Professional Development and Collaborative Teaching in an Undergraduate Engineering Curriculum: A Case Study from the University of Virginia

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Since early 1995 a small committee of University of Virginia engineering faculty and staff has worked to define professional development values and objectives and to determine how they can be fostered in an undergraduate engineering curriculum. The committee developed a framework document outlining the key attributes and experiences of professional development (PD); met with alumni, business, faculty, and other representatives to solicit their input to the document; and, starting in fall 1995, pursued teaching collaborations to implement aspects of the professional development vision outlined in the document.

Part I of this paper outlines the professional development framework and how it relates to ABET 2000. Part II shows how we attempted to achieve the objectives in first year courses of our School through an unusual collaborative teaching effort in fall 1996 to cultivate PD among first-year undergraduates. Part III gives a model for assessment of how well the collaboration was able to fulfill its PD objectives. The paper concludes by examining some broader lessons learned from UVa's model of professional development in undergraduate education.

I. Foundations and Benchmarks of Professional Development: The UVa Model

A small committee of University of Virginia engineering faculty and staff began meeting and collaborating in early 1995 to define how an undergraduate engineering curriculum could foster the values and objectives of professional development (PD). The committee developed a framework document outlining the key attributes and experiences of PD; met with alumni, business, faculty, and other representatives to solicit their input to the document; and, starting in fall 1995, pursued teaching collaborations to implement aspects of the PD vision outlined in the document. The collaborations of 1995 are described in Pfaffenberger et al.[1]

The internal document, "Foundations and Benchmarks of Professional Development," identified seven "**attributes**" and six "**experiences**" which represent the key dimensions of PD that our undergraduate engineering curriculum should cultivate. Although these attributes and experiences were formulated before any of the participants were aware of the ABET 2000 criteria, we believe that our expressions are quite compatible with ABET 2000. Table 1 lists both the 11 outcomes of Criteria 3 of ABET 2000[2] and the UVa PD attributes. The ABET criteria connected to the attributes are given. Comparison of the wordings shows that our PD framework is more comprehensive and possibly more ambitious.

It should also be recognized that we anticipated the demands of ABET 2000 for the formulation of objectives and for the educational process to achieve them. Our **attributes** were developed by a varied constituency of alumni, business, faculty and staff. Further, the **experiences** given in Table 2 are general expressions of a process intended to achieve the objectives. Thus, we are confident that a UVa PD program can meet all of the items - and more - expected for ABET 2000.

TABLE 1
Relationship of ABET 2000 Criteria to UVa PD Attributes

ABET 2000 Criteria 3 Outcomes[2]

a) An ability to apply knowledge of mathematics, science and engineering;
b) An ability to design and conduct experiments, analyze and interpret data;
c) An ability to design a system, component, or process to meet desired needs;
d) An ability to function on multidisciplinary 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 societal context;
i) A recognition of the need for and an ability to engage in lifelong learning;
j) A knowledge of contemporary issues; and,
k) An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

University of Virginia Professional Development Attributes

Graduates beginning their careers should have certain qualities (related ABET Criteria):

<u>Technological Capability</u>: Know and be able to practice the fundamental technical facets of engineering (a, b, e, k)
<u>Leadership/Cultural Competence</u>: Become leaders in a diverse, complex world (h, j)
<u>Industrial Readiness</u>: Appreciate functions, dynamics and evolution of "industry"; understand the expectations about their roles, contributions and attitudes (c)
<u>Individual/Team Effectiveness</u>: Understand themselves and others; thrive in diverse and ambiguous situations (d)
<u>Ethics/Values/Service Commitment</u>: Be dedicated to the highest professional and human values (f, h)
<u>Communication Skills</u>: Can inform others and make decisions in diverse contexts (e, g)
<u>Career Vision</u>: Begun moving in the direction of their life's work (i)

The expectation is that students possessing a significant measure and balance of these characteristics are most likely to become successful professionals.

Our view is that to nurture these attributes, students must have a rich variety of experiences and environments. Table 2 gives a concise expression of these experiences.

