Co-op and ABET 2000: The Added Learning Dimension!

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Abstract

Student perceptions are only one method to assess learning. However, student perceptions of learning are an important factor that the Accreditation Board for Engineering and Technology (ABET) review teams take into consideration as they make their decisions. This paper seeks to examine student perceptions as to the impact of cooperative education in the development of the specific attributes of the engineering graduate as described in ABET 2000's Criterion Three. Studies were conducted at the University of Cincinnati and at Northeastern University with students in mandatory and optional engineering co-op programs. In 1998, Cates surveyed all students in Materials Science and Engineering and Industrial Engineering to get their perceptions. Students were asked to rank their abilities within each of the eleven categories on a scale of Excellent to Poor. They were then asked to attribute the development of each ability on a percentage basis to xx % Classroom, yy % Co-op and zz % Other (please specify) to total 100%. A second, and more comprehensive survey, was administered by Cates to the graduating Class of 1999 for the University of Cincinnati, College of Engineering. This survey used the same format and gathered results for 10 distinct disciplines in the undergraduate program. Canale & Duwart conducted parallel studies at Northeastern University. Results from both sets of studies are consistent. They indicate that the students' perceptions of the learning that occurred through cooperative education has a direct and significant impact on their development in the eleven ABET attributes. Within all engineering disciplines surveyed, and without special treatment, cooperative education shows itself to be a strong partner, along with traditional academic coursework and laboratories, in the development of these attributes in the engineering graduate. The authors propose that colleges who can document the results of cooperative education learning will be in a strong position to demonstrate that their students meet ABET EC 2000 criteria.

I. Introduction

As student learning outcomes become the focus within higher education, it is important that cooperative education establish its place in the development of such learning outcomes. Historically co-op professionals have been at the forefront of documenting learning. Student reports and employer evaluations have long captured important information regarding what

students have learned in the workplace. But little has been done to compare classroom learning with co-op learning in predetermined learning outcomes.

Professors Richard Canale and Ellen Duwart at Northeastern University and Professor Cheryl Cates at the University of Cincinnati have conducted research with undergraduate students in engineering disciplines. These studies have been designed to compare student perceptions of classroom learning with co-op learning within the framework of the Accreditation Board for Engineering and Technology (ABET) EC 2000 Attributes of an Engineer.

Results from both sets of studies are consistent. They indicate that the students' perceptions of the learning that occurred through cooperative education has a direct and significant impact on their development in these eleven ABET attributes. Within all engineering disciplines surveyed, and without special treatment, cooperative education shows itself to be a strong partner along with traditional academic coursework, in the development of these attributes in the engineering graduate. The authors propose that colleges who can document the results of cooperative education learning will be in a stronger position to demonstrate that their students meet ABET EC 2000 criteria.

Background Information on Accreditation and Cooperative Education

The Accreditation Board for Engineering and Technology (ABET) is recognized in the United States as the sole agency for accreditation of educational programs leading to degrees in engineering. This voluntary accreditation system assures that graduates of an accredited engineering program are adequately prepared to enter and practice within the field of engineering. There are eight criterion upon which accreditation is based. These criteria include students, program educational objectives, program outcomes and assessment, professional component, faculty, facilities, institutional support and financial resources and program criteria. Beginning in the year 2000, ABET will review all engineering programs under a new set of criteria.

Under the conventional criteria for engineering accreditation (Section D.) [1], and under the present EC 2000 criteria, (Section II of the present EC 2000 criteria) [2] Cooperative Education Programs have separate criteria and separate accreditation. However, at the October, 1999 ABET Board Meeting, the following was adopted, *"Approved for First Reading, the Board of Directors considered the proposal of the Engineering Accreditation Commission (EAC) to discontinue the accreditation of cooperative education as a separate element. A cooperative educational component can be evaluated as part of the total educational program without reference to separate criteria under EC 2000. If approved on Second Reading, this change will be effective with the 2001-02 accreditation cycle."* [3] This proposed change takes co-op away from the periphery and places it in the mainstream of engineering education.

Of the eight criterion areas within EC 2000, one criterion seems particularly well suited to the learning outcomes of cooperative education. That criterion is program outcomes and assessment. Under this criterion area, ABET requires that engineering programs demonstrate that their graduates have acquired eleven attributes of an engineer. Each program must have an assessment process with documented results. Evidence that ABET suggests may be used to

document results include student portfolios, design projects, alumni surveys that document professional accomplishments and career development activities, employer surveys, and placement data of graduates.

Cooperative education is a viable educational strategy that enhances the learning of engineering undergraduate students. However, additional research in this area is needed to document the contribution that cooperative education plays in the overall undergraduate education of engineering students. As two of the leading institutions in cooperative education, the University of Cincinnati and Northeastern University have conducted much needed research that documents the strong partnership between cooperative education and traditional classroom learning in developing the student learning outcomes required under ABET 2000.

Co-op Research and Assessment

The four research studies presented here examined one of the eight ABET criteria areas – program outcomes and assessment, to determine the level to which cooperative education contributes to the development of the eleven attributes mentioned in this criterion. These attributes are:

a) An ability to apply knowledge of mathematics, science, and engineering
b) An ability to design and conduct experiments, as well as to analyze and interpret data
c) An ability to design a system, component, or process to meet desired needs
d) An ability to function on multi-disciplinary teams
e) An ability to identify, formulate and solve engineering problems
f) An understanding of professional and ethical responsibility
g) An ability to communicate effectively
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context
i) A recognition for the need for, and ability to engage in life-long learning
j) A knowledge of contemporary issues
k) The ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The authors are not alone in their efforts. For the past two years, the Conference for Industry and Education Collaboration, sponsored by the Cooperative Education Division of the American Society for Engineering Education, has been looking into student learning outcomes and ABET 2000. The 1998 Conference Proceedings, "Developing a Framework for the Assessment of Engineering Education: The Role of Cooperative Education", looks at this important issue[4]. This paper proposes that "By evaluating the student according to the 'Soft Skills' or 'Core Skills', as outlined by ABET 2000 and by The Attributes of Cooperative Education, the evaluators can be assured that co-op is an academic function." Also in the proceedings, "Cooperative Education and EC 2000" describes the efforts of the University of Kentucky in revamping its assessment tools to produce facts and figures which can be used to validate the benefit of cooperative education in the professional development of engineering students[5]. In the 1997 CIEC Conference Proceedings, "Re-Engineering Cooperative Education Learning: A Call for Action" looks at ABET 2000 and its potential effect on the way cooperative education is viewed by

