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The Broad and Strategic Value of the Freshmen Engineering Experience—FEE*

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Many papers have been written on the teaching and learning value of the 'freshmen engineering experience' (FEE), where FEE is an experimental, design project based course that provides a stimulating introduction to engineering for freshmen students. The research has largely focused on the pedagogical benefits obtained via the problem-based learning techniques implicit in well designed FEEs. Less well reported are the accompanying issues of pass and retention rates, integration with K-12 outreach programs, contributions towards national rankings and their overall strategic importance in engineering programs. This paper reviews the broad value and strategic role of FEE programs in the framework of engineering education.

Keywords: freshmen experience; design; retention; integration; internationalization.

INTRODUCTION

NUMEROUS PAPERS have been published in the USA on innovative teaching and learning projects for freshmen engineering programs and details of these are readily available [1, 2]. Many of these papers concern themselves with courses that attempt to bring together diverse topics such as engineering science, mathematics, design, ethics, introduction to the profession and sustainability [3–7]. These first-year courses can be grouped under the overarching description of 'freshmen engineering experiences' (FEEs). For a better understanding of the scope of FEE experiences, both Ollis as well as Sheppard and Jenison provide good organizational frameworks for the types of course designs common in FEEs [8, 9]. While these papers do provide an adequate description of the pedagogical benefits of FEEs they rarely address the many other direct and indirect outcomes stemming from a well designed FEE, such as:

- linking to K-12 outreach programs
- marketing, recruitment and rankings
- promoting diversity in engineering
- supplementing math and science skills
- providing superior learning experiences for students
- improving pass and retention rates
- maintaining an income stream
- the role of the profession and industry
- additional workload, costs and the role of faculty
- improving grades
- internationalization of the curricula
- integration into the overall engineering program and strategic planning.

LINKING TO K-12 OUTREACH

A well designed FEE can be used to found a good K-12 outreach program while making more effective use of the resources consumed by the FEE. Variations of existing FEEs can be readily transferred to high schools with minimal extra course design costs being incurred. The expensive and available infrastructure required by FEEs can be used by high schools involved with the outreach programs [10, 11].

A wealth of literature [12–26] confirms that engineering educators have become increasingly involved in promoting change and improving the technological content of K-12 education. In this section, the authors trace the parallel development of K-12 outreach programs and FEEs, now both widely established in USA universities.

In 1996, Burghardt [12] reported the efforts made by the Center for Technology Education (CTE) at Hofstra University to improve the technological literacy of Long Island high school students. Working closely with teachers, Hofstra developed a Principles of Engineering (POE) course for high schools, which incorporated a competition on magnetic levitation (maglev). Burghardt stated that prior to the project he considered that 'learning educational pedagogy is not typically part of an engineering faculty

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members' background'. It was found during the workshops associated with the CTE, that cooperative learning, authentic assessment, design and problem solving had direct applications in engineering courses. These 'new' teaching approaches were applied by Hofstra University to improve their Introduction to Engineering course.

Similar developments occurred around the USA, one example being described by Rathod and Gipson [13] regarding the Southeast Michigan Alliance for Reinvestment in Technological Education (SMARTE), which included Wayne State University. The curriculum was designed for '8th grade students to explore applications in engineering and technology'. The authors listed similar programs supported by Miami, Western Kentucky, Iowa, Carnegie Mellon, Purdue and Penn State Universities. Other approaches were more discipline focused as reported by Fadali, Robinson and McNicols [14] who adopted a role-playing approach to teach K-12 students about computer, control and power systems engineering. Such approaches are used in FEEs to develop teamwork skills.

As well as looking at developing K-12 content, there was a move by universities to 'teach the teachers'. Jordan, Silver and Elmore [15] describe teaching pre-service teachers by providing hands-on laboratory-based courses, explaining the fundamentals of engineering science. Hein and Sorby [16] approached teaching the teachers about the different engineering disciplines via a three-day workshop. They found that participation increased knowledge from 34% to 76% and it is interesting to note that a FEE-type design project 'providing drinking water in remote areas using reverse osmosis', formed an integral part of the workshop.

