

## **AC 2008-188: THE ROLE OF CO OP EXPERIENCE IN ACHIEVING ENGINEERING EDUCATIONAL OUTCOMES**

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# **The Role of Co-op Education in Achieving Educational Outcomes**

## **Abstract**

To address the ABET learning outcomes in engineering education many assessment methodologies have been developed. One of such methodologies is based on the use of “profile of an engineer” developed by Davis et. al.<sup>6</sup> This work documents the important roles filled by a practicing engineer and the observable behaviors necessary for effective performance. Some learning outcomes, developed in this work, can be achieved at an elementary level in the classroom. However, the classroom being a part of a university setting, not a corporate environment is limited in context and scope and can only provide a limited simulation to real life work setting of an engineer. To provide the educational experiences for producing the full desired set of outcomes and to close the gap between a graduating engineer and a real practitioner co op education or internships are the key. During this type of experiential learning, engineers in the field provide the real life model of professional behaviors and practices directly to students. Meanwhile, engineering students are also being socialized to the corporate environment and gradually begin to perform some professional activities with increasing responsibility. The knowledge constructed through co op experiences can lead to the students’ development of the Holistic Interpersonal Skills and Professional Behaviors of Davis’ engineering profile. This paper presents evidence that co op and classroom education are complementary and necessary components for the development of a quality engineering education and job-ready engineering graduates.

## **Introduction**

Apprenticeship has long been held as one way to learn a craft from an expert. Before there were formal learning institutions, this was the most prevalent means that a society used to educate its youth. As education became more formalized, the experiential means of teaching were largely set aside. Experiential learning and classroom learning became two separate silos. Theory was communicated through lectures in classrooms, while practical knowledge was imparted through vocational training and deemed secondary. However, feedback from industrial advisory boards and employers of engineering graduates has brought to the forefront that practical know-how must be integrated into engineering education. It is not enough to be “book smart.” Industry wants engineers who are flexible, savvy and can produce quality results in real world situations. Higher education must find ways to educate engineering students with both practical and theoretical knowledge to ensure the student’s success.

ABET<sup>1</sup> has led the charge by instituting learning outcomes for accreditation. Many of these outcomes are not technical but are considered “soft skills.” Soft skills include interpersonal, “people” skills. Following ABET’s lead, higher education is experimenting with methodologies to address all outcomes, and to find ways to instill them in to their students. Because of increased assessment analysis of the learning outcomes, there have been documented deficiencies in engineering graduates for some outcomes, especially those pertaining to the soft skills such as effective communication, multidisciplinary teamwork and professional self-development.<sup>2</sup> Higher education has taken steps to address such deficiencies by increasing student oral

presentations in classes to practice communication skills and increasing the use of team projects in courses such as capstones<sup>3</sup> in order to expose students to multi-disciplinary teams. This has been shown to be helpful. Students experience the frustration of being misunderstood or conflicts of personalities and learn coping mechanisms to some extent, however engineers work in the real world where the variables are much more diverse and pronounced. The gap between simulating the corporate environment in the classroom and the real world is great. Because the classroom is a part of a university setting, not a corporate setting, it is limited in context and scope and can only provide a limited simulation to real life work situation of an engineering professional.

To close the gap between the classroom environment and the corporate environment, we must draw upon the wisdom of past practices such as apprenticeship and other forms of experiential learning. This is the advantage of co op education and internships for engineering education. Through co op, students are immersed into the real world while still having the benefit of being learners and being perceived as engineers-in-training. In co op, professional engineers act as role models for student learning, modeling the expert behaviors and ways of being. Students interact with these experts and try to imitate their behaviors and attitudes. They can experiment and try different techniques, and through consequences, learn what works and what doesn't. Because of the immersion in the environment, they can construct knowledge through all four learning domains: affective, cognitive, social and psycho-motor.<sup>4</sup> Therefore, students construct knowledge that allows them to take technical classroom knowledge to the next level of expertise. With respect to Bloom's Taxonomy,<sup>5</sup> students appear to engage at higher learning levels, from Bloom's level 1-5 knowledge of a good quality engineering education program to Bloom's level 4- 6, since co op students in a corporate environment learn through integrating Bloom's categories of Level 4: Analysis, Level 5: Synthesis and Level 6: Evaluation. Co op students learn communication, team collaboration, program and project management, leadership of implementation, and achieving through consequences, accountability and evaluation, as well as many other skills.