engineering educators[6]. It states that “Estimates have been made that the education provided in engineering programs account for less than half of the education that the marketplace needs from entry level engineers. Although universities are now attempting to respond, a simple makeover of traditional course work and laboratories alone can not provide what the marketplace demands". The paper proposed that cooperative education can become a key contributor to filling the missing educational piece of the engineering student’s education.

To professionals in engineering cooperative education, the issue of ABET 2000 and its student outcomes is perhaps one of the most important issues as we enter the 21st century. It provides a significant opportunity for cooperative education to assert its place as an equal partner with traditional academic coursework in educating engineering students.

II. The University of Cincinnati Study

Two separate studies were conducted at the University of Cincinnati regarding student perceptions as to the impact of cooperative education in the development of the specific attributes of the engineering graduate as described in ABET 2000's Criterion Three. The first study involved all students in the Industrial Engineering and the Materials Science and Engineering programs regardless of class level. The second study involved engineering students in the class of 1999. This provided data from engineering students in the discipline areas of Aerospace Engineering, Chemical Engineering, Civil and Environmental Engineering, Computer Engineering, Electrical Engineering, Engineering Mechanics, Industrial Engineering, Materials Science and Engineering, Mechanical Engineering and Nuclear Engineering.

All undergraduate engineering students at the University of Cincinnati participate in cooperative education as a mandatory part of their degree requirements. The Division of Professional Practice administers the cooperative education program at the University of Cincinnati within a centralized unit serving four colleges. Students follow a full time alternating model operating on the quarter system. Most engineering students will complete six quarters or 18 months of co-op work assignments.

A similar research instrument was used in both studies. The instrument asks students to assess their current abilities in each of the eleven attributes on a five-point scale. They are then asked to isolate which percentage of this ability came from classroom education, from co-op experience and from other (please specify) to total 100%. The simple design of this form made it easily administered while allowing for clear and readily understandable reporting of results.

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University of Cincinnati, First Study

The first study, funded by the Ohio Cooperative Education Association, was administered as a mail survey to engineering students in the disciplines of Materials Science and Engineering and Industrial Engineering. The response rate for Industrial Engineering students was 39%. The response rate for Materials Engineering students was 32%. For the Industrial Engineering students they determined co-op to have a more significant percentage impact on the development of these attributes in seven of the total eleven attributes. For Materials Science and Engineering they determined co-op to have a more significant percentage impact on the development of all eleven attributes.

Industrial Engineering Results	% Co-op	% Class	% Other
a.. Ability to apply knowledge of mathematics, science and engineering	37%	59%	4%
b. Ability to design and conduct experiments as well as analyze and interpret data	47%	**57%**	2%
c. Ability to design a system, component or process to meet desired needs	**54%**	44%	2%
d. Ability to identify, formulate and solve engineering problems	38%	**60%**	4%
e. Ability to function on a multi-disciplinary team	**59%**	30%	11%
f. Understanding of ethical and professional responsibility	**59%**	20%	21%
g. Ability to communicate effectively	**56%**	26%	18%
h. Having the broad education necessary to understand the impact of engineering solutions in a global/societal context	**56%**	40%	4%
i. Recognition of the need for and the ability to engage in lifelong learning	**51%**	34%	15%
j. Knowledge of contemporary issues	41%	**42%**	17%

k. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice	**50%**	45%	5%

Materials Engineering Results	% Co-op	% Class	% Other
a. Ability to apply knowledge of mathematics, science and engineering	**50%**	39%	11%
b. Ability to design and conduct experiments as well as analyze and interpret data	**54%**	39%	7%
c. Ability to design a system, component or process to meet desired needs	**52%**	38%	10%
d. Ability to identify, formulate and solve engineering problems	**51%**	46%	3%
e. Ability to function on a multi-disciplinary team	**58%**	25%	17%
f. Understanding of ethical and professional responsibility	**67%**	19%	14%
g. Ability to communicate effectively	**49%**	32%	19%
h. Having the broad education necessary to understand the impact of engineering solutions in a global/societal context	**61%**	37%	2%
i. Recognition of the need for and the ability to engage in lifelong learning	**49%**	31%	20%
j. Knowledge of contemporary issues	**49%**	28%	23%
k. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice	**61%**	39%	0%

Another interesting result was found by comparing the students who had completed one co-op term versus three terms verses five terms. The data indicated that, in general, with only one term completed, students did not judge co-op as having a more significant impact than the classroom. Looking at combined data from both Materials and Industrial engineering students with only one co-op term completed, students judge their classroom experience as having a more significant impact on the development of their abilities in five of the eleven attribute areas. With three co-op terms completed co-op had a much more dramatic impact and was ranked as contributing more significantly to their development than even those students with five quarters. With three co-op terms completed students judge co-op as having a more significant impact on the development of all eleven of the ABET 2000 attributes. With five co-op terms completed students still judge co-op as having a more significant impact on their abilities in all eleven of the ABET 2000 attributes, however, statistics indicate an increase in the impact of their classroom experience. Five of the eleven attributes showed a decline in the impact of co-op experience and a rise in the impact of classroom experience from the third to the fifth co-op work term. The likely explanation for this is that with only one term the students have not accumulated enough work experience to make a significant impact as they would with three work terms. But by the time they have reached their fifth work term students have completed all of their foundation studies. Their academic coursework is becoming more specific and therefore more relevant to the development of ABET 2000's specific attributes.