Local initiatives have been ongoing: Jack [17] wrote of using outreach to increase manufacturing enrolments, Gannod [18] described the Arizona State University TEK program (Technology Education for Kids) and Feldaus [19] recently outlined Project PETE—Pathways to Engineering and Technology Education—between the Indianapolis Public Schools and Purdue School of Engineering and Technology at Indiana University Purdue University [20].

Up until 2001, projects were mostly locally based. Yoder, et al. [21], describe the introduction of the still operational national INFINITY Project to help districts incorporate engineering and technology in high school curricula. The INFINITY Project focuses on how engineering underpins modern-day multimedia and information technology. Resources available are a Technology Kit and Textbook and an intensive 40-hour teacher training program. The kits are adaptable for use in FEEs.

In 2003, Custer and Daugherty suggested that engineering education was confronted by challenges including lack of engineering awareness in K-12 curricula and a lack of dialog between collegiate engineering and K-12 educators [22]. They reported on the then current diverse range of initiatives across the USA including the Massachusetts state-mandated pre-engineering requirement and the engineering outreach program at the University of Colorado. They described the efforts being made by the National Academy of Engineering's Committee on Engineering Education to map what was happening at national, regional and local efforts at the K-12 level and their own ProBase project, which was developing a series of nine-week modules for 11th and 12th grade to be disseminated nationally [22].

A very recent national coordination development is the National Centre for Engineering and Technology Education (NCETE) funded for five years to study how to infuse engineering design into technology education in grades 9–12 [23]. A similar national approach to the design of FEEs would be beneficial to the profession.

One of the emerging developments has been the move to use engineering exploration days such as described by Carpenter, et al. [24], where the 'shock and awe' method has been used effectively in the state of Michigan, the Toledo Ohio area and the Providence of Ontario. This approach has been mirrored in Australia in the form of Science and Engineering Challenges [25]. Often the innovative and hands-on design project aspects of FEEs are used as tools in the exploration days.

Bayles, Spence and Morrell [26] wrote how the University of Maryland Baltimore College (UMBC) moved from lecture and design on paper to the now standard active learning centre and hands on engineering design course (FEE). The Eastern Technical High School teaches the equivalent, and although not intended as a recruitment strategy, students receive credit at UMBC and 90% of students who took part in the partnership were currently in 2004 majoring in engineering at UMBC.

MARKETING AND RECRUITMENT

As indicated by the example cited by Bayles, Spence and Morrell [26] FEEs can indirectly lead to recruitment of students. Most integrated freshmen engineering programs involve hands-on design and manufacture of a product. Many universities use their FEEs and the derived products as a resource to be employed for recruiting new cohorts of freshmen. As an example, at the University of Colorado, Boulder the Integrated Teaching and Learning Laboratory (ITLL) holds a Design Expo at the end of the fall and spring semesters where outcomes from their First Year Engineering Projects course (a FEE) are displayed [11].

Participation is compulsory for students enrolled in the course and teams are required to display a poster about their project and are judged by industry professionals; UCB faculty and course instructors with respect to design robustness, creativity and innovation. The Expo is well advertised and the public is also provided with the opportunity to vote for the 'People's Choice Award'. Thus, the FEE indirectly helps recruit new engineering students.

Retention rates for freshmen are used by US News [27] when compiling their annual list of America's Best Colleges. The tied top-ranked colleges for 2006, are Harvard and Princeton, both listed as being 'most exclusive', having annual fees in excess of $30,000, freshmen retention rates of 97% and acceptance rates less than 12%. Improved retention rates can help colleges to move up the ranking list and may also provide them with marketing opportunities otherwise not available, such as 'The (hypothetical) University of Belmont is a top 50 U.S. College, renowned for its FEE and freshmen retention'.

