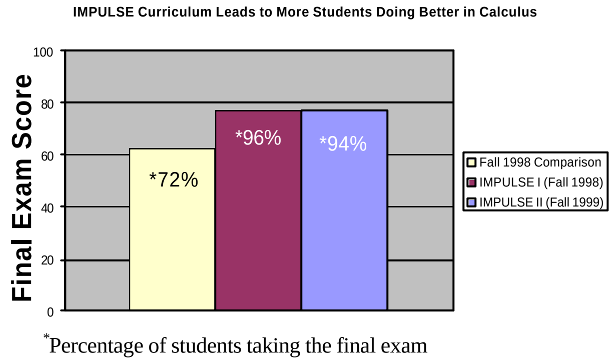

FIGURE 2
PERFORMANCE OF IMPULSE STUDENTS IN FIRST SEMESTER CALCULUS

First-year Engineering Learning Communities at Texas A&M University

At Texas A&M University (TAMU), the restructured, college-wide first-year program was implemented in 1998. Learning communities in which students take two or more of their required first-year science, engineering, and mathematics courses together in groups of one hundred are a feature that built on the experiences of the first-year prototype curricula. Learning communities value diversity, are accessible to all interested individuals, and bring real world situations into the engineering classroom. The key components of learning communities are: (1) clustering of students in common courses (math, engineering, science); (2) teaming; (3) active/cooperative learning; (4) industry involvement in the classroom; (5) technology-enhanced classrooms; (6) undergraduate peer teachers; (7) curriculum integration; (8) faculty team teaching; and (9) assessment and evaluation. Learning communities, since they facilitate social relationships in a context directly connected with the classes students are taking, should increase retention and encourage students to continue in their first-year classes as a coherent unit. More information on first-year learning communities and the pilot curricula that provided the practical base for learning communities can be found in [8-12]. Based on the experience with its pilot curricula and the experiences since institutionalization in 1998-99, A&M believes that learning communities offer a superior educational experience for engineering students.

Figure 3 compares the retention in engineering after two years for the male and female cohort students who participated in learning communities (With LC) for two semesters with the male and female students who never participated in learning communities (Without LC). Note that to participate in a learning community for two semesters

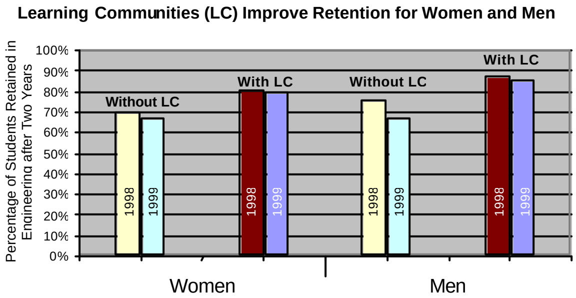

FIGURE 3
COMPARISON OF RETENTION IN ENGINEERING AFTER TWO YEARS FOR STUDENTS WITH RESPECT TO PARTICIPATION IN LEARNING COMMUNITIES AT TEXAS A&M UNIVERSITY

students must pass their first semester engineering, physics, and mathematics courses with a grade of C or better. Therefore, students in the comparison group must also have passed these same first semester courses. Retention after two years in engineering for female students who did not participate in learning communities was about 70% in both 1998 and 1999 while female students who participated in learning communities were retained at almost 80%. Retention percentages for male students were approximately 70% and 85%, respectively. Participation in learning communities, i.e., clustered sections of required first-year engineering courses appears to have a positive impact on retention.

In addition to favorably affecting retention, participation in learning communities is also related to reduced time to complete courses required to enter the sophomore curriculum at TAMU. At TAMU, students enter the college of engineering. After they have completed a set of courses called the Common Body of Knowledge (CBK) courses, they may apply to enter an engineering department and begin their sophomore engineering courses. Figure 4 shows the percentage of the students prepared to enter sophomore engineering courses, i.e., those students who have completed their CBK courses, at various points in time after starting engineering. At every point in time after the students entered Texas A&M University, the percentage of students who participated in learning communities (With LC) is greater than the percentage of students who did not participate in learning communities (Without LC).