Experiences are connected to attributes in several concrete ways. For example, students may enhance their Technological Capability through a variety of experiences including analyzing the concept and design of an engineering device or system. Likewise, students may expand their Industrial Readiness by visiting engineering and manufacturing companies or by assessing the potential impacts of a novel device's cost, reliability, and safety. And students may sharpen their

Communication Skills by researching a technical subject and compiling a professional annotated bibliography or by explaining a complex technological topic in terms that non engineers might understand. The intention is to support each attribute with a variety of experiences as well as to have students work on projects that provide multi-attribute experiences.

TABLE 2
UVa Professional Development Experiences

Students grow and develop confidence best in certain environments and situations

Introspection/Self-Assessment: Who am I? How should I develop? Self-discovery and self-improvement

Learning/Growing: Building my competencies; recognizing my changes in: technical and non-technical knowledge and concepts; communication skills; challenges; varieties

Performing/Doing: Practice, practice, practice. Resource utilization, abstracting and analyzing; job searching; oral presentations; helping others; decision making and risk-taking, physical tasks (labs, equipment)

Leading/Following: What's my most effective role? Orientations and beginnings, closures and endings; goal-oriented teamwork; workings of professional, social, and service organizations

Employment/Service: Real work and how it's done. Outside the university in externships, internships, community service; inside in modules/courses, research and student organizations

Interactions: Being and working with others. Students in academic settings, university personnel, professionals, general public

The expectation is that living these experiences and assimilating their lessons should give graduates confidence, wisdom, and adaptability for lifelong service and accomplishment.

II. Collaborative Teaching and Professional Development at UVa

During the fall semester 1996, the authors (a sociologist of technology and a chemical engineer) collaboratively taught two courses in an attempt to put the professional development model to work in first-semester undergraduate studies at UVa. One was a required core technical communications course (TCC 101) typically taught in sections of 25 students by faculty of the multidisciplinary Division of Technology, Culture, and Communications, using a common syllabus but with specific assignments tailored to each instructor's disciplinary strengths. (Approximately 25% of entering students are given advanced placement credit for this course.) The course introduces students to the uses of oral and written language communication, stressing their relevance to professionalism in engineering and applied science. Students learn how to search and retrieve technical information, write abstracts, essays, and reports, and give oral presentations for a variety of audiences. One key project assignment introduces students to fields of engineering and helps them choose a major. Other assignments address technical and humanistic aspects of engineering, technology, society, and ethics.

The other course, taken concurrently, was a required cross-disciplinary engineering design class (ENGR 164) taught in multiple sections of 35 students by engineering faculty from several different disciplines working from a common set of goals but not the same syllabus. These goals involve lectures, workshops, and five assigned projects to cover: open-ended design case studies via individual and team designs; methodologies for computation, problem solving and conceptual design; consideration of engineering economics, environmental aspects, quality and safety; professional responsibilities and ethics; and career opportunities for engineers.

Student enrollments in TCC 101 and ENGR 164 sections are not normally coordinated and were not coordinated for the other sections taught during 1995-6. (These courses were coordinated in a similar way in fall, 1995 with four instructors.) Both years, we received assistance from the Engineering Dean's Office to assign incoming students at random to the paired sections.

In the present (1996) collaboration there were two groups of 28 students (totaling 12% of the entering class), each group taking a section of TCC 101 and a section of ENGR 164 from the authors. The section classes were of the same length on mostly the same days of the week, and the individual syllabi for the sections of each course were identical. As in the regular sections of each course, assignments ranged from short ones in resource utilization and generic communication skills to multiple-week projects analyzing information and designing alternative products and processes. Compared to the regular sections of each course, the paired sections were distinguished by generally more intensive student teamwork; more extensive assignments and in-class activities of broader socio-technological concern; joint formulation of project goals, statements and activities of the courses; coordinated due dates; generally more extensive use of university library and electronic information resources; joint grading of team oral presentations; and more extensively coupled and systematic evaluations of the courses and teachers.

In terms of the PD Attributes, our course objectives were selected in the order of importance of Table 3. Students were also taking 2 or more technically oriented courses such as chemistry, mathematics, and computers at the same time as our courses. This influenced our selection of attributes.