For the top ranked universities, high freshmen retention may not be an indication of excellence in teaching or pastoral care, but more likely reflects the difficulty of entry and the very high academic quality of the freshmen students. As we move deeper into the ranks, retention rates should start to become indicative of the effort expended to retain students. It becomes interesting to ponder the effort required by colleges, ranked as being non-selective and with students with low academic levels entering, to achieve high retention rates. As an example in the US News 2006 list, UCB is ranked 78 overall, its engineering is ranked 30 and civil, environmental and architectural engineering is ranked 19. The opportunity to further improve retention at UCB, and perhaps national ranking, exists.

DIVERSITY IN ENGINEERING

In some well-developed western countries such as Australia, high schools no longer see universities as their prime stakeholders but rather take the view that their focus should be more on preparing large cohorts of young people with the skills to enter and play a contributing role in their local communities and society in general. The process has become one where academic streaming is less obvious and the teaching of broad skills in numerical, communication and information technology rules. When combined with the expansion of tertiary education over the last 30 years it means that universities now need to accept students with an ever-widening spectrum of social background and academic merit. Catering for this social and learning skills diversity has historically been a challenge for engineering educators and FEEs have been found useful in this context [28].

Rowe [29] sees that diversity in assessment strategies (inherent in FEEs) play an important role in achieving good progression rates as faculty move away from final examinations (that promote rote learning) to continuous assessment, problem-based learning and better linking of learning outcomes to assessment criteria. As an implied word of caution, Rowe states that exams in engineering 'would seem to divide the engineers from the non-engineers in a way that continuous assessment and course work cannot'.

Table 1. Seventh semester retention gains [21]

Sample	Takers retention	Non-takers retention	Retention gain
All students	64%	54%	+19%
Women	71%	56%	+27%
Latino	77%	50%	+54%
African-American	60%	44%	+36%

FEEs in general promote diversity in engineering as minority groups appreciate the teaching and learning approach and the social and international context in which the FEE often sits. Knight, Carlson and Sullivan [30] reported that the FYEP course at the University of Colorado at Bolder improved retention rates for Latino and women above the average for the course (Table 1). The increases in part were attributed to 'increased sense of community and a supportive culture that emphasizes teamwork'. This supportive culture is important because it has been found that under-represented students (particularly women) have been found to have lower confidence and more negative attitudes about engineering upon entry into university [31].

MATH AND SCIENCE SKILLS

A widespread belief is that the main reasons for poor freshmen performance in engineering is due to a lack of knowledge and skill in mathematics and the sciences. Such reactions may stem from the 1983 report *A Nation at Risk* by the National Commission on Excellence in Education [32], which found in math that 'between 1975 and 1980, remedial mathematics courses in public 4-year colleges increased by 72 percent and now constitute one-quarter of all mathematics courses taught in those institutions'. In science it was reported that, 'there was a steady decline in science achievement scores of U.S. 17-year-olds as measured by national assessments of science in 1969, 1973, and 1977'.

The report appears to have spurred activity across the USA with states implementing new content standards in the 1990s, as typified by the Content Standards for California Public Schools—Kindergarten through Grade Twelve—series of publications [33] and the Colorado Model Standards [34]. The outcomes from these content standards will not be seen at the Year 12 level until 2007–2010, dependent upon when they were implemented. As discussed earlier, K-12 outreach programs can assist in addressing the present apparent shortcomings until the student benefactors of the most recent changes in the K-12

Table 2. Number of 17-year-olds reaching basic and proficient levels in math and science

		1996/Grade			2000/Grade		
Variable	Sex	4	8	12	4	8	12
Math at or above basic	Male	65	62	70	70	67	66
	Female	63	63	69	68	65	64
Math at or above proficient	Male	24	25	18	28	29	20
	Female	19	23	14	24	25	14
Science at or above basic	Male	68	62	60	69	64	54
	Female	67	61	55	64	57	51
Science at or above proficient	Male	31	31	25	33	36	21
	Female	27	27	17	26	27	16

programs reach their senior high school years and graduate into engineering.