EnGAGE – Arizona State University

At Arizona State University (ASU), the Engineering Groups for Academic Growth and Excellence (EnGAGE) program uses integrated curriculum, learning communities,

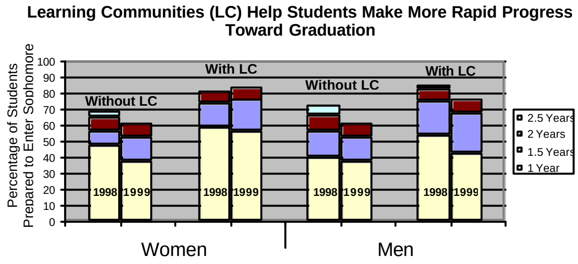

FIGURE 4
COMPARISON OF TIME REQUIRED TO COMPLETE REQUIREMENTS TO ENTER SOPHOMORE YEAR WITH RESPECT TO PARTICIPATION IN LEARNING COMMUNITIES AT TEXAS A&M UNIVERSITY

and non-traditional pedagogies to improve learning environments for all first-year engineering students. Developing a comprehensive program to accommodate all engineering students at a large, urban public university like ASU is a challenging undertaking because of the myriad of students, e.g., full-time students, part-time students, commuter students, that ASU has chosen to serve. To accommodate the broad spectrum of students EnGAGE offers three options. In option 1, students enroll in a tightly integrated set of courses called the Freshman Integrated Program in Engineering (FIPE). Each semester students take engineering (2 credits), physics (4 credits), calculus (4 credits), and English (3 credits) as well as another course, usually chemistry or a humanities or social science elective. Approximately ten percent of entering students participate in option 1. For more information on FIPE, see [13-17]. In option 2, students elect three courses from a list of ten different courses and enroll in common sections of twenty for these three courses. Approximately forty percent of entering students participate in option 2. Option 3, to accommodate students whose requirements or course schedules are not met by options 1 and 2, allows students to select courses and sections in an ad hoc manner. EnGAGE provides a comprehensive approach that fits the requirements of the student body it serves.

One of the ways to examine the effect of FIPE on student learning is to examine grades in first-year chemistry. Chemistry is not a part of FIPE and students typically take chemistry in the second semester of their freshman year. Therefore, grades in chemistry might be one indicator of difference in student learning. Performance in chemistry by students who participated in FIPE is substantially better than comparable students in a group who participated in the traditional curriculum. Figure 5 shows the percentage of students earning different letter grades in chemistry. The percentages of students that earned an A or B was higher for students who participated in FIPE than a comparable group of students who participated in the traditional curriculum.

Another innovative aspect of the first-year engineering curricula at ASU has been innovations in physics instruction that follow the core competencies of the FC, e.g., interactive and cooperative learning, curricular integration, the infusion

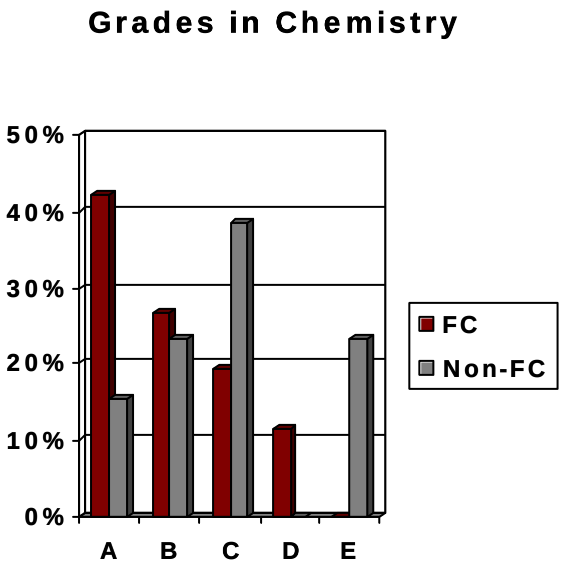

FIGURE 5
COMPARISON OF PERFORMANCE IN CHEMISTRY FOR STUDENTS PARTICIPATING IN FIPE WITH A COMPARABLE GROUP OF STUDENTS IN A TRADITIONAL CURRICULUM

of technology, etc., in attempts to improve conceptual understanding of students. Conceptual understanding in mechanics is often measured by the Force Concept Inventory (FCI) that was developed by Halloun and Hestenes [18, 19]. Therefore, ASU collected pre- and post-test results on the FCI. Also, ASU used the Reformed Teaching Observation Protocol (RTOP), a measure of the degree of reform in the classroom, was used to gauge the following pedagogical changes: lesson design, communication, and student teacher relationships. Analysis of data showed (see Figure 6 that illustrates improvement in percentage gain, pre- to post-test, on the FCI over the first eight years of the FC) improvement on the FCI. Year 8