In order to be able to document these educational advantages, one must have a vision of the desired result. Only then can a methodology be formed to produce the desired effect. For educators to produce engineering graduates with deliberate attributes and characteristics, an engineering expert profile needed to be defined. In 2005, Davis et. al.<sup>6</sup> developed an expert profile that is broadly applicable to all engineering disciplines. The profile consists of ten roles that are grouped into three categories, each supported by five professional behaviors. Table 1, reproduced from this work, lists the holistic description of each role divided into the categories of technical, interpersonal, and professional behaviors. Technical behaviors include the roles of Analyst, Problem Solver, Designer, and Researcher. Interpersonal behaviors include the roles of Communicator, Collaborator, and Leader. Professional behaviors include the roles of Self-Grower, Achiever, and Practitioner. The authors of this work also provided contextual descriptions of these roles to aid understanding.

The Behavior Based Profile is provided in Table 2, also from this work. This lists five observable behaviors supporting each role. As documented in the work,<sup>6</sup> the behaviors given in Table 2 encompass all aspects of ABET engineering criteria 3 a-k, but have been optimized to limit overlap. Tables 1 and 2 have been reproduced here with the author's permission.

**Table 1: Roles and Holistic Behaviors of an Engineer (From Davis et. al. 2005)<sup>6</sup>**

<b>Technical Roles</b>	<b>Holistic Technical Behaviors</b>
Analyst	When conducting engineering analysis, the engineer adeptly applies principles and tools of mathematics and science to develop understanding, explore possibilities and produce credible conclusions.
Problem Solver	When facing an engineering problem, the engineer produces solutions that properly address critical issues and assumptions and that are conceptually and contextually valid.
Designer	When facing an engineering design challenge, the engineer develops designs that satisfy stakeholder needs while complying with important implementation, societal, and other constraints.
Researcher	When conducting applied research, the engineer designs and conducts studies that yield defensible results and answer important applicable research questions.
<b>Interpersonal Roles</b>	<b>Holistic Interpersonal Behaviors</b>
Communicator	When exchanging information with others, the engineer prepares, delivers, and receives messages that achieve desired outcomes.
Collaborator	When working with others in joint efforts, the engineer supports a diverse, capable team and contributes toward achievement of its collective and individual goals.
Leader	When providing needed leadership, the engineer promotes shared vision to individuals, teams, and organizations and empowers them to achieve their individual and collective goals.
<b>Professional Roles</b>	<b>Holistic Professional Behaviors</b>
Self-Grower	Motivated for lifelong success, the engineer plans, self-assesses, and achieves necessary personal growth in knowledge, skills, and attitudes.
Achiever	When given an assignment, the engineer demonstrates initiative, focus, and flexibility to deliver quality results in a timely manner.
Practitioner	Driven by personal and professional values, the engineer demonstrates integrity and responsibility in engineering practice and contributes engineering perspectives in addressing societal issues.