Assignments in both courses emphasized fundamentals of concise technical writing, well-organized written reports and oral presentations with rich graphical materials, and extensive use of the library and the World Wide Web. Most projects, ranging in duration from one to five weeks, were carried out either in pairs or in teams of three or more.

In ENGR 164 the projects were: finding and analyzing a current product liability case; physically unwrapping and disassembling an inexpensive consumer product (in two workshops) and discussing its scientific principles, conceptual design, materials, economics, manufacture, maintenance, failure, disposal; brainstorming options, selecting viable concepts and doing detailed designs of ways to "make the UVa libraries more user-friendly"; researching and expressing in detail the range of impacts of commercial air transportation on the environment; designing a single piece of equipment or facility and a procedure for an instructor-selected aspect of flight, ground and support operations that would minimize adverse effects while maintaining safety and economic viability in a global setting. The first assignment was for individuals. The next was in pairs, the third was in trios and the last two multi-week projects were done by quarters. Each project had one or two written reports, with the final project also having 25-minute group oral presentations and questioning. A field trip was taken to the regional airport. There were also two "hands-on" workshops analyzing the workings of a refrigerator and air conditioner. These workshops utilized the laboratories and benefited from the participation of the laboratory instructor for the Department of Mechanical, Aerospace and Nuclear Engineering.

TABLE 3
UVa PD Attributes in First Year Course Objectives, Fall 1996

Engineering Design (ENGR 164) Objectives

1. Expand Industrial Readiness: Engineering analysis and conceptual designs, including issues such as safety, quality, reliability and optimization
2. Sharpen Technical Communication Skills: Written and oral reports describing recommended designs to meet performance requirements of open-ended problems
3. Increase Individual/Team Effectiveness: Use recognized methodologies involving individual and collaborative work to formulate problems and report on projects
4. Broaden Career Vision: Self-assessment and career investigation in choosing a major
5. Enhance Technological Capability: Formulate and solve quantitative problems, including computations requiring conversions between systems of units. Apply basic computational techniques used in economic decision making, including interest, time-value of money, capital costs, annual costs, comparison techniques
6. Raise Leadership/Cultural Competence: Understand professional responsibility through evaluating cases illustrating successful and unsuccessful designs
7. Nurture Ethics/Values/Service Commitment: Analyze product liability issues, risk assessment and cross-cultural practices

Technical Communication (TCC 101) Course Objectives

1. Sharpen Technical Communication Skills: Learn principles and practices of concise technical communication for multiple audiences, effective use of high-quality information sources, graphical display of information for individual/team written reports, oral presentations, homework exercises, peer-critique, and revision
2. Broaden Career Vision: Research engineering fields, interview faculty and practicing engineers, learn about career opportunities in each field, relate one's personal strengths to career options, and use knowledge to choose major intelligently
3. Increase Individual/Team Effectiveness: Apply principles of cooperative work to major team projects, including team research, writing, and presentations. Learn how to adapt to different team members and problems, and know the key ingredients for successful team work
4. Raise Leadership/Cultural Competence: Understand implications of cross-cultural differences for exercising engineering expertise appropriately; analyze in depth one major engineering-related social transformation either in U. S. or abroad

5. Nurture Ethics/Values/Service Commitment: Analyze ethical aspects of product design,
marketing, and impact, including how ethical professional judgment can be applied
to real-world product development
6. Expand Industrial Readiness: Develop appreciation for the importance of effective
technical communication for professional success
7. Enhance Technological Capability: Understand the "human-machine interface": how the
technical features of devices and systems have non-technical consequences