The data from The National Center for Education Statistics (NCES) [35] in Table 2 do not show any substantial decrease in math skills for 17-year-olds over the period 1996 to 2000 although a slight decrease in male performance is noted. The NCES data for 17-year-olds does indicate that those who reached proficiency in multi-step problem solving and algebra reduced from 8.4% in 1999 to 6.9% in 2004 [36].

Of interest also is where the USA sits globally in math and science literacy. The data in Table 3 indicates that the USA does not sit high in the data produced by the NCES [26], below the Organisation for Economic Co-operation and Development (OCED) mean for both math and science. There was a slight decline in both math and science literacy for the USA from 2000 to 2003.

The perception that faculty considered, that there had been a drop in math ability, was verified in the results of an extensive national survey carried out by MathSoft Engineering in 2001 [37]. The survey found that the top reason that faculty felt that freshmen were not performing well at university was that high schools were failing in their role of providing students with the necessary (mathematical) skills, and in particular algebra and geometry. The top 5 reasons cited in the study for poor freshman performance are shown in Table 4. The data from the survey was well analyzed, but was based on faculty opinion.

Table 3. Average mathematics and science literacy scores of 15-year-olds

Year	Country	Math	Science
2003	OCED	500	500
	Finland	544	548
	Japan	534	548
	Australia	524	525
	France	511	511
	UK	508	518
	Germany	503	502
	U.S.	483	491
2000	U.S.	493	499

Table 4. Why students do not succeed in engineering

Faculty Belief	Responses
High schools are failing	29%
Lack of support at university	16%
More practical applications needed	15%
Poor work ethic	14%
More software needed	10%

These beliefs are not limited to USA faculty. Green, et al. [38], when outlining their HELM (Helping Engineers Learn Mathematics) Project in the United Kingdom cite numerous publications where it has been mooted that high schools no longer provide adequate skills in mathematics [39, 40]. The authors however also offer strategies for overcoming these shortcomings, by innovative teaching, in first-year engineering. This is a role readily filled by a well designed FEE

The role of an FEE in helping students deal with some lack of math and physical sciences skills is through application. Green, at al. [38], assume that students will enter as freshmen with some minimal mathematical skills and that an open learning regime, with workbooks, computer-based material and assessment provide flexible learning pathways, which will help students make the transition from high school. As students are able to apply and advance their knowledge through FEE projects, they see the value of math and science in engineering, and that it is worth their while persisting with their engineering studies.

SUPERIOR LEARNING EXPERIENCES

Much has been written about the pedagogical benefits of FEE and these aspects are only briefly referred to in this paper. The key components include project/problem-based learning (PBL), active learning, problem solving and communication skills aspects [41] and the situated learning and collaborative learning teams design aspects [42] where freshmen ‘discover’ themselves.

The PBL part of the FEE has been around for more than 35 years in the USA, being introduced at McMaster University in 1969 [43]) and over 25 years in Australia after being introduced at the University of Newcastle in 1978 [44]. Its use in engineering has become endemic in tertiary education, flowing from its early application in medical schools. Engineering educators have embraced the concept whole-heartedly [45–47]. It is accepted that PBL has a special role to play in the FEE.

It is generally agreed that the level of integration of freshmen with their department (faculty, laboratories) peers and profession during their first year will shape their desire to continue through their degree program [30, 41, 42]. As students become part of the engineering community they are more likely to continue their engineering studies. The FEE provides the perfect vehicle for introducing freshmen students into their new learning community.

IMPROVING RETENTION RATES

The advent of the ABET 2000 Criteria had an unexpected benefit in that to better meet the graduate outcomes, educators introduced broad-based design work for engineering freshmen. This broad-based design work evolved into the FEE. One outcome from the new FEEs was reduced attrition rates [30, 41, 42, 48].