University of Cincinnati, Second Study

The second study, funded by the Midwest Cooperative Education Association, examined the perceptions of the Class of 1999 for the College of Engineering at the University of Cincinnati. This provided data from engineering students in the discipline areas of Aerospace Engineering, Chemical Engineering, Civil and Environmental Engineering, Computer Engineering, Electrical Engineering, Engineering Mechanics, Industrial Engineering, Materials Science and Engineering, Mechanical Engineering and Nuclear Engineering.

This survey was similar to the first survey but was distributed along with a mandatory senior survey that is required of all students prior to graduation. While this survey was not a graduation requirement, it enjoyed an extremely high response rate by association. The overall response rate was 88% and ranged from a high of 100% response in Engineering Mechanics to a low of 64% response in Computer Engineering. On average, students had completed 6 co-op work terms, which equates to 18 months of full time co-op work experience.

The data was analyzed using simple numerical averages of students perceived abilities in each attribute and percentage attributed to co-op, classroom, and other. An average was determined for the entire college as well as within each of the discipline areas. Additionally an examination of the extremes (those responses which attributed 80% or more to co-op, classroom, or other) was conducted to determine if students perceived a decided advantage to one method of development in each of the eleven attribute areas.

University of Cincinnati
Class of 1999

Ability to apply knowledge of mathematics, science and engineering	% Co-op	% Class	% Other
College of Engineering – All Disciplines	42%	**52%**	6%
Aerospace Engineering	35%	**56%**	9%
Chemical Engineering	47%	47%	6%
Civil and Environmental Engineering	36%	**58%**	6%
Computer Engineering	**51%**	37%	12%
Electrical Engineering	44%	**50%**	6%
Engineering Mechanics	47%	**53%**	0%
Industrial Engineering	**49%**	45%	6%
Materials Science and Engineering	**54%**	44%	2%
Mechanical Engineering	36%	**58%**	6%
Nuclear Engineering	24%	**72%**	4%

Students perceive their abilities in this area as good to excellent, with an average of 4.22 on a scale of 1 – 5 for College of Engineering. The range went from a low of 3.3 in Engineering Mechanics to a high of 4.8 in Nuclear Engineering. In this first attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignment. This holds true within six of the ten disciplines as well. A seventh discipline attributes the exact same

proportion of ability as coming from classroom and from co-op experiences. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of classroom studies on the development of this attribute. For the College of Engineering's Class of 1999, 73% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies.

Ability to design and conduct experiments as well as analyze and interpret data	% Co-op	% Class	% Other
College of Engineering – All Disciplines	45%	**51%**	4%
Aerospace Engineering	36%	**58%**	6%
Chemical Engineering	**54%**	42%	4%
Civil and Environmental Engineering	32%	**64%**	4%
Computer Engineering	45%	**49%**	6%
Electrical Engineering	48%	**49%**	3%
Engineering Mechanics	**65%**	35%	0%
Industrial Engineering	43%	**54%**	3%
Materials Science and Engineering	**56%**	41%	3%
Mechanical Engineering	47%	**49%**	4%
Nuclear Engineering	**50%**	40%	10%

Students perceive their abilities in this attribute area as good to excellent, with a 4.05 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.76 in Civil and Environmental Engineering to a high of 4.22 in Computer Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignment. This holds true within six of the ten disciplines as well. But when the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) students were split in their perceptions of the impact of classroom studies and their co-op assignments on the development of this attribute. For the College of Engineering's Class of 1999, 51% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies. Another 49% attribute 80% or more of their abilities on their co-op assignments. This is likely due to the nature of the work experience itself. For example, Chemical Engineering, Materials Science and Engineering, Nuclear Engineering and Engineering Mechanics judge their co-op experiences as having a more significant impact than their classroom studies. These disciplines are also more likely to design and conduct experiments as well as analyze and interpret data while on the co-op work assignment due to the nature of the positions themselves.

Ability to design a system, component or process to meet desired needs	% Co-op	% Class	% Other
College of Engineering – All Disciplines	47%	**50%**	3%
Aerospace Engineering	33%	**65%**	2%
Chemical Engineering	43%	**54%**	3%
Civil and Environmental Engineering	42%	**54%**	4%
Computer Engineering	**60%**	36%	4%

Electrical Engineering	**56%**	43%	1%
Engineering Mechanics	42%	**50%**	8%
Industrial Engineering	**55%**	42%	3%
Materials Science and Engineering	**54%**	44%	2%
Mechanical Engineering	48%	**49%**	3%
Nuclear Engineering	24%	**63%**	13%

Students perceive their abilities in this attribute area as good to excellent, with a 4.09 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.71 in Aerospace Engineering to a high of 4.5 in Computer Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignment. This holds true within six of the ten disciplines as well. But when the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) students were split in their perceptions of the impact of classroom studies and their co-op assignments on the development of this attribute. For the College of Engineering's Class of 1999, 55% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies. Another 44% attribute 80% or more of their abilities on their co-op assignments. Only one percent of students viewed "Other" as having the most significant impact.

Ability to identify, formulate and solve engineering problems	% Co-op	% Class	% Other
College of Engineering – All Disciplines	44%	**53%**	3%
Aerospace Engineering	43%	**47%**	10%
Chemical Engineering	42%	**54%**	4%
Civil and Environmental Engineering	38%	**60%**	2%
Computer Engineering	**57%**	38%	5%
Electrical Engineering	45%	**54%**	1%
Engineering Mechanics	40%	**60%**	0%
Industrial Engineering	**50%**	45%	5%
Materials Science and Engineering	**63%**	33%	4%
Mechanical Engineering	44%	**53%**	3%
Nuclear Engineering	34%	**53%**	13%

Students perceive their abilities in this attribute area as good to excellent, with a 4.13 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.67 in Engineering Mechanics to a high of 4.4 in Nuclear Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignment. This holds true within seven of the ten disciplines as well. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of classroom studies on the development of this attribute. For the College of Engineering's Class of 1999, 68% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies.