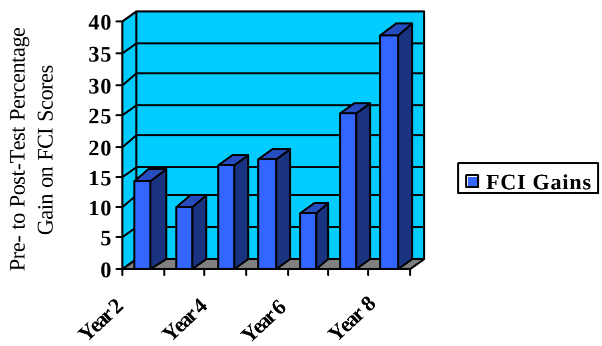

FIGURE 6
IMPROVEMENTS ON THE FORCE CONCEPT INVENTORY AT ARIZONA STATE UNIVERSITY

shows the most dramatic gain and this gain is consistent with the evaluation by the RTOP that showed the most evidence of reformed instruction in the classroom. So, the FC is positively affecting physics instruction and student learning at ASU.

First-year Engineering Program at the University of Alabama

Faculty members at the University of Alabama (UA) designed a pilot first-year curriculum that integrated engineering, calculus, physics, and chemistry. The pilot program, initially designed for calculus-ready students, was first implemented in the 1994-95 academic year. As expansion to the entire college of engineering was considered, faculty members recognized that not all entering students were calculus ready and that additional curricular options were required to accommodate the entire student body. So UA faculty members prepared additional integrated options for students who were prepared to start in both trigonometry and college algebra. For more information about the integrated curricular options at UA see [20-26]. After implementing all three curricular options as pilot programs, retention after one year in the program was collected and compared to comparable students who participated in the traditional curricular options. Results of

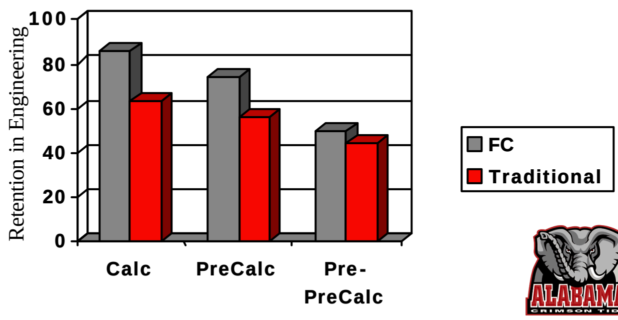

FIGURE 7
COMPARISON OF RETENTION IN ENGINEERING AFTER ONE YEAR AT THE UNIVERSITY OF ALABAMA

the comparison are shown in Figure 7. Cohorts labeled “Calc” are calculus ready; cohorts labeled “PreCalc” started in trigonometry; and cohorts labeled “PrePreCalc” started in college algebra. For each curricular option, students in the FC program were retained at a higher rate that students in the traditional program.

A UNIFIED APPROACH TO ENGINEERING SCIENCE

In 1955, the Grintner report introduced engineering science as a set of separate courses that provided a foundation for engineering curricula. Thousands of students who took these courses learned specialized approaches for each separate course, but often failed to grasp the larger picture in which they could apply these approaches to a broad set of problems. Beginning in 1988, TAMU, then ASU, and finally Rose-Hulman Institute of Technology (RHIT) have restructured engineering science using a framework in which students focus on a set of five broadly applicable principles instead of separate engineering topics. Louis Everett, now Department Head of Mechanical and Industrial Engineering at University of Texas El Paso, describes when he caught the difference. Dr. Everett's research area is robotics, but when he was teaching fluids, a student asked him a question that he pondered until the next class period. When he applied the new framework, the light bulb went on and he provided a clear, understandable explanation. That is when he saw the power of the five broadly applicable. Students who were taking initial offerings of the restructured courses performed better on many common instruments than students who were taking traditional, separate engineering science courses. At A&M, the College of Engineering restructured the sophomore engineering science courses for all engineering majors in 1997. More information on the sophomore engineering science core at TAMU can be found in [27-34]. At ASU, the Chemical Engineering Department has used the framework for a required set of courses for nine years. At RHIT, the Computer, Electrical and Mechanical Engineering departments restructured their sophomore engineering curriculum (SEC) between 1995 and 1998. For more information on the SEC see [35-40].

