Cooperative Engineering Education Program

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1 Introduction

Each year the first co-author (WBK) tries to attend the annual meeting of the American Association for Engineering Education because it serves to remind him why he really entered academia. ASEE caters to his highest ideals insofar as his profession is concerned. He is also highly motivated to present a paper at the annual ASEE meeting on some subject concerning pedagogy or other aspect of engineering education. The impetus for this paper came from the first co-author's recent move from the University of Colorado where he spent 32 years on the faculty to the University of Cincinnati where he just completed his 2nd year on the faculty. This co-author has been particularly impressed with the Engineering Cooperative Education Program at the University of Cincinnati, which has no counterpart at the University of Colorado.

This paper was inspired by a recent experience of the first co-author in which he had the opportunity to teach the same pediment graduate course, which also served as a technical elective for seniors, at both the University of Colorado and the University of Cincinnati. The subject of the course was "Fundamentals of Membrane Science and Technology". The enrollment was similar at both Colorado and Cincinnati, namely about 50:50 graduate and undergraduate students. It is rare that one has the opportunity to teach the same course at two different universities. Indeed, it offers the opportunity to make some interesting comparisons! In teaching this course for the first time at Cincinnati, the first co-author decided to do something that he never would do if he were teaching the course again at the same University, namely to give the same set of hour exams (two) and final exam. He did this to provide some metric to compare the students at Colorado and Cincinnati. When he taught this course at Colorado, the graduate students outscored the undergraduates rather handily, as might be expected. Interestingly, when he taught this course at Cincinnati, the undergraduates outscored the graduate students! At first, he thought that this was an indication that Colorado recruited better graduate students than Cincinnati. However, this is easy to check via GRE scores and undergraduate class rank. If anything, the graduate students at Cincinnati looked better on paper, possibly because Cincinnati recruited more international students for their graduate program than did Colorado (because Cincinnati allows nonresident tuition waivers for international graduate students but Colorado does not). In looking into this interesting comparison, he attributed the success of the undergraduates at Cincinnati to the fact that they had the opportunity to participate in a cooperative education program, which was not possible at Colorado. In the opinion of the first co-author, the mandatory Engineering Cooperative Education Program at Cincinnati produces a more professionally mature engineering student by the time they reach their senior year.

The above anecdote provided the motivation for the first co-author to write this article. However, being a new faculty, he did not have the background information on the co-op program at Cincinnati to write this article. Hence, he enlisted the willing aid of the faculty in the Division of Professional that administers the Cooperative Education Program for the entire University of Cincinnati. These included Professor Kettil Cedercreutz, Associate Provost and Director of the Division of Professional Practice that administers the co-op program at the University of Cincinnati, and Professor Anthony Dardy, the faculty mentor/advisor for the co-op program in Chemical Engineering. The resulting co-author team is justifiably proud of the success of the Cooperative Engineering Education Program at Cincinnati and hopes to provide some motivation, via this article, for other universities to consider implementing a similar program.

2 The Coop Program at Cincinnati

2.1 About the Program

Cooperative education or co-op is a program that enriches the student's education by integrating professionally related work experience with academic study. The University of Cincinnati has the distinction of establishing the first co-op program in the U.S. Indeed, Professor Herman Schneider, Dean of the College of Engineering at Cincinnati, developed this pioneering program in 1906. Professional Practice is the name given by the University of Cincinnati to its model for co-op education. Co-op exposes the student to the real world of work and to career options. The benefits of co-op are multifold:

- It helps students to interrelate theory and practice;
- It promotes a sense of independence and professional maturity;
- It increases opportunities for career positions following graduation;
- It provides an opportunity for students to 'test drive' their career choice;
- It greatly strengthens a student's resume;
- It gives students an edge in hiring and salary in the job market;
- It permits students to earn while they learn

2.2 How Co-op Works

The co-op program is administered by the Division of Professional Practice at the University of Cincinnati. Participation in the co-op program is mandatory for undergraduate students in the College of Engineering and the College of Design, Architecture, Art and Planning. It is optional for students in the College of Business Administration, College of Applied Science, College of Arts and Sciences, and University College. The focus of this article will be on the co-op program in the College of Engineering and College of Applied Science.

The University of Cincinnati operates on a quarter system, in part because it lends itself so well to the co-op program. All students in the co-op program are enrolled in the Division of Professional Practice, which is administered by Professor Kettil Cedercreutz, Associate Provost and Director, 17 faculty, and 8 staff. Students participate on a year-round schedule that results in the prescribed number of professionally related work experiences (usually six work quarters or a

year and a half of experience in their major) prior to graduation. The schedule is arranged so that co-op students have approximately five weeks of vacation each year.