Ability to function on a multi-disciplinary team			

	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**61%**	32%	7%
Aerospace Engineering	**53%**	39%	8%
Chemical Engineering	**58%**	32%	10%
Civil and Environmental Engineering	**61%**	32%	7%
Computer Engineering	**56%**	36%	8%
Electrical Engineering	**64%**	30%	6%
Engineering Mechanics	**62%**	31%	7%
Industrial Engineering	**60%**	36%	4%
Materials Science and Engineering	**67%**	27%	6%
Mechanical Engineering	**64%**	31%	5%
Nuclear Engineering	**53%**	35%	12%

Students perceive their abilities in this attribute area as good to excellent, with a 4.46 on a scale of 1 – 5 for the College of Engineering. This was only a fraction below the highest rating of a 4.47 received by an of the eleven attribute areas. The range went from a low of 4 in Engineering Mechanics to a high of 5 in Nuclear Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true within each of the ten disciplines as well. Another interesting finding was the increase of "Other" within this attribute area. Students attributed at least a portion of their abilities in this area to participation in student activities and team sports. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 87% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience.

Understanding of professional and ethical responsibility	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**66%**	25%	9%
Aerospace Engineering	**60%**	22%	18%
Chemical Engineering	**67%**	25%	8%
Civil and Environmental Engineering	**64%**	29%	7%
Computer Engineering	**63%**	24%	13%
Electrical Engineering	**64%**	23%	13%
Engineering Mechanics	43%	**45%**	12%
Industrial Engineering	**65%**	27%	8%
Materials Science and Engineering	**78%**	19%	3%
Mechanical Engineering	**67%**	24%	9%
Nuclear Engineering	**72%**	28%	0%

Students perceive their abilities in this attribute area as good to excellent, with a 4.25 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 4 in Engineering Mechanics to a high of 4.54 in Industrial Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds

true within nine of the ten disciplines as well. Another interesting finding within those nine disciplines is the fact that they overwhelmingly rated co-op's impact as highly significant. This ranged from a high of 72% attributed to the co-op assignment in Nuclear Engineering to a low of 60% in Aerospace Engineering. Nine of the ten disciplines attributed over 60% of their understanding of professional and ethical responsibility to cooperative education. Students also attributed at least a portion of their understanding to "other", which included parental influence and personal beliefs. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 88% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience.

Ability to communicate effectively	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**60%**	28%	12%
Aerospace Engineering	**55%**	29%	16%
Chemical Engineering	**63%**	27%	10%
Civil and Environmental Engineering	**61%**	27%	12%
Computer Engineering	**69%**	20%	11%
Electrical Engineering	**61%**	26%	13%
Engineering Mechanics	**62%**	31%	7%
Industrial Engineering	**48%**	36%	16%
Materials Science and Engineering	**62%**	25%	13%
Mechanical Engineering	**62%**	27%	11%
Nuclear Engineering	**52%**	44%	4%

Students perceive their abilities in this attribute area as good to excellent, with a 4.16 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.6 in Aerospace Engineering to a high of 4.4 in Materials Science and Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true within each of the ten disciplines as well. Another interesting finding was the increase of "other" within this attribute area. Students attributed at least a portion of their abilities in this area to participation in student activities. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 86% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience.

Having the broad education necessary to understand the impact of engineering solutions in a global / societal context	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**50%**	45%	5%
Aerospace Engineering	**52%**	39%	9%
Chemical Engineering	**54%**	41%	5%
Civil and Environmental Engineering	41%	**53%**	6%

Computer Engineering	**52%**	43%	5%
Electrical Engineering	**59%**	40%	1%
Engineering Mechanics	46%	**52%**	2%
Industrial Engineering	**50%**	48%	2%
Materials Science and Engineering	**59%**	37%	4%
Mechanical Engineering	**48%**	47%	5%
Nuclear Engineering	**52%**	48%	0%

Students perceive their abilities in this attribute area as good to excellent, with a 4.04 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.75 in Computer Engineering to a high of 4.3 in both Engineering Mechanics and Mechanical Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true within eight of the ten disciplines as well. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) students were split in their perceptions of the impact of classroom studies and their co-op assignments on the development of this attribute. For the College of Engineering's Class of 1999, 42% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies. Another 55% attribute 80% or more of their abilities on their co-op assignments.

Recognition of the need for and ability to engage in lifelong learning	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**51%**	37%	12%
Aerospace Engineering	37%	**42%**	21%
Chemical Engineering	**53%**	33%	14%
Civil and Environmental Engineering	**48%**	40%	12%
Computer Engineering	**60%**	28%	12%
Electrical Engineering	**58%**	34%	8%
Engineering Mechanics	**47%**	40%	13%
Industrial Engineering	**53%**	36%	11%
Materials Science and Engineering	**56%**	39%	5%
Mechanical Engineering	**48%**	37%	15%
Nuclear Engineering	36%	**58%**	6%

Students perceive their abilities in this attribute area as good to excellent, with a 4.47 on a scale of 1 – 5 for the College of Engineering. This was the highest that students rated themselves in any of the eleven attribute areas. The range went from a low of 4.16 in Industrial Engineering to a high of 4.8 in Nuclear Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true within eight of the ten disciplines as well. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 66% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience. The rest of the extremes were divided

between classroom studies (19%) and other (15%). The "other" category included parental influence as well as an inner drive to continue to learn.

Knowledge of contemporary issues	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**48%**	35%	17%
Aerospace Engineering	**40%**	27%	33%
Chemical Engineering	**52%**	26%	20%
Civil and Environmental Engineering	**46%**	40%	14%
Computer Engineering	**48%**	32%	20%
Electrical Engineering	**50%**	30%	20%
Engineering Mechanics	**48%**	45%	7%
Industrial Engineering	**49%**	36%	15%
Materials Science and Engineering	**46%**	39%	15%
Mechanical Engineering	**47%**	38%	15%
Nuclear Engineering	**60%**	38%	2%

Students perceive their abilities in this attribute area as satisfactory to good, with a 3.87 on a scale of 1 – 5 for the College of Engineering. This was the lowest rating received by an of the eleven attribute areas. The range went from a low of 3.62 in Computer Engineering to a high of 4.08 in Industrial Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true within each of the ten disciplines as well. Another interesting finding was the strength of "Other" within this attribute area. Students attributed a significant portion of their abilities in this area to the outside media such as radio, television and newspapers. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 57% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience. Twenty seven percent of those students attribute "other" as primarily contributing to the development of this attribute while only 16% report that their classroom studies are the primary contributor to their knowledge of contemporary issues.