The SEC is organized around an a systems, accounting, and modeling approach to engineering science that provides a common framework for presenting, interpreting, and applying the basic physical principles. Figure 8 shows scores on the common multiple choice portion of the final examination given in both a traditional dynamics course and in ES204 Mechanical Systems, one of the five new engineering science courses in the SEC. The average score of the students in ES204 was approximately the same or better on most of the multiple choice questions. Improved

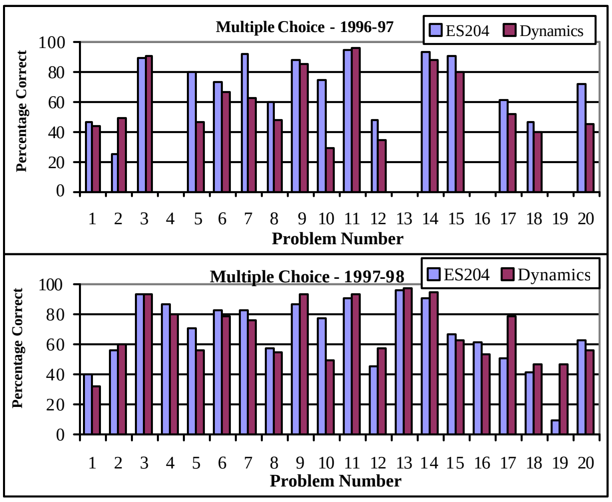

FIGURE 8
COMPARISON OF STUDENT PERFORMANCE ON COMMON MULTIPLE CHOICE DYNAMICS FINAL EXAMINATION QUESTIONS

performance on common final examination questions was one factor in the choice of the Mechanical Engineering Department to require the SEC for its majors.

BEYOND THE FOUNDATION COALITION

Other institutions have initiated significant curricular reform since the FC was first funded in 1993. Some of these institutions have built on the work of the Foundation Coalition as they designed and implemented their new curricula. For example, the University of Pittsburgh has implemented an integrated, first-year curriculum using FC experience to improve its versions. Engineering students at Louisiana Technological University take a common integrated engineering program for their first two years [41]. The program built on the FC unified approach to engineering science and the first-year programs that have been implemented across the Foundation Coalition. South Dakota School of Mines modeled its Freshman Curriculum 2000 [42] after some of the FC first-year curricula. As faculty members Michigan Technological University developed their integrated, first-year curriculum [43], they drew upon the experiences of FC partner institutions. Finally, Embry-Riddle Aeronautical University used lessons and ideas from the FC first-year programs as its faculty members engineered its integrated, first-year curriculum. These institutions have learned from FC experiences and implementations to build exciting learning environments for their students.

CONCLUSION

Partner institutions across the FC have implemented curricular changes using its core competencies. Samples of the curricular changes and samples of the assessment data that have been collected have been presented to illustrate how the same curricular renewal principles have been put in practice at a wide variety of institutions. The assessment samples indicate that the diverse implementations of the same curricular principles have had a positive impact on student retention, learning, and progress toward graduation. Further, FC programs are influencing curricular reform at institutions beyond the coalition.

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REFERENCES

[1] Wilson, J. and Jennings, W., "Studio Courses: How Information Technology Is Changing the Way We Teach, On Campus and Off," *Proceedings of the IEEE*, 88:1, 72-80.

[2] Pendergrass, N.A., Laoulache, R.N., Dowd, J.P., and Kowalczyk, R.E., 1998, "Efficient Development and Implementation of an Integrated First Year Engineering Curriculum," *Proceedings of the Frontiers in Education Conference*.

[3] Pendergrass, N.A., Kowalczyk, R.E., Dowd, J.P., Laoulache, R.N., Nelles, W., Golen, J.A., and Fowler, E., 2001, "Improving First-Year Engineering Education," *Journal of Engineering Education*, 90:1, 33-41.