The schedule comprised mainly of two alternating sections – Section I for summer and winter work quarters, and Section II for autumn and spring work quarters. Students may also work double sections, either in the autumn and winter or the spring and summer. Employers usually choose two students to alternate on each co-op job so that one or the other is always on the work assignment while the other is in school.

Each student admitted into the Division of Professional Practice is assigned to a co-op faculty member who helps the student identify program objectives and suggests work assignments. This faculty member also functions as liaison between the student and the co-op employer.

All co-op students are required to submit a written report on their co-op experience for the quarter. At the end of each co-op quarter the student, the employer and the faculty member participate in a three-party evaluation process. The faculty and employers assess the students who in turn assess the employers. Both the student report and the employer's performance review are discussed with the student by their co-op faculty advisor after each work quarter. At this time goals may also be adjusted, or reinforced, and experiences are related to what is also being presented in their academic program. This process forms a solid foundation for further enhancement of co-op relations. Assessment questionnaires support the Accreditation Board for Engineering and Technology, ABET criteria *a ... k*. The information thereby generated is used to further develop the academic programs.

2.3 The Co-op Program in the College of Engineering

As stated above, the co-op program is mandatory for all undergraduates in the College of Engineering and College of Applied Science. The co-op program involves approximately 200 quarter credit hours of courses and six quarters of work experience distributed over five years.

During the winter quarter of 2001, 1165 engineering students participated in the co-op program. Table 1 shows the breakdown of these students by department. Employers were drawn from 32 states and 8 foreign countries. These employers included 698 companies from the State of Ohio (74%), 454 companies from other states (25%), and 23 from foreign countries (1%).

3 Metrics of Success

3.1 Comments from Former Co-op Students

It is challenging to write an article on a program that the co-authors themselves have not experienced directly. A sincere measure of the value of the co-op experience is provided by the following comments from former co-op students:

"*In the last 20 plus years my perspective on the co-op education experience has taken on several angles…Leaving my final co-op term with multiple job offers gave me a strong sense of confidence. I was not prepared, however, for the value that other major companies placed on the 22 months of experience I had gained at Dow. Needless to say, I was in an enviable position given the economy of the day. I shudder to think how things might have turned out if I had to*

compete in the market without this experience. Another subtle but significant point is that my decision process was really quite easy. I had a 22 month in depth 'interview' with Dow, so I had great data for evaluation and comparison…I cannot imagine any better 'hunting ground' for the future leadership of our company than students who took advantage of the blend of practical and technical education offered at a co-op school. While the debate between which of these areas in more important may go on forever, there is no debate in my mind regarding the character that is built when these two are blended. In my opinion, this character is a competitive advantage that drives success in any organization."

Tom Parker
North American Supply Chain Manager
The Dow Chemical Company
UC Co-op Recruiter for Dow Chemical
UC Chemical Engineering Class of 1982

Table 1: Student Enrollment in Coop Program for the Winter Quarter, 2001.

Department	No. of Students in Coop Program
Aerospace Engineering	75
Civil and Environmental Engineering	146
Chemical Engineering	188
Computer Engineering	115
Computer Science	52
Electrical Engineering	153
Engineering Mechanics	26
Industrial Engineering	60
Materials Science and Engineering	65
Mechanical Engineering	285
College of Engineering Total	**1165**

"*I believe that co-op is an exceptional program to be involved in as an engineering undergraduate. Not only does co-op allow students to merge the theory that they learn in the classroom with practical applications in industry but they get paid to do it. In addition, co-op provides students with the opportunity to see that in industry, an engineer must work with people from all different backgrounds, business, labor, management, etc. This encourages students to enhance their ability to cross-disciplines and to see the business strategy of the company as a whole and where every piece of the puzzle fits in, something not able to be taught in the classroom. I believe that this makes students better employees upon graduation because they understand the expectations of them in industry and can be valuable assets to their respective employers from the get go*."

Brian Boczek
Graduate Student
UC Chemical Engineering Class of 2001

"*The co-op program at the University of Cincinnati was the deciding factor when it came to choosing a university during my last year in high school. Co-op truly is the ultimate scholarship.*

I gained real-world experience that could never be taught in a classroom, and better yet – they paid me for it! My seven quarters of co-op employment gave me insight into the types of career paths that I could follow, helped me narrow down my fields of interest, and more importantly helped me to identify early on the types of jobs that I was not interested in. I cannot imagine beginning the post-graduation job search without having the knowledge and experience gained from co-op. Interviews and site visits are taken to a whole new level, as I can both ask and answer serious technical questions with confidence….I recall one experience in which I was the first interviewee with co-op experience that the company representative had every interviewed. She asked "tell me about a time when you had to work effectively in a group to accomplish a goal," and was astonished when I recalled the occasion when I was part of a five-member group responsible for a 1.5 million dollar de-bottlenecking project. She later confided in me that she was at a loss for words, as she had been expecting an example related to a school project or group."