**Table 2: Behavior-Based Profile of an Engineer (From Davis et. al. 2005)<sup>6</sup>**

<b>Role</b>	<b>Behaviors or Observable Actions</b>
Analyst	<ul style="list-style-type: none"> <li>a. Searches strategically to identify all conditions, phenomena, and assumptions influencing the situation</li> <li>b. Identifies applicable governing principles of mathematics, natural sciences, and engineering sciences</li> <li>c. Selects analysis tools consistent with governing principles, desired results, assumptions, and efficiency</li> <li>d. Produces and validates results through skillful use of contemporary engineering tools and models</li> <li>e. Extracts desired understanding and conclusions consistent with objectives and limitations of the analysis</li> </ul>
Problem Solver	<ul style="list-style-type: none"> <li>a. Examines problem setting to understand critical issues, assumptions, limitations, and solution requirements</li> <li>b. Considers all relevant perspectives, solution models, and alternative solution paths</li> <li>c. Selects models for obtaining solutions consistent with problem type, assumptions, and solution quality</li> <li>d. Uses selected models, methods, and data to produce desired solution</li> <li>e. Validates results, interprets and extends the solution for wider application</li> </ul>
Designer	<ul style="list-style-type: none"> <li>a. Searches widely to determine stakeholder needs, existing solutions, and constraints on solutions</li> <li>b. Formulates clear design goals, solution specifications (including cost, performance, manufacturability, sustainability, social impact), and constraints that must be satisfied to yield a valuable design solution</li> <li>c. Thinks independently, cooperatively, and creatively to identify relevant existing ideas and generate original solution ideas</li> <li>d. Synthesizes, evaluates, selects, and defends alternatives that result in products (components, systems, processes, or plans) that satisfy established design criteria and constraints to meet stakeholder needs</li> <li>e. Reviews and refines design processes for improved efficiency and product (solution) quality</li> </ul>
Researcher	<ul style="list-style-type: none"> <li>a. Formulates research questions that identify relevant hypotheses or other new knowledge sought</li> <li>b. Plans experiments or other data gathering strategies to address questions posed and to control error</li> <li>c. Conducts experiments or other procedures carefully to obtain reliable data for answering questions</li> <li>d. Uses accepted data analysis procedures to infer trends, parameters, and data error</li> <li>e. Interprets and validates results to offer answers to posed questions and to make useful application</li> </ul>
Communicator	<ul style="list-style-type: none"> <li>a. Listens, observes, and questions to assess audience background and information needs</li> <li>b. Documents and mines available information and differing perspectives for understanding and application</li> <li>c. Prepares a message with the content, organization, format, and quality fitting the audience and purpose</li> <li>d. Delivers a message with timeliness, credibility, and engagement that achieve desired outcomes efficiently</li> <li>e. Assesses the communication process and responds in real-time to advance its effectiveness</li> </ul>
Collaborator	<ul style="list-style-type: none"> <li>a. Respects individuals with diverse backgrounds, perspectives, and skills important to the effort</li> <li>b. Values roles, accepts role assignments, and supports others in their roles</li> <li>c. Contributes to development of consensus goals and procedures for effective cooperation</li> <li>d. Resolves conflicts toward enhanced buy-in, creativity, trust, and enjoyment by all</li> <li>e. Contributes to and accepts feedback and change that support continuous improvement</li> </ul>
Leader	<ul style="list-style-type: none"> <li>a. Facilitates and articulates a shared vision valued by targeted individuals, groups, or organizations</li> <li>b. Motivates others to action by crafting a compelling yet credible case for achieving individual and organizational goals</li> <li>c. Provides authority and resources and removes barriers to aid others' success</li> <li>d. Supports risk-taking and growth by creating trust, providing counsel, and modeling desired attributes</li> <li>e. Encourages achievement by recognizing and rewarding individual and group successes</li> </ul>
Self-Grower	<ul style="list-style-type: none"> <li>a. Takes ownership for one's own personal and professional status and growth</li> <li>b. Defines personal professional goals that support lifelong productivity and satisfaction</li> <li>c. Regularly self-assesses personal growth and challenges to achieving personal goals</li> <li>d. Achieves development planned to reach personal goals</li> <li>e. Seeks out mentors to support and challenge future growth and development</li> </ul>
Achiever	<ul style="list-style-type: none"> <li>a. Accepts responsibility and takes ownership in assignments</li> <li>b. Maintains focus to complete tasks on time amidst multiple demands</li> <li>c. Takes appropriate actions and risks to overcome obstacles and achieve objectives</li> <li>d. Monitors and adapts to changing conditions to ensure success</li> <li>e. Seeks help when the challenge exceeds current capability in the given time constraints</li> </ul>
Practitioner	<ul style="list-style-type: none"> <li>a. Displays integrity, consistency, ethical, and professional demeanor in engineering practice and relationships</li> <li>b. Embraces and employs appropriate professional codes, standards, and regulations</li> <li>c. Engages with engineering professionals and organizations to support excellence in engineering practice</li> <li>d. Demonstrates citizenship through service to society on local, national and/or global scales</li> <li>e. Brings responsible engineering perspectives to global and societal issues</li> </ul>

### Learning outcomes for co op education

Kettering University's program<sup>7</sup> is the only completely co op education program in the country. Kettering was formerly owned by General Motors and known as GMI, however has evolved partnerships with over 650 co op industrial sponsors. In 2005 the Office of Institutional Effectiveness surveyed Kettering new alumni as to the effectiveness and quality of the Kettering education. Because co op education is a graduation requirement for all students, these Kettering,

alumni were asked to indicate the degree to which the Kettering/GMI education and co op experience increased their abilities in a variety of areas. Classroom education and co op education ratings were separated. From this survey Table 3 was developed to map the survey results to the behaviors listed in the engineering expert profile. The percentage of alumni indicating Low (L), Medium (M) and High (H) increases are shown. For the level of high increase, co op was rated significantly higher in every category over classroom education. These correspond to seven of the ten roles of the expert profile, including Analyst, Problem Solver, Designer, Communicator, Self Grower, and Practitioner. The behaviors of Collaborator and Communicator showed the highest comparative differences. Collaborator and Communicator are categorized as Holistic Interpersonal Skills. Self-Grower and Practitioner are categorized as Holistic Professional Behaviors. Several of the expert profile behaviors were not addressed in directly by this survey of Kettering alumni: Researcher, Leader, and Achiever.