In TCC 101, projects included several individual writing assignments to improve style, grammar, punctuation, conciseness, word choice, topic sentences, critical analysis, and argumentation. Some of these were peer-reviewed and subsequently revised. One key early paper was to weigh the ethical aspects of the Dow Corning silicone breast implants controversy in light of scientific-technical knowledge. Students also received instruction in organizing and delivering one individual and two team oral presentations. Most class time was used for cooperative learning workshops in which students discussed an issue, solved a problem, and/or gathered information in groups of three or more and then shared their group's results with the rest of the class. These exercises also improved students' abilities to give extemporaneous talks. Two large, multi-week projects were the other major focus of the course. The first had students work in eight teams of 3-4 members to gather information on each of the eight UVa undergraduate major fields. In addition to using printed information sources, this project required each team to interview an engineering faculty member in the relevant field, as well as practicing engineers and senior engineering students. Teams gave 15-minute oral presentations on their research and wrote a detailed 20-page team report on their project. Another multi-week team project in the communication course had student teams conduct extensive research on current global topics related to technology and human development, culminating in each team giving an oral/poster presentation and a 25-page report. This project, lasting five weeks toward the end of the semester, was research-intensive and required students to apply virtually all of the skills they had learned earlier (See Shields[3].)

In both courses, students cooperated in all phases of the team projects in both courses from problem formulation and data gathering to report writing and oral presentations. Time commitments for several activities were fully shared between the two courses. These included two professional-level, team-based simulations of design and manufacturing, both involving model construction, led by a staff member of the Virginia Engineering Foundation trained in such activities. Also, a staff member of the Engineering School Office of Career Services used class meetings to administer and review personality and aptitude indicators including the Myers-Briggs Type Indicator[4] and the Strong Interest Indicator[5]; to conduct a workshop on informational interviewing, and describe career-oriented materials available in that Office.

III. Assessment

How well did the collaboration fulfill its professional development objectives? To answer this question, we draw on two sources of evaluation: the instructors' informal observations and formal student feedback from anonymous questionnaires completed near mid-term and during the final class meetings of ENGR 164 and TCC 101.

Instructors

Both instructors concluded that the collaboration was beneficial to meeting professional development objectives. The range and mixture of assignments and activities between the two courses meant that essentially all of the attributes of the PD model were fulfilled appropriately for beginning students. Table 4 shows that the joint teaching allowed weak connections to specific PD attributes in one course to be compensated by moderate or strong connections in the other.

Table 4
Instructors' Subjective Assessments of PD Attributes in Their Courses

Attribute	ENGR 164	TCC 101
Industrial Readiness	Strong	Weak
Communication Skills	Moderate	Strong
Individual/Team Effectiveness	Strong	Moderate
Career Vision	Weak	Strong
Technological Capability	Moderate	Weak
Leadership/Cultural Competence, Ethics/Values/Service Commitment	Moderate	Moderate

Students - ENGR 164

Students in the design course were asked to assess how well the catalog description and course PD objectives were fulfilled. They used a five-point scale ranging from "Very Well" (1) to "Not At All" (5). Overall, students felt the design course fulfilled both aspects well. The aggregate mean ratings were 1.8 for design and case studies and 2.4 for the other catalog items. As shown in
Table 5, the objectives met the best were technical communication and individual/team effectiveness with ratings of 1.7, while industrial readiness and leadership/culture/ethics were rated at 2.1. Technological capabilities and career vision had ratings of 2.5. Comparisons with the
objectives in Table 4 indicate that the impressions made upon the students were generally consistent with the intentions of the instructors. There were significant differences between the responses of the two sections about some of the catalog items (design, case studies and career opportunities) and all of the attributes. One group was always more favorable than the other with the item mean scores differing by about the item standard deviation (which was about the same for both sections).

In addition to having students in the paired sections of the design course complete a final course evaluation, 50 students in other (unpaired) design sections completed the same questionnaire. Those results also appear in Table 5. In most areas, there appear to be beneficial differences in the paired sections with the largest ones occurring in the areas of case studies, technical communication and leadership/culture/ethics/service. However, it is possible that these differences merely reflect variations in the approaches, goals and effectiveness of ENGR 164 instructors rather than any direct benefits of collaborative PD teaching.

Finally, students also responded to questions about the importance of various activities to what they learned in ENGR 164, using a scale ranging from "Very Important" (1) to "Not Important" (4). The highest-rated components (based on mean scores) were "group projects" (1.4) "electronic information" (1.5), and "oral presentations" and "workshops" (1.8). The lowest-rated were readings (3.4) and lectures (2.8), with class activities (2.1) and individual projects (2.3) in between. Students in the design course rated team-based projects more highly than individual projects. This reflects the relative emphasis in the course, which was chosen to provide opportunities and experiences that made direct connections to multiple attributes of professional development.