Shaun Howard
Graduate Student
UC Chemical Engineering Class of 2001

"The University of Cincinnati co-op program is an essential tool in learning the chemical engineering profession. Through my co-op experience I have learned to apply theories and principles taught in the classroom in a real world setting, such as heat exchanger design and working within a team. My experience has also taught me valuable experiences in expanding on classroom material, while also teaching real world applications that are never seen in a classroom such as different areas and jobs with in the profession. The co-op experience has reinforced my interest in being a chemical engineer and provided with me with an initial career path, something school could never do."

Allison Creed
Senior and President
Student Chapter of the AIChE
UC Chemical Engineering Class of 2002

3.2 Comments from Co-op Employers

A successful co-op program must be bi-directional; that is, it must provide a meaningful experience for the students but it also must be useful to the employers. Roughly 20% of UC current co-op employers participated in the program for more than 20 years. Cincinnati Machine has participated continuously since 1906. Cinergy came on board in the 1920s. Dow Chemical has continuously participated in the program since 1934. The following comments from representative employers also underscore the success of this co-op program:

"*As a leader in the global energy industry, BP understands the importance of maintaining a dynamic and innovative organization that relies on the skills of its employees. Only by attracting, developing, and retaining today's best students and professionals, can BP meet its top-tier performance goals. BP's U.S. cooperative education program, which draws on many of the nation's top schools, plays an integral part in this drive for success. Each year, BP's co-op students provide valuable support to research & development and manufacturing sites in several regions of the country. These opportunities not only allow the students to gain an insight into BP*

and the energy industry as a whole, but they also provide the hands-on, practical experience which complements the students' formal classroom education. By utilizing this co-op program effectively, BP is able to maintain strong relationships with its university partners, and can develop the talented individuals who will become the leaders of tomorrow."

Jon Radabaugh
Catalyst Product Manager
BP – Amoco

"*At Aventis, we make full-time offers to approximately 50% of our alternating term co-op students. We think the experience obtained by students who alternate terms with Aventis clearly allows those students to stand out from others who have no other engineering-related work experience. In addition, the alternating term co-op student has more in-depth knowledge and practical experience, based on a variety of assignments in various areas of the Aventis plant, than students who have chosen to intern with multiple companies. This comes as a result of not having to learn the 'lay of the land' when the co-op returns. The returning alternating term co-op can move directly into completing projects instead of learning where to park, where the cafeteria is, etc. By their last two terms, the alternating term co-ops are essentially functioning as full-time engineers for Aventis.*"

Jeff Musser
Technology Leader – Engineering
Aventis Pharmaceuticals

"*Co-op is a tremendous benefit to both the company and the students. The students benefit immediately by gaining valuable real life work experiences that enhance their education, provide insights into multiple career positions and build business skills, and by earning a good salary helping to defray educational costs. Longer term benefits for the students include being able to focus their job search in areas of interest, having 'substance' to talk about during interviews and getting acclimated as full-time employees more quickly. Companies benefit by having broader name recognition on campuses, gaining early access to the best students, and completing extra work at a lower cost rate. In addition, students with co-op experience, especially our own, can come in full-time upon graduation and make a more immediate impact. Co-op is a true 'win-win'.*"

Tim Sepelak
Process Development Engineer
Co-op Coordinator
The Lubrizol Corporation

"*We have interest in UC co-ops for Product Development at Procter and Gamble because we believe we get higher quality engineers through the co-op program than through other avenues. I've been involved in interviewing new hire engineers from several different schools for manufacturing and product development about 14 years. I've been responsible for recruiting or interviewing both full-time straight out of college and co-ops/interns. Those students who have co-op-ed have consistently better views of what industry is all about, are more mature and are productive sooner. They have a more practical and collaborative approach to problem solving and the work environment. They understand the cooperative nature of work in industry, i.e.*

rarely are projects done by a solo problem solver/designer/engineer. Everything we do is done in teams, so people who have experience through their co-op, working in teams, working in a collaborative environment are better candidates. They fit in sooner, and are productive sooner…"