**Table 3: Comparison of degree of increase in ability due to classroom and co op education**

Indicate degree of increase in your abilities	L		M		H	
	CR	Coop	CR	Coop	CR	Coop
<b>Analyst</b>	15.9	14.3	38.1	14.3	46	71.5
<b>Problem Solver</b>	17.4	12.7	36.5	22.2	46	65.1
<b>Designer</b>	20.7	22.2	34.9	20.6	44.5	57.2
<b>Communicator</b>	30	20.9	41.3	14.5	28.6	64.5
<b>Collaborator</b>	33.3	13.1	39.7	21.3	27.0	65.6
<b>Self-Grower</b>	17.4	27.5	33.3	17.7	49.2	54.8
<b>Practitioner</b>	22.2	19.0	28.6	17.5	49.2	63.5

While the survey did not ask the alumni comparative questions about being a Leader, Achiever or Researcher, direct questions were asked including, “Have you been given a leadership position at work?” The response of the alumni who responded was 60% in the affirmative. Since all students must complete multiple co op terms as a graduation requirement at Kettering, it can be interpreted that skills learned in a combined classroom/co op education program tend to result in leadership skills for the majority to gain such positions.

In addition, the Kettering Student Government Academic Committee in partnership with the Center for Excellence in Teaching and Learning held a Student Faculty Forum on August 28, 2007. The topic of discussion was the Kettering Co op Experience. A list was developed from the student body as to the outcomes of their co op experience. Several outcomes compiled in the forum were behaviors listed in Table 2 that correspond to the expert profile roles of Leader and Achiever. These included behaviors such as learning to take ownership of the results of one’s work (accountability), being allowed to experiment then learn from failure or success (calculated risk), having to work through both functional and dysfunctional work processes (flexibility) and learning to get things done through people by motivation since co op students have limited authority.

Also listed as outcomes in this forum were experiential learning such as witnessing engineering managers making decisions, and being socialized into the corporate environment. By a show of hands, most students in this forum were satisfied with their co op experience and felt that it was

extremely valuable. This appears to correspond with the results of the Kettering alumni survey conducted in 2005, which are documented in Table 4.

**Table 4: Satisfaction and benefits of program**

Question	High	Medium	Low
How satisfied with co op?	90%	6.3%	3.2%
Rate the overall cost to benefits of program.	69.9%	20.6%	9.5%

## Conclusion

From the literature, deficiencies have been documented in graduates of engineering education, especially in the area of soft skills such as effective communication, multidisciplinary teamwork and professional self-development. These map to three of the roles outlined in the expert professional profile of an engineer developed by Davis, et. al.<sup>6</sup> The ability to use effective communication, work in multidisciplinary teams and display self-initiated professional growth corresponds to the roles of Communicator, Collaborator and Self-Grower. The roles of Communicator and Collaborator are categorized under the Holistic Behaviors of the Holistic Interpersonal Skills and the role of Self-Grower is categorized under the Holistic Professional Behaviors of the engineering profile. From a survey of Kettering alumni in 2005, the answers of the alumni that responded suggest that co op education is more effective than classroom education in increasing graduate abilities in the Holistic Interpersonal Skills and Professional Behaviors, with the roles of Communicator and Collaborator showing among the highest relative mastery due to co op education.

Overall, the alumni who responded to the survey indicated that co op increased their abilities in seven of the ten roles of an expert engineer including Analyst, Problem Solver, Designer, Communicator, Self Grower, and Practitioner. In addition, from a forum of Kettering students, students indicated that two additional roles of an expert engineer, those of Leader and Achiever were addressed successfully by co op education. The majority of students also indicated that they were satisfied with co op education. This corresponds to the results of the Kettering alumni survey, where a very high majority of alumni who responded felt satisfied with co op education and that it was beneficial.

Therefore, knowledge constructed through co op experiences can lead to the students' development of the Holistic Interpersonal Skills and Professional Behaviors of Davis' engineering profile, which are not sufficiently addressed in traditional classroom education. The evidence presented in this paper suggests that co op and classroom education are complementary and necessary components for the development of a quality engineering education and job-ready engineering graduates.

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