Ability to use the techniques, skills and modern engineering tools necessary for engineering practice	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**52%**	44%	4%
Aerospace Engineering	**56%**	39%	5%
Chemical Engineering	**52%**	47%	1%
Civil and Environmental Engineering	**54%**	43%	3%
Computer Engineering	**63%**	37%	0%
Electrical Engineering	**57%**	43%	0%
Engineering Mechanics	42%	**58%**	0%
Industrial Engineering	**56%**	40%	4%
Materials Science and Engineering	**52%**	47%	1%
Mechanical Engineering	48%	48%	4%

Nuclear Engineering	**45%**	44%	11%

Students perceive their abilities in this attribute area as good to excellent, with a 4.15 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 4 in Engineering Mechanics to a high of 4.8 in Nuclear Engineering. In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true within eight of the ten disciplines as well. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 70% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience.

III. The Northeastern University Study

In a parallel fashion to the two University of Cincinnati studies, Canale and Duwart conducted two separate studies at Northeastern University regarding student perceptions as to the impact of cooperative education in the development of the specific attributes of the engineering graduate as described in ABET 2000's Criterion Three. The first study, conducted in 1997 involved all co-op students in the Electrical and Computer Engineering programs regardless of class level. The second study involved all engineering students in the class of 2000. This provided data from engineering students in the discipline areas of Chemical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Mechanical Engineering, and Industrial Engineering.

Although the co-op program at Northeastern University is optional, most undergraduate engineering students (95%) participate in cooperative education. The Department of Cooperative Education administers the cooperative education program at Northeastern University within a centralized unit serving six colleges. Students follow a full time alternating model operating on the quarter system. Engineering students are normally scheduled to complete seven quarters or 21 months of co-op work assignments.

In both studies, a similar research instrument was used. The standard instrument used for the first study asked students to account for their learning attributable to either classroom/laboratory experiences or to their co-op learning. In the second study, students were asked to assess their current abilities in each of the eleven attributes on a five-point scale and they are then asked to isolate which percentage of this ability came from classroom education, from co-op experience and from other (please specify) to total 100%.

Northeastern University, First Study

The first study was conducted as part of a Pilot Program for Internet Based Reflective Learning for Cooperative Education Students which was funded by a University Instructional Development Fund Grant and an Asa Knowles Research Grant[7]. . During the 1997 winter and spring quarters, Canale and Duwart conducted 11 focus groups in which more than 80% of the ECE students, sophomores through seniors, participated. Within a written survey, they were

asked to identify the learning that took place in each of the 11 attributes as a result of their classroom, laboratory, and co-op learning. Each group of students then discussed their assessments with their peers and with the researchers.

This following table shows the results of the student responses to the written survey. Students reported that they gained more proficiency in a number of attributes through co-op than in the classroom. These ECE students determined co-op to have a more significant percentage impact on the development of these attributes in six of the total eleven attributes.

Electrical and Computer Engineering Results 1997

Electrical and Computer Engineering	% Co-op	% Class
a. Ability to apply knowledge of mathematics, science and engineering	29%	**71%**
b. Ability to design and conduct experiments as well as analyze and interpret data	43%	**57%**
c. Ability to design a system, component or process to meet desired needs	47%	**53%**
d. Ability to identify, formulate and solve engineering problems	44%	**56%**
e. Ability to function on a multi-disciplinary team	**65%**	35%
f. Understanding of ethical and professional responsibility	**69%**	31%
g. Ability to communicate effectively	**63%**	37%
h Having the broad education necessary to understand the impact of engineering solutions in a global/societal context	47%	**53%**
i. Recognition of the need for and the ability to engage in lifelong learning	**59%**	41%
j. Knowledge of contemporary issues	**58%**	42%
k. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice	**60%**	40%

The discussions elicited coherent qualitative information to supplement the quantitative data. We asked students to weight the attributes and to decide whether any were not required to become competent engineers. The response from each of the eleven groups consistently was that they are all essential and that, as a consequence, they felt weighting was not an important issue. We asked students how to quantify much co-op has contributed to their overall competency in their engineering proficiency (with instructions to account for what their individual perceptions of weighting for each attribute). On the average, students reported that they gained about 40% from co-op and 60% from school. Given that these students averaged 40% of their time on co-op and 60% of their time in school (average of 4.2 quarters of co-op and 6.2 quarters of school quarters) one implication might be that students are as efficient learners on co-op as they are in school. The students expressed consensus that the "overall" proficiency had more relevance to them than the isolated parts. The students repeatedly stated that it was the intertwining of periods of co-op and school that really made a difference. The students expressed in a number of ways that the total learning is greater than the sum of the parts.

A parallel statistic that emerged concerns the percentage of time engaged in co-op vs. time engaged in school. There is a minor but direct correlation between the percentage of time on co-op and the students' perception of the contribution of co-op to overall learning (in the "softer skills" area). The sophomores in the study completed on the average 1.5 quarters of co-op and 3.4 quarters of school (31% of time on co-op). The seniors in the study completed on the average 7.1 quarters of co-op and 9.5 quarters of school (43% of time on co-op). In some of the dimensions, the percentages attributable to co-op was higher the closer students moved towards graduation.