Tim Owens
Assistant Director
Product Development
Procter & Gamble Company

"*We have been hiring chemical engineering co-ops from the University of Cincinnati since the fall of 1994. We have always tried to hire students with an interest in or experience at using computers. Most of our co-ops have done two or more terms in our Engineering and Analytical Services department helping prepare software for refinery-based technical service engineers. (Three of our best also did several quarters at our Detroit refinery helping the computer controls department.) We are a small department. From our viewpoint it is much more convenient to be able to hire two engineers to be able to work on opposite schedules rather than trying to force fit everyone into a summer session. During the first term we invest a substantial amount of time showing the student how we do things. During the second term we can earn back our investment as students complete similar projects with minimal supervision. It is always surprising to see how much more a student accomplishes in succeeding terms.*"

Dr. James Miller
Advanced Senior Chemical Engineer
Marathon Ashland Petroleum, LLC

3.3 Facts and Figures

The sophomore students participating in this co-op program averaged $12,600/year for 2001. The pre-juniors (3rd year) and junior (4th year) students averaged $14,148/year. Overall, the co-op program provided over $12.7 million in gross earnings for the engineering students at Cincinnati during the past year. Co-op helps students generate a significant cash flow throughout their studies. The student's average earnings total approximately $33,000 over six work quarters. As the total in-state tuition for the entire baccalaureate degree is less than $25,000, it is easy to see that the co-op program generates a significant positive cash flow. This feature makes cooperative education a unique concept. Its social implications cannot be underestimated either.

As stated above, the cooperative five-year B.S. Engineering program at the University of Cincinnati involves six quarters of work experience. Students require, on an average, 5.2 years to complete the program. Surprisingly, the average graduation time for students enrolled in competing conventional four-year engineering programs is almost five years. This comparison weakens the argument that a co-op program delays graduation significantly beyond that for conventional four-year engineering programs.

Nearly all engineering and engineering technology students at UC have at least one permanent job offer at graduation. Figure 1 shows the placement statistics for graduates of the College of Applied Science for the past ten years. Former co-op employers account for 60% of the

permanent job offers that these students received. Approximately one-half of these job offers from former co-op employers are accepted by Cincinnati students.

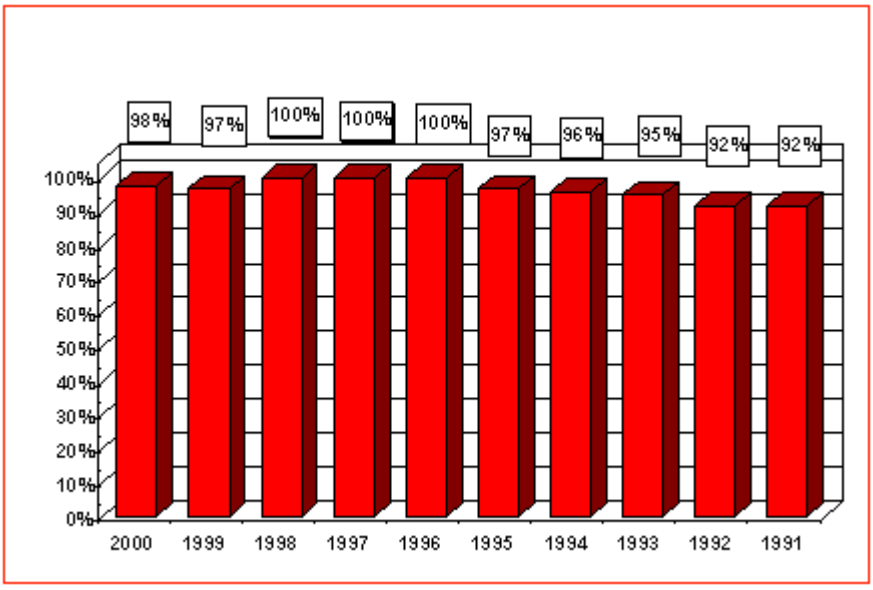

Figure 1: Placement statistics; University of Cincinnati, College of Applied Science 1991 – 2000. [Averages of: Architectural Technology, Chemical Technology, Civil & Construction Engineering Technology, Electrical Engineering Technology, Manufacturing Engineering Technology, Mechanical Engineering Technology Baccalaureate and Associates degrees.]

Local industry rapidly embraced the co-op concept developed at the University of Cincinnati. Co-op today is an integral part of the Cincinnati industrial fabric. It is no coincidence that Greater Cincinnati today, almost 100 years after the introduction of co-op, hosts in excess of 4,000 manufacturing companies. The local industry is diverse, advanced and stable; however, it is affected by fluctuations in the national economy. The co-op program at Cincinnati provides industry with both a learning work force, and an effective recruitment channel. The program additionally assures a close interaction between industry and academia, keeping university offerings well aligned with industrial needs.