Table 5
Mean Ratings* by Students in Design Course (ENGR 164) Sections

(Course met attributes "Very Well" = 1, "Well" = 2, "OK" = 3, "Not Very Well" = 4, "Not At All" = 5)

Catalog Description	Paired+ (n=40)	Others+ (n=50)
Open-ended Design	1.8	2.3
Case Studies	2.0	2.9
Career Opportunities	2.4	2.9
Individual/Team Designs	1.6	2.1
Methodologies	2.5	2.9
Economics, etc.	2.3	2.6
Professional Responsibilities/Ethics	2.3	2.8
Attribute		
Industrial Readiness	2.1	2.5
Communication Skills	1.7	2.3
Individual/Team Effectiveness	1.7	2.0
Career Vision	2.5	2.9
Technological Capability	2.5	2.6
Leadership/Culture/Ethics	2.1	2.7

* Standard deviations of sections ranged from 0.7 to 1.1 in paired sections and from 0.9 to 1.3 in others.
+ "Paired" sections with collaborating instructors; "Others" in sections of unpaired TCC 101/ENGR 164 courses. Instructors of the latter were not identifiable.

Students - TCC 101

Fifty-three of the 55 students in the technical communication course completed a final course evaluation questionnaire. While the questionnaire did not ask students for direct ratings of specific PD attributes, it did ask them for detailed feedback on several aspects of the course related to PD. In particular, the student data indicate that the TCC 101 course provided rich experiences in support of three key attributes: Communication Skills (CS), Individual/Team Effectiveness (I/TE), and Career Vision (CV). One series of questions asked students to indicate how well the course had helped them improve several specific skills; responses ranged from "Very Well" (1) to "Not At All" (5). Table 6 indicates the mean ratings for each skill-improvement item, and also suggests each item's primary links to PD attributes (in parentheses).

Another set of questions asked students to indicate the relative importance of several specific class components to what they had learned in the technical communication course. Table 7 shows how students rated each component on a scale ranging from "Very Important" (1) to "Not Important" (4). As in the paired ENGR 164 sections, students in the paired TCC 101 sections rated team projects as most important; in fact, the lowest-rated item was individual writing assignments, though there were several such exercises in the course.

Table 6
Student Assessment of Skill Improved in Communication Course (TCC 101)

(Course improved skills "Very Well" = 1, "Well" = 2, "OK" = 3, "Not Very Well" = 4, "Not At All" = 5)

Specific Skill	Attribute*	Mean Rating+ (n=53)
Describe technological objects clearly	(CS)	2.4
Write effective technical papers	(CS)	2.1
Ability to critique/revise own writing	(CS)	2.4
Communicate with non-technical audiences	(CS)	2.3
Ability to critique/revise others' writing	(CS, I/TE)	2.3
Give effective oral presentations	(CS, I/TE)	1.6
Write effectively as team member	(CS, I/TE)	2.1
Use information sources effectively	(CS, I/TE, CV)	1.7
Solve team project problems	(I/TE)	2.0
Work effectively as team member	(I/TE)	1.8
Relate personal strengths to major	(CV)	2.3
Describe engineering fields	(CV)	1.9

* CS = Communication Skills, I/TE = Individual/Team Effectiveness, CV = Career Vision
\+ Standard deviations do not exceed 1.0

Table 7
Student Assessment of Course Components and Learning Importance

(Component's contribution to student learning judged as
"Very Important" = 1, "Important" = 2, "Somewhat Important" = 3, "Not Important" = 4)

Component	Attributes*	Mean Rating+ (n=53)
Engineering Career Options Project	(CV, I/TE, CS, L/CC, E/V/S, IR)	2.0
Technology & Human Development Project	(I/TE, CS, L/CC)	2.0
Poster Exhibition and Competition	(I/TE, CS, L/CC)	1.7
Individual Writing Assignments	(CS, E/V/S, L/CC)	2.4
Team Writing Projects	(CS, I/TE, L/CC, CV, E/V/S, IR)	1.8
Oral Presentations	(CS, I/TE, CV, L/CC, E/V/S, IR)	1.4
Use of Electronic Information Sources	(CS, I/TE, CV)	1.6