Some of the better longitudinal data on the effect of FEEs on retention rates comes from the College of Engineering and Applied Science (CEAS) at the University of Colorado, Boulder (CU-B). The CEAS offers a FEE program, GEEN1400—First Year Engineering Projects (FYEP), which is conducted in its Integrated Teaching and Learning Laboratory (ITLL). The CEAS data is used here to illustrate how FEEs can increase retention rates (Fig. 1). Detailed information has been published about the success of the course including increased retention levels of engineering students across all disciplines [30].

Between fall 1994 and fall 2001 semesters, 4393 students were enrolled in the CEAS, classified as freshmen, non-transfer students. Of these, 1809

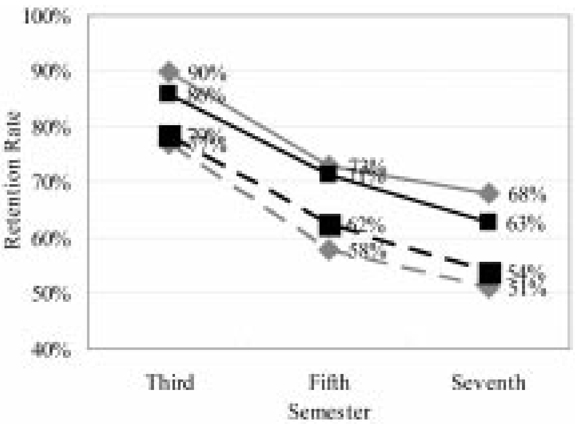

Fig. 1. ITLL retention data to seventh semester.

took the First Year Engineering Projects (FYEP) course and 2584 did not take the course. During this time, 258 students began as civil engineering majors (CVEN). Of these, 41 took the FYEP course and 217 students did not take the course (ee Fig. 1).

Students are classified as FYEP-takers if they took the course during their first two semesters. Retention data were collected for students at the third, fifth, and seventh semester with students classified as retained if they remain in the COE. Results of the analysis reveal that FYEP takers, represented by the solid line, are retained at a significantly higher rate than non-takers, represented by the broken line, across all measured semesters. Results were strongest at the seventh semester, with stronger results for CVEN students (51% rising to 68%) than the overall population (54% rising to 63%).

MAINTAINING INCOME

Student tertiary education fees have increased in many countries in the Western world as state and national governments review their priorities and reduce their contribution to universities. The data for Australia is shown in Table 5 and it is apparent that real funding for universities has decreased from 1996 to 2003 while the contribution from students has increased from 19.6% to 38%.

The USA system is one of the few in the world where funding by the national government has continued to increase in real terms. The data shown in Fig. 2 indicates that while the average student contribution has continued to increase so has the public and private levels. The widening gap has however, led to significant increases in the level of student contribution during the period 2003–2005.

In 2003–2004, in all postsecondary institutions the average price of attendance was $12,300 and about 35% of students took out loans at an average of $5800 [26]. As students become more financially responsible for their education they typically expect an accountable, good teaching and learning experience. They also expect to succeed at their

Table 5. Funding per student place [49]

	University operating funds/ student ($ per equivalent full time student)	
YEAR	Federal funding 2003 prices	Student contribution
1996	$13,351	19.6%
1997	$13,369	23.1%
1998	$13,228	26.5%
1999	$13,189	29.3%
2000	$12,687	31.8%
2001	$12,148	34.5%
2002	$11,659	37.6%
2003	$11,612	38.0%