Northeastern University, Second Study

The second study examined the perceptions of the Class of 2000 for the College of Engineering at Northeastern University. This provided data from engineering students in the discipline areas of Chemical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Mechanical Engineering, and Industrial Engineering. Because of the few number of Industrial Engineers at Northeastern and because they are housed with the Mechanical Engineers within the Mechanical, Industrial, and Manufacturing Engineering Department, Industrial Engineers have been consolidated with the Mechanical Engineers for this report.

This survey was similar to the first Northeastern survey but all students in this study had the option of accounting for the source of students proficiency outside of classes, labs, and co-op similar to the University of Cincinnati surveys. During the fall, 1999, the survey was mailed to the two hundred and twenty two (222) senior engineers identified by the Registrar's Office. Fifteen were returned because of no forwarding address. Seventy-one (71) of the remaining two hundred and seven returned the surveys (34%). Ninety six percent of the responses (68) were from students who had co-oped more than once. The respondents reported that they have completed, on the average, 6.2 co-op work quarters (18.6 months) and 8.7 school quarters. Four percent had not co-oped at all. The percentage of students who were co-op participators as well as the degree of co-op participation of the respondents mirrored the general population of all engineering seniors.

We asked students to report their proficiency each ABET attribute and to assess as to the source of their proficiency. Due to consideration of the qualitative comments on our first study, we also asked them to also report an assessment of their overall proficiency in being ready to become an engineer and in their assessment as to the source of their overall proficiency.

The data was analyzed using simple numerical averages of students perceived abilities in each attribute and percentage attributed to co-op, classroom, and other. An average was determined for the entire college as well as within each of the discipline areas. Additionally an examination of the extremes (those responses which attributed 80% or more to co-op, classroom, or other) was conducted to determine if students perceived a decided advantage to one method of development in each of the eleven attribute areas.

Northeastern University
Class of 2000

Overall my ability to perform as an engineer (a composite of the eleven attributes)	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**46%**	44%	11%
Chemical Engineering	42%	**46**%	11%
Civil and Environmental Engineering	**45%**	43%	12
Electrical and Computer Engineering	**52%**	41%	8%
Mechanical and Industrial Engineering	43%	**46%**	11%

Students perceive their abilities in this area as good to excellent, with an average of 4.25 on a scale of 1 – 5 for College of Engineering. The range went from a low of 4.15 in Mechanical and Industrial Engineering to a high of 4.38 in Civil Engineering Engineering.

In this overall assessment students report that the contributions from co-op and classroom experiences are relatively equal. There was only one student who reported more than 80% was attributable to one source (classroom). That student has completed four co-op quarters and eleven school quarters (about half the average NU engineering student).

Only 11% were attributed to other than classes, labs, or co-op. The following attribute analysis will list descriptions for "other".

a. Ability to apply knowledge of mathematics, science and engineering	% Co-op	% Class	% Other
College of Engineering – All Disciplines	33%	**58%**	9%
Chemical Engineering	34%	**54**%	12%
Civil and Environmental Engineering	31%	**62%**	7%
Electrical and Computer Engineering	33%	**59%**	8%
Mechanical and Industrial Engineering	33%	**57%**	10%

Students perceive their abilities in this area as good to excellent, with an average of 4.14 on a scale of 1 – 5 for College of Engineering. The range went from a low of 3.95 in Mechanical Engineering to a high of 4.24 in Civil Engineering.

In this first attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignment. This holds true within all five disciplines as well. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of classroom studies on the development of this attribute. For the College of Engineering's Class of 2000, 27% of the students judge their abilities at least 80% attributable from their classroom studies. No student claimed a rating higher than 75% for the co-op contribution.

Forty-two percent of the respondents reported "other" listings, which represents 9% of the contribution towards proficiency in this area. The list includes: life experiences, outside reading, and genetics.

Ability to design and conduct experiments as well as analyze and interpret data	% Co-op	% Class	% Other
College of Engineering – All Disciplines	41%	**53%**	5%
Chemical Engineering	43%	**51%**	6%
Civil and Environmental Engineering	35%	**61%**	4%
Electrical and Computer Engineering	**49%**	**46%**	5%
Mechanical and Industrial Engineering	25%	**69%**	6%

Students perceive their abilities in this attribute area as good to excellent, with a 4.17 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.83 in Mechanical and Industrial Engineering to a high of 4.29 in Civil Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignments. This holds true within all disciplines except ECE. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) 22.5% of the students were weighted toward classroom studies and only 2.5% of the students were weighted toward their co-op assignments on the development of this attribute.

Twenty percent of the respondents reported "other" listings, which represents 5% of the contribution towards proficiency in this area. The list includes: life experiences, outside reading, and genetics.

Ability to design a system, component or process to meet desired needs	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**48**%	47%	5%
Chemical Engineering	**51%**	46%	3%
Civil and Environmental Engineering	41%	**57%**	2%
Electrical and Computer Engineering	**51%**	45%	5%
Mechanical and Industrial Engineering	**48%**	43%	7%

Students perceive their abilities in this attribute area as good to excellent, with a 3.96 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.69 in Chemical Engineering to a high of 4.28 in Mechanical and Industrial Computer Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having the same impact on their abilities as their co-op assignment. There is some variability among the disciplines. Also, when the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) students were split in their perceptions of the impact of classroom studies and their co-op assignments on the development of this attribute. For the College of Engineering's Class of 2000, only 12.5% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies. Fewer, 7.5%, of the students attribute 80% or more of their abilities to their co-op assignments.

Twenty percent of the respondents reported "other" listings, which represents 5% of the contribution towards proficiency in this area. The list includes: life experiences, outside reading, and genetics.

Ability to identify, formulate and solve engineering problems	% Co-op	% Class	% Other
College of Engineering – All Disciplines	41%	**54%**	6%
Chemical Engineering	32%	**62%**	4%
Civil and Environmental Engineering	45%	**53%**	2%
Electrical and Computer Engineering	**48%**	46%	6%
Mechanical and Industrial Engineering	26%	**67%**	7%

Students perceive their abilities in this attribute area as good to excellent, with a 4.18 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.98 in Mechanical and Industrial Engineering to a high of 4.36 in Chemical Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive their classroom studies as having a more significant impact on their abilities than their co-op assignment. This holds true within four of the five disciplines with ECE students holding almost even. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of classroom studies on the development of this attribute. For the College of Engineering's Class of 1999, only 7.5% of the students judge their abilities as coming primarily from classroom studies (80% or more). Only 5% of the students judge their abilities as coming primarily from co-op (80% or more).