[4] Pendergrass, N.A., Laoulache, R.N., and Fortier, P.J., 2000, "Mainstreaming an Innovative 31-Credit Curriculum for First-Year Engineering Majors," *Proceedings of the Frontiers in Education Conference*.

[5] Dowd, J.P., Laoulache, R.N., and Pendergrass, N.A., 1999, "Project IMPULSE: Teaching Physics in an Integrated Studio Based Curriculum for Freshman Engineering Majors," *Proceedings of the ASEE Annual Conference*.

[6] Pendergrass, N.A., Laoulache, R.N., and Fowler, E., 2001, "Can An Integrated First-Year Program Continue To Work As Well After The Novelty Has Worn Off?" *Proceedings of the ASEE Annual Conference*.

[7] Wilson, V.L., Monogue, T., Malave, C.O., 1995, " First Year Comparative Evaluation of the Texas A&M Freshman Integrated Engineering Program," *Proceedings of the Frontiers in Education Conference.*

[8] Ackerman, C.M., Wilson, V.L., 1997, "Learning Styles and Student Achievement in the Texas A&M Freshman Foundation Coalition Program," Southwest Educational Research Association Annual Meeting, Austin, TX.

[9] Everett, L.J., Imbrie, P.K., Morgan, J.R., 2000, "Integrated Curricula: Purpose and Design," *Journal of Engineering Education*, 89:2, 167-175.

[10] Fournier-Bonilla, S.D., Watson, K.L., Malave, C.O., 2000, "Quality Planning in Engineering Education: Analysis of Alternative Implementations of New First-year Curriculum at Texas A&M University," *Journal of Engineering Education*, 89:3, 315-322.

[11] Morgan, J.R., Rinehart, J., Froyd, J.E., 2001, "Industry Case Studies at Texas A&M University," *Proceedings of the Frontiers in Education Conference.*

[12] Fournier-Bonilla, S.D., Watson, K., Malavé, C., and Froyd, J., 2001, "Managing Curricula Change in Engineering at Texas A&M University," *International Journal of Engineering Education*, 17:3, 222-235.

[13] Roedel, R.J., Kawski, M., Doak, B., Politano, M., Duerden, S., Green, M., Kelly, J., Linder, D., Evans, D.L., 1995, "An Integrated, Project-based, Introductory Course in Calculus, Physics, English, and Engineering," *Proceedings of the Frontiers in Education Conference.*

[14] Green, M., Duerden, S., 1996, "Collaboration, English Composition, and the Engineering Student: Constructing Knowledge in the Integrated Engineering Program," *Proceedings of the Frontiers in Education Conference.*

[15] Evans, D.L., Doak, B., Duerden, S., Green, M., McCarter, J., Roedel, R.J., Williams, P., 1996, "Team-Based Projects for Assessment in First Year Physics Courses Supporting Engineering," *Proceedings of the Frontiers in Education Conference.*

[16] Roedel, R.J., Green, M., Garland, J., Doak, B., McCarter, J., Evans, D.L., Duerden, S., 1997, "Projects that integrate engineering, physics, calculus, and English in the Arizona State University Foundation Coalition freshman program," *Proceedings of the Frontiers in Education Conference.*

[17] Duerden, S., Graham, J.M., Garland, J., Doak, B., McCarter, J., Roedel, R.J., Evans, D.L., Williams, P., 1997, "Scaling Up Arizona State University's First-Year Integrated Program in Engineering: Problems and Solutions," *Proceedings of the Frontiers in Education Conference.*

[18] Hestenes, D., Wells, M., and Swackhamer, G., 1992, "Force Concept Inventory," *The Physics Teacher*, 30:3, 141-151.

[19] Hestenes, D., and Halloun, I., 1995, "Interpreting the Force Concept Inventory," *The Physics Teacher*, 33:8, 502-506.

[20] Parker, J.K., Cordes, D., Hopenwasser, A., Izatt, J.R., Laurie, C., and Nikles, D., 1995, "Curriculum Integration in the Freshman Year at the University of Alabama – Foundation Coalition Program," *Proceedings of the Frontiers in Education Conference*.