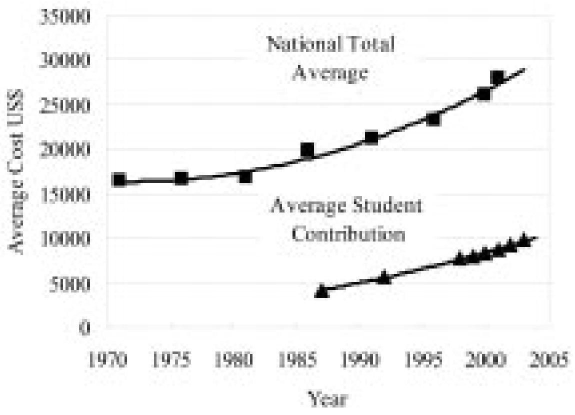

Fig 2. USA higher education contributions [35].

studies if they work hard and if not they will quickly leave their study program. Loss of students from a program impacts teaching budgets, and significantly increasing retention rates from (say) 51% to 68% (Fig. 1) can have major positive financial implications (Fig. 2).

A well-designed FEE can play a major role in assisting departments to retain their students and maintain their teaching budgets. This is very significant in the case of out-of-state or foreign students who typically pay full costs of their education.

THE ROLE OF INDUSTRY

If we were to be pragmatic, we could hypothesize that universities collaborate with industry for two reasons: accessing their wisdom and their money. In return for this, universities will often state that it is the responsibility for industry to invest, as they (universities) provide them (industry) with intellectual and human resources, without which they could not survive. Industry input into engineering programs should then span, and be integrated across, the entire spectrum of engineering education from course and program advising, provision of case studies, to strategic planning at the college and university level.

It is very popular to involve industry at the course level (including FEEs) with the obvious benefits being: students are exposed to real-world professional engineering; faculty obtain support in their teaching and access to potential research; and industry are provided with the opportunity to influence course curricula and access potential employees [50–52]. This level of interaction is typically at the individual faculty level and the use of industry panels to review course curriculum is also well established [53]. The FEE is an ideal situation where industry can be involved as it can provide the foundation for all subsequent engineering studies.

Industry partners may not derive full benefits from the symbiotic relationship if they do not take a proactive role in academic issues such as attrition rates, curriculum and facilities development and also review the implementation of their recommendations. Selvaduray [54] terms this to be 'constructive interference' and suggests that many industries spend significant resources providing additional training. This training is in areas such as ethics, environmental issues, multi-discipline design, and globalization. All of these are components of a well designed FEE and it becomes obvious that it is in the self interest of industry to help develop, and provide ongoing support to FEEs.

WORKLOAD, COST AND FACULTY

The role of faculty has changed greatly over the last few decades in many universities from the aloof learned scholar to the all-rounder who can research, and teach, mentor and care for students. The authors accept that there is research-intensive and teaching-focused universities but FEEs can be designed for any situation. One thing in common to any FEE is the need for teaching faculty to adopt a pastoral–carer role. FEEs are by nature an interactive exercise between students, their peers and instructors and pastoral care is implicit. Once most students progress beyond freshmen their needs for such care greatly diminish as they become more self-sufficient and learned in their study skills.

In the absence of specialist staff, pastoral care may be bundled into 'teaching' by most universities and then seen to be a responsibility for teaching departments. It is recognised that providing experimental, hands-on, team project-based design courses is very expensive, requiring high quality physical infrastructure and high ratios of faculty, instructors and teaching assistants [30].

IMPROVING GRADES AND GRADUATION

Many studies have shown that student academic standing at entry, either in the form of high school GPA or SAT, can be an indicator of freshmen performance [55]. There is still some discussion whether SAT correlates with retention to the same degree and Dee and Livesay [56] suggest not. However a detailed study by Bundy, LeBold and Bjedov [57] suggests that there is a well defined correlation over the full spectrum of math SAT scores for the years 1981 to 1993 (Fig. 3). Work carried out at the ITTL at the UCB does not indicate any correlation, but that may be due to the narrow band of SAT scores involved.