Twenty-four percent of the respondents reported "other" listings, which represents 6% of the contribution towards proficiency in this area. The list includes: life experiences, outside reading, intelligence, and genetics.

Ability to function on a multi-disciplinary team	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**58%**	31%	11%
Chemical Engineering	**66%**	24%	10%
Civil and Environmental Engineering	**52%**	37%	11%
Electrical and Computer Engineering	**60%**	31%	9%
Mechanical and Industrial Engineering	**55%**	27%	18%

Students perceive their abilities in this attribute area as good to excellent, with a 4.35 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 4.14 in Electrical and Computer Engineering to a high of 4.62 in Mechanical and Industrial Engineering. In this attribute area, the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a highly significant impact on their abilities compared to their classroom studies. This holds true within each of the five disciplines as well. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or

other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 90% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience.

Thirty-seven percent of the respondents reported "other" listings, which represents 11% of the contribution towards proficiency in this area. The list includes: sports, school clubs, other activities, life experiences, and interactions with others.

Understanding of professional and ethical responsibility	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**61%**	24%	15%
Chemical Engineering	**46%**	31%	23%
Civil and Environmental Engineering	**59%**	22%	19%
Electrical and Computer Engineering	**72%**	24%	4%
Mechanical and Industrial Engineering	**60%**	22%	19%

Students perceive their abilities in this attribute area as good to excellent, with a 4.26 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 4.17 in Electrical and Computer Engineering to a high of 4.44 in Chemical Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a highly significant impact on their abilities as compared to their classroom studies. This holds true within all five disciplines as well. Another finding within those five disciplines is the fact that they overwhelmingly rated co-op's impact as highly significant. This ranged from a high of 72% attributed to the co-op assignment in Electrical and Computer Engineering to a low of 42% in Chemical Engineering. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 2000, 86% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience. Fourteen say that area is "Other and 0% say it is classroom.

Thirty-five percent of the respondents reported "other" listings, which represents 15% of the contribution towards proficiency in this area. The list includes: parents, ethical upbringing and personal beliefs, life experiences, and interactions with others.

Ability to communicate effectively	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**49%**	31%	20%
Chemical Engineering	**38%**	37%	25%
Civil and Environmental Engineering	**48%**	30%	22%
Electrical and Computer Engineering	**43%**	33%	15%
Mechanical and Industrial Engineering	**48%**	30%	25%

Students perceive their abilities in this attribute area as good to excellent, with a 4.08 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 4.04 in Electrical and Computer Engineering to a high of 4.18 in Civil Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true for each of the disciplines except for Chemical, which was evenly split. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 60% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience. 30% say it is "other" and 10% say it is classroom experience.

Another interesting finding was the increase of "other" within this attribute area. Students attributed at least a portion of their abilities in this area to participation in student activities.

Having the broad education necessary to understand the impact of engineering solutions in a global / societal context	% Co-op	% Class	% Other
College of Engineering – All Disciplines	41%	**48%**	11%
Chemical Engineering	41%	**49%**	11%
Civil and Environmental Engineering	**54%**	44%	2%
Electrical and Computer Engineering	**49%**	45%	5%
Mechanical and Industrial Engineering	27%	**49%**	25%

Students perceive their abilities in this attribute area as good to excellent, with a 3.84 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.66 in Civil Engineering to a high of 4.22 in Mechanical and Industrial Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students in two disciplines perceive their co-op experience as having a more significant impact on their abilities than their classroom studies while three perceive the opposite. This attribute contains the greatest disparity across disciplines. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) only 15 % stated a single source greater than 80% in their perceptions of the impact of classroom studies and their co-op assignments on the development of this attribute. For the College of Engineering's Class of 2000, 86% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their classroom studies. Another 14% attribute 80% or more of their abilities on their co-op assignments.

Twenty-nine percent of the respondents reported "other" listings, which represents 11% of the contribution towards proficiency in this area. The list includes: life experiences, personality, interactions with others, genetics.

Recognition of the need for and ability to engage in lifelong learning	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**47%**	31%	20%
Chemical Engineering	35%	**36%**	28%
Civil and Environmental Engineering	**50%**	26%	24%
Electrical and Computer Engineering	**53%**	28%	19%
Mechanical and Industrial Engineering	**46%**	29%	25%

Students perceive their abilities in this attribute area as good to excellent, with a 4.39 on a scale of 1 – 5 for the College of Engineering. This was the highest that students rated themselves in any of the eleven attribute areas. The range went from a low of 4.15 in Mechanical and Industrial Engineering to a high of 4.56 in Chemical Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies. This holds true for four of the five disciplines. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute although only 10% chose a single source with such a weighting. For the College of Engineering's Class of 1999, 60% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience. The rest of the extremes were divided between classroom studies (20%) and other (20%).

Forty-two percent of the respondents reported "other" listings, which represents 20% of the contribution towards proficiency in this area. The list includes: media, travel, life experiences, personality, and interactions with others.

Knowledge of contemporary issues	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**44%**	28%	28%
Chemical Engineering	**38%**	27%	36%
Civil and Environmental Engineering	**51%**	28%	21%
Electrical and Computer Engineering	**47%**	16%	36%
Mechanical and Industrial Engineering	**38%**	29%	33%

Students perceive their abilities in this attribute area as satisfactory to good, with a 3.61 on a scale of 1 – 5 for the College of Engineering. This was the lowest rating received by any of the eleven attribute areas. The range went from a low of 3.41 in Mechanical and Industrial Engineering to a high of 3.72 in Electrical and Computer Engineering and in Civil Engineering.