[21] Parker, J.K., Cordes, D., and Richardson, J., 1995, "Engineering Design in the Freshman Year at The University of Alabama - Foundation Coalition Program," *Proceedings of the Frontiers in Education Conference.*

[22] Frair, K., 1995, "An Integrated First Year Curriculum at the University of Alabama Problems and Solutions," *Proceedings of the Frontiers in Education Conference.*

[23] Harrell, J.W., and Izatt, J.R., 1996, "Freshman Engineering Physics in the Foundation Coalition at the University of Alabama," *Proceedings of the International Conference on Undergraduate Physics Education*.

[24] Nikles, D., 1996, "General Chemistry for an Integrated Freshman Engineering Curriculum," *Proceedings of the Frontiers in Education Conference*.

[25] Parker, J.K., Richardson, J., and Cordes, D., 1996, "Problem Solving and Design in the Freshman Year: The Foundation Coalition," *Proceedings of the ASEE Southeastern Section Conference*.

[26] Richardson, J., Parker, J.K., and Cordes, D., 1996, "The Foundation Coalition Freshman Year: Lessons Learned," *Proceedings of the Frontiers in Education Conference.*

[27] Glover, C.J., and. Erdman, C.A., 1992, "Overview of the Texas A&M/NSF Engineering Core Curriculum Development," *Proceedings of the Frontiers in Education Conference.*

[28] Glover, C.J., Lunsford, K.M., and Fleming, J.A., 1992, *Conservation Principles and the Structure of Engineering, 3rd edition*, New York: McGraw-Hill College Custom Series.

[29] Pollock, T.C., 1992, *Properties of Matter, 3rd edition*, New York: McGraw-Hill College Custom Series.

[30] Everett, L.J., 1992, *Understanding Engineering Systems via Conservation, 2nd edition*, New York: McGraw-Hill College Custom Series.

[31] Glover, C.J., and Jones, H.L., 1992, *Conservation Principles for Continuous Media* , 2d edition, New York: McGraw-Hill College Custom Series.

[32] Erdman, C.A., Glover, C.J., and Willson, V.L., 1992, "Curriculum Change: Acceptance and Dissemination," *Proceedings of the Frontiers in Education Conference.*

[33] Everett, L.J., 1996, "Experiences in the Integrated Sophomore Year of the Foundation Coalition at Texas A&M," *Proceedings of the ASEE Annual Conference.*

[34] Everett, L.J., 1997, "Dynamics as a Process, Helping Undergraduates Understand Design and Analysis of Dynamics Systems," *Proceedings of the ASEE Annual Conference.*

[35] Black, B. A., 1996, "From Conservation to Kirchoff: Getting Started in Circuits with Conservation and Accounting," *Proceedings of the Frontiers in Education Conference.*

[36] Richards, D.E., Rogers, G.J., 1996 "A New Sophomore Engineering Curriculum—The First Year Experience," *Proceedings of the Frontiers in Education Conference.*

[37] Doering, E., 1997, "Electronics Lab Bench in a Laptop: Using Electronics Workbench to Enhance Learning in an Introductory Circuits Course," *Proceedings of the Frontiers in Education Conference*.

[38] Cornwell, P.J., and Fine, J.M., 1999, "Integrating Dynamics throughout the Sophomore Year," *Proceedings of the ASEE Annual Conference*.

[39] Cornwell, P.J., and Fine, J.M., 2000, "Mechanics in the Rose-Hulman Foundation Coalition Sophomore Curriculum," *International Journal of Engineering Education*, 16:5, 441–446.

[40] Richards, D.E., 2001, "Integrating the Mechanical Engineering Core", *Proceedings of the ASEE Annual Conference.*

[41] Nelson, J.D., and Schröder, B., 2001, "Establishing an Integrated Mathematics, Engineering, and Science Curriculum: Lessons Learned," *Proceedings of the ASEE Annual Conference*.

[42] Kellar, J.J., Hovey, W., Langerman, M., Howard, S., Simonson, L., Kjerengtroen, L., Stetler, L., Heilhecker, H., Arneson-Meyer, L., and. Kellogg, S.D., 2000, "A Problem Based Learning Approach for Freshman Engineering," *Proceedings of the Frontiers in Education Conference*.

[43] Sorby, S.A., and Hamlin, A.J., 2001, The Implementation of a First-year Engineering Program and its Impact on Calculus Performance, *Proceedings of the International Conference on Engineering Education*.