The influence of FEEs on retention rates will be most apparent for the students with low math SAT scores. If students can survive their freshmen year, they stand a very good chance of graduating. For example, Purdue University data demonstrated that over the period from 1976 to 1993, 63.6% students on average successfully transferred into

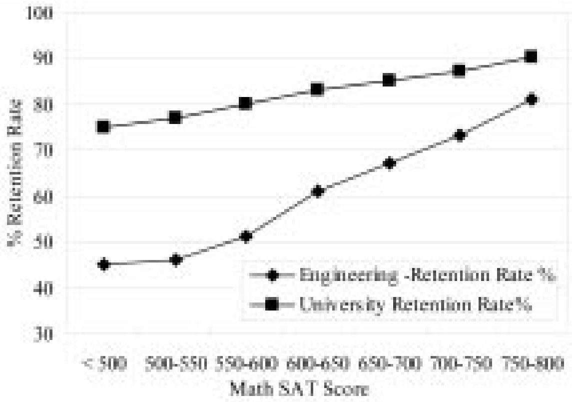

Fig. 3. Retention rates related to math SAT scores.

Table 6. GPA data for all engineering students

COE Overall, n = 4393, $p < 0.05$

Semester	Overall (out of 4)	Takers	Non-takers	Change
Third	2.83	2.86	2.81	2%
Fifth	2.93	2.94	2.93	0%
Seventh	3.02	3.01	3.02	0%

CVEN, n = 258, $p < 0.05$

Semester	Overall (out of 4)	Takers	Non-takers	Change
Third	2.73	2.79	2.71	3%
Fifth	2.89	2.88	2.89	0%
Seventh	2.99	2.98	2.99	0%

engineering and that 89.4% on average of those students subsequently successfully graduated [57].

While the introduction of FEEs has been shown to reduce attrition, unfortunately there is much less data available on the impact of FEEs on grades and virtually none on their influence on producing better graduates. GPA data for engineering students at UCB were collected at the beginning of the third, fifth, and seventh semester. Overall, differences were few between FYEP takers and non-takers (Table 6).

One significant difference was found, with FYEP takers in the overall population scoring slightly higher (2%) than non-takers at the third semester. A similar difference was found for CVEN students, but this difference tested as non-significant. The data shows that the two cohorts have similar grades expressed as GPAs, which was expected given the similar SAT banding for both cohorts.

The only conclusion that can be made here is that FEE does not significantly impact on graduate quality as measured by GPA for UCB. No data could be located that indicated how the different cohorts were perceived by their profession after graduation.

INTERNATIONALIZATION

Given the drive towards the globalization of engineering it is expected that USA engineering departments and faculty would see potential in internationalizing curricula. One issue with internationalization is how to fit it into a crowded curriculum. Wankat and Oreovicz [58] state 'no professor has ever complained of having too little material to cover in a course'. A FEE is the ideal place to introduce students to 'internationalization' as the design component can be internationally orientated.

This is well illustrated by the FYEP course at the University of Colorado, Boulder, taught through its ITLL. Since 2002, students have been able to sign up for a section of the course that emphasizes appropriate technological systems for the developing world with emphasis on solving water, sanitation, energy and health problems. In fall 2005, students worked on projects including [59]: see-saw water pumping, sea wave power generation, river hydropower, bicycle driven water pumping, cooling systems for vaccines and a crank phone charger. Thus the opportunity exists for all freshmen engineers at UCB to experience some aspects of international engineering, via its FEE.

Another example in which international issues have been incorporated into a FEE can be found at the University of Washington where a bi-national FEE program was set up for students to participate and learn from authentic international research and design projects [60]. The project brought together freshmen design teams at Washington with freshmen teams at Tohoku University in Japan to collaborate on design projects.

PROGRAM INTEGRATION

One reason integration of the FEE into a program may be difficult is simply due to a lack of ongoing resources. This is one of the key factors identified by Cutler and Pulko [61] who investigated UK engineering attrition and listed 50 strategic responses that could be used by higher education to improve retention rates of engineering students.