In this attribute area the numerical average for the entire college of engineering shows that students perceive both their co-op experience as having a more significant impact on their abilities than their classroom studies. Other and classroom studies are perceived as equal contributors. This holds true for each of the five disciplines. For the College of Engineering's Class of 1999, 46% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience, while 38% attribute it to "other".

Forty-eight percent of the respondents reported "other" listings, which represents 28% of the contribution towards proficiency in this area. The list includes: media (including radio, television and newspapers, and Internet), travel, life experiences, personality, student chapter professional societies, and interactions with others.

Ability to use the techniques, skills and modern engineering tools necessary for engineering practice	% Co-op	% Class	% Other
College of Engineering – All Disciplines	**50%**	45%	5%
Chemical Engineering	43%	**53%**	5%
Civil and Environmental Engineering	43%	**55%**	2%
Electrical and Computer Engineering	**55%**	40%	5%
Mechanical and Industrial Engineering s	**53%**	40%	7%

Students perceive their abilities in this attribute area as good to excellent, with a 4.22 on a scale of 1 – 5 for the College of Engineering. The range went from a low of 3.99 in Mechanical and Industrial Engineering to a high of 4.34 in Chemical Engineering.

In this attribute area the numerical average for the entire college of engineering shows a disciplinary split in the way that students perceive their co-op experience as having a more significant impact on their abilities than their classroom studies in three of the five disciplines. When the extremes were examined (those students who attributed 80% or more to co-op, classroom or other) more evidence was found to support the impact of cooperative education on the development of this attribute. For the College of Engineering's Class of 1999, 67% of the students who judge their abilities as coming primarily from one area (80% or more) say that area is their co-op experience.

Twenty percent of the respondents reported "other" listings, which represents 5% of the contribution towards proficiency in this area. The list includes: life experiences, personality, and interactions with others.

III. Comparison of University of Cincinnati and Northeastern University Studies

The two sets of studies were conducted independently. Students in the two University of Cincinnati studies and in the latter Northeastern study were given minimal background information on ABET and Criterion Three. For the first study at Northeastern, students were given more background information, but that did not change the general response themes that emerged.

The results from the two studies show a strong parallel relationship in how students at both institutions view their classroom and co-op learning. There are actually more differences between disciplines at either institution than between the institutions themselves. The only difference in responses occurred as a result of Northeastern University students attributing a somewhat larger contribution of "other" sources towards their engineering development (the total contribution attributed by Northeastern students was 11%).

IV. Summary and Conclusions

One stereotype that persists is that co-op work makes Universities too vocational. Another issue stems from the University not being "in control" of the co-op work. Because students of different abilities work at differing levels of responsibilities and usually cover differing technical content during the co-op work, co-op is not seen as a consistent partner by the educational community. With the advent of ABET EC2000, we have a new paradigm in which to understand co-op learning. EC2000 embraces individualized student learning and is less prescriptive of engineering content. Co-op learning goals have always mirrored the full range of ABET Criterion Three, including the technical and "soft" skill attributes. These four studies can enable engineering educators better understand how co-op learning fits into a bigger picture.

Our engineering students, in the study, state that their co-op learning covers broad human development dimensions more so than does classroom learning. Each of these studies supports the idea that cooperative education plays an important role in the development of these eleven attributes of the engineering graduate as described in the ABET 2000 Criteria. In all attribute areas, cooperative education shows itself to be a strong partner along with classroom experience. While the percentages may change, cooperative education and classroom education share in the development of students' abilities. The impact of cooperative education on the development of these attributes within all engineering disciplines surveyed indicates that its role is realized across disciplines. Based upon these strong student perceptions of cooperative education's impact on the development of these eleven attributes, it would be wise for Colleges of Engineering to consider implementing a co-op program if they do not have one in place or increasing student involvement in their existing cooperative education program.

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Biographical Information

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As an Associate Professor at the University of Cincinnati, Ms. Cates has 10 years of experience in cooperative education with optional and mandatory programs in a variety of disciplines. Currently she is responsible for mandatory co-op programs within Materials Science and Engineering, as well as Industrial Engineering. In 1999 she co-authored Learning Outcomes, The Educational Value of Cooperative Education, as a work commissioned by the Cooperative Education Association. She is among the first to become a qualified reviewer for the Accreditation Council for Cooperative Education. She has received research grants on the state, regional and national level to fund her efforts to determine learning outcomes through cooperative education. She has presented on the subject of learning at the World Association for Cooperative Education, the Cooperative Education Association, and the Cooperative Education Division of the American Society of Engineering and the Ohio Cooperative Education Association. Within the Division of Professional Practice, Ms. Cates is a member of the Curriculum Committee and chair of the Project to Improve and Reward Teaching. She has a Master of Business Administration degree.

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Richard Canale and Ellen Duwart are the Cooperative Education Faculty Coordinators in the electrical and computer engineering program at Northeastern University. Their cooperative education work experience covers three decades of work with students and employers. They have been at the forefront of change by leading student group reflection seminars and implementing computer communication technology tools as strategies for enhancing student learning that occurs as a result of students' coop work. They are members of the Cooperative Education Association (CEA), the Institute of Electrical and Electronic Engineers (IEEE), and the American Society for Engineering Education (ASEE) and are active participants in the Research Committee work of the Cooperative Education Division of ASEE. They are both qualified reviewers for the Accreditation Council for Cooperative Education. They have presented at the ASEE/IEEE Frontiers in Education Conference, the ASEE/CIEC Conference, and the Cooperative

Education Association/World Association for Cooperative Education (CEA/WACE) Conference. Their journal publications are on cooperative education learning.

Richard is a graduate of a cooperative education program, having received his Bachelor of Science degree in Electrical Engineering degree from Northeastern University. He has two graduate degrees in Education: one in Counseling and one in Cooperative Education.

Ellen received a BSBA degree from the University of Rhode Island and a Master's Degree in Education from Northeastern University. She is currently a co-PI on an NSF Grant for CONNECTIONS, a program which links girls and women along a life and career spectrum involving science, engineering, and math.