Successful cooperative education programs respond rapidly to changes in the industrial environment. A co-op program, during good economic times, typically supports an employer/student ratio between 1.3 and 1.8. A ratio of less than 1.3 leads to disgruntled students. Employers, on the other hand, typically lose interest in a program when the odds of attracting a co-op student are less than 60%. In a declining economy co-op practitioners are forced to invest significantly in attracting additional employers. The extraordinary cost benefit of co-op students obviously alleviates the situation. As the economic tide turns, employers typically reinstate the volume of their co-op programs to match their increased demand.

4 Discussion and Recommendations

In the Introduction we cited seven advantages of the co-op program. In addition to these well-recognized advantages, there are several other potential benefits of a co-op program that should be mentioned. Since the co-op program provides significant income to the student during his/her university studies, it is particularly attractive to recruiting minority students coming from financially disadvantaged families. Note also that the co-op program at Cincinnati has involved 23 employers from foreign countries. Hence, the potential exists to combine the co-op program with a study-abroad experience, thereby enriching the cultural as well as the technical education of the student. Another potential advantage of co-op relates to satisfying ABET 2000 accreditation criteria. In particular, ABET 2000 requires assessment of the student's learning experience. This is provided quite well by the combination of written reports by the students and by the employers after each co-op quarter is completed. One might also consider the potential for combining co-op with either a five-year M.S. as the first degree program or with a six-year combined B.S./M.S. degree program.

Clearly the co-authors are quite enthusiastic about the co-op program at the University of Cincinnati. Co-op is still associated with significant costs. In an effective co-op program the students are divided in alternating sections. As 'section one' is on work assignment, 'section two' is in school, and vice versa. Double offerings obviously lead to increased costs. Mandatory co-op allows the use of simple alternating schedules. Optional co-op schedules are increasingly more complicated. In order to be both functional and flexible, the curriculum needs to offer three pathways: one for 'section one', one for 'section two', and one for students that do not co-op. This either leads to increased costs, or more cumbersome schedules. In the age of budget cuts, institutions offering voluntary co-op tend to gravitate towards the former solution. Universities moving from mandatory to voluntary co-op, typically see their alternating co-op schedule eroding thereby making co-op less attractive for both students and industry.

Graduation statistics clearly show that co-op students complete their degrees in about the same time as most students on non-co-op, nominal four-year engineering programs. The co-authors believe that a successful co-op program requires a substantial student time commitment to the co-op experience. The six quarters of co-op experience required of all engineering students at Cincinnati clearly requires a five-year program. In order to provide continuity for the employer as well as for scheduling classes at the University, it is essential to run two alternate sections of co-op students. This necessarily requires that essential courses be offered throughout the calendar year for both sections of co-op students; this means that substantive course offerings must be made available during the summer. This in turn lends itself quite well to the quarter rather than the semester system. An ancillary benefit of this two co-op section, four-quarter system is that it provides for very efficient use of University resources, in particular the physical plant since it is in use throughout the year. Moreover, it gives faculty the opportunity to earn extra salary for teaching an extra quarter and to take off a quarter other during the summer.

An article such as this is far too limited to answer all questions that might arise concerning the co-op program in engineering at Cincinnati. The interested reader is referred to the web site of the Division of Professional Practice at the University of Cincinnati for more information at the address: http://www.uc.edu/propractice/.

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Kettil Cedercreutz is an Associate Professor and past Head of the Department of Mechanical Engineering Technology in the College of Applied Science at the University of Cincinnati. He is the Associate Provost and Director of the Division of Professional Practice, which administers the co-op program at the University of Cincinnati. He received a M.Sc. in 1995 and a Ph.D. degree in 1995 in manufacturing engineering from Helsinki University of Technology in Finland. He was a faculty member and Head of the Department of Mechanical Engineering at the Swedish Institute of Technology.

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Anthony F. Dardy is an Associate Professor of Professional Practice. He teaches cooperative education classes and is the cooperative education faculty advisor for chemical engineering students in the College of Engineering. He has held several administrative positions within the Division of Professional Practice. He has a B.S. in Education from the University of Dayton, a M.Ed. in Curriculum Design and Teaching Strategies from Xavier University and, in addition, has extensive graduate course work in educational administration and designing computer-based interactive instruction from the University of Cincinnati.