The strategy of truly integrating a new FEE into the curricula is complex and difficult, but obviously worthwhile pursuing [62, 63]. Froyd and Ohland [64] rationalize that an integrated curricula both helps and retains students by improving intra-disciplinary and inter-disciplinary learning. They indicate however, that the published assessment data has not shown that students make better connections across courses and that successful and broad integration requires appropriate faculty rewards and institutional support. Interestingly they summarize that, *'the most significant outcome of integrated programs may be staff development',* as student benefits are

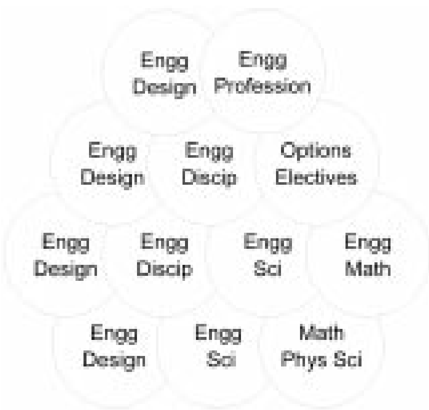

Fig. 4. Schematic of seamless course integration.

realized through faculty having better understanding of their own input into the teaching and learning process.

The complexity of program integration stems from the fact that it is neither the integration of a 'year' nor a 'stream' but rather an entire matrix. As an example for freshmen, Math 1 must integrate with the Physical Sciences and Engineering Sciences while preparing the same students for their sophomore studies in Math 2 and specific (engineering) discipline-related courses. This complexity is well outlined by Pendergrass, et al. [41], who describe a 31-credit IMPULSE (Integrated Math, Physics, Laboratory Science, English and Engineering) at University of Massachusetts, Dartmouth. IMPULSE runs over 2 semesters (17 credits in semester 1 and 14 credits in semester 2) and the course was 'carefully sequenced to maximize synergism among them'. Such integration becomes even more complex as students move into their senior years and faculty become protective of their teaching specializations. Figure 4 shows a representation of what is desirable, an overlapping and seamless knowledge integration.

One aspect of program design that is often under continual scrutiny is the integration of externally taught courses with mainstream engineering curricula. The teaching of math and physical science courses is seen as a service, where students take the courses, not as part of a stream, but rather to acquire learning tools for enabling the study, understanding and applications of engineering. Unfortunately faculty teaching service courses often expect the engineers to merge into programs designed for students taking (say) a math major. This fragmentation can be minimized by a well-designed FEE where engineers, mathematicians and scientists can all contribute to the teaching and learning process. The FEE can then become the keystone to a well-integrated program.

CONCLUSIONS

The need for engineering departments to meet the ABET desire to expose freshmen to elements such as teambuilding and hands-on design has assisted the implementation of FEEs. It has been widely reported that this has been accompanied by the benefit of superior learning experiences for students and increased retention rates, as students become part of their university's engineering community. The paper indicates that the benefits extend far beyond retention and included linking to K-12 outreach programs, assisting with course marketing and recruitment, promoting diversity in engineering, supplementing math and science skills, maintaining an income stream and internationalization of the curricula.

There is little data available that shows that students who have undertaken FEE possess 'better' attributes than those who have not. This reflects both the difficulty of measuring such variables and the fact that the FEE is usually not truly integrated into the overall program. This integration is very complex due to program structures and resourcing. No solution is presented here, other than suggesting that the issue must be considered at the strategic level when introducing a FEE into a program.

Constructing and maintaining a FEE can be very expensive and it is here that the profession and industry can and should play a larger role as it has been the profession's need for more rounded graduates that has stimulated FEE growth. Such involvement will cost industry significant funds and they will look to be provided with measurable outcomes from their investment, including student quality when entering the workforce and retention rates.

The paper has outlined the broad and strategic benefits of the FEE from linking to K-12 programs to internationalization. Creating a FEE as the foundation of a well-integrated program is a very difficult and complex with many variables to be considered. It is an exercise that requires strategic planning and management at the highest institutional level.

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