* In order of emphasis.
CS = Communication Skills, I/TE = Individual/Team Effectiveness, CV = Career Vision,
L/CC = Leadership/Cultural Competence, E/V/S = Ethics/Values/Service, IR = Industrial Readiness
\+ Standard deviations do not exceed 1.0

When asked "Would you recommend a collaborative 101/164 section pairing to next-year's incoming students?," 72% of the students answered yes (36 of 50 who responded to the question). As one student put it: “TCC helped us to write more effectively and present effectively in ENGR 164. 164 helped us to understand the technical aspects of engineering.” Another student wrote that “teamwork skills development occurred through assignments in both classes, and writing style improvements from TCC helped with ENGR 164 papers.” Similarly, another commented approvingly that “oral presentation skills and group skills were used in both [courses].” Most students emphasized the benefits of having the same classmates in two courses and of having coordinated course schedules that avoided conflicting deadlines on major projects.

By far, the major student complaint focused on the workload for the paired courses; this also occurred with the paired sections of the previous year. It was a widely held perception even among students who were positive about the advantages of pairing, yet especially pronounced among the 28% of students who would not recommend the pairing to future students. This response was much more prevalent in one section than the other. However, many of these students recognized that the learning benefits were substantial despite the heavy workload: “Although you do learn a lot from these two sections”, wrote one student, “the workload in each makes it very difficult to get your work done in your other three classes . . . .” Likewise, as another student noted: “Actually, TCC and ENGR hurt other courses because we spent a lot of time for both classes. However, I think we learned many things from both classes.” Still another student wrote that “the amount of work between the two courses was so overwhelming. It did not help me to do better in TCC, Design, or any other course. The overall amount of writing, though I hated it, helped improve my technical writing skills immensely.” Student perceptions of the relatively heavier workload in the paired sections may well have been correct, based on some indicative but not definitive data we collected at mid-semester. Those data suggested that students in the paired sections of TCC 101 and ENGR 164 were indeed inclined to rate their workloads as more time-consuming than students enrolled in unpaired sections of those courses. In any case, students obviously believed the workloads were greater; we expect that their beliefs, in turn, influenced student evaluations of the two courses.

IV. Conclusions and Implications

Our experience suggests that first-semester engineering can be positively influenced with collaborative implementation of a carefully articulated PD vision and framework. The objective in pairing our sections was to provide students with a “compleat” professional development experience; their formal evaluations of the courses confirm that this was largely accomplished. Even most of the students who would not recommend paired sections to future incoming students (because of the heavy workload) agreed with the value obtained. While many engineering educators believe (perhaps somewhat correctly) that first-year students lack the intellectual maturity and personal autonomy needed for optimal success in a rigorous curriculum, our experience is encouraging: many of our students seemed to rise to the challenge. In particular, the pairing of technical design and technical communication seems to provide a genuine synergy to reinforce and complement a shared set of PD goals. Further, most students said that they also benefited from the social integration of the two courses: stronger interpersonal ties and other aspects that supported cross-course teamings, such as the predictability and convenience of coordinating team meetings when meeting classmates twice a day.

What about the instructors? Two conclusions stand out. First, our collaboration worked because of a shared vision of PD and its importance as well as our willingness and enjoyment of sustaining it by frequent interactions for planning and execution throughout the semester. Our sense is that both of these are not only desirable but essential. We were fortunate to have participated in developing the shared PD vision as it emerged over months of intensive discussion; we were more able to implement a systematic model in our sections than might someone who came in “cold.”

Second, in contrast to the PD framework that stimulated and guided our collaboration, we had no formal model for collaborative teaching - let alone for a cross-disciplinary collaboration like ours. Our experience was thus unusually fortunate - and perhaps fortuitous. In fact, at this point we probably know much more about collaborative (or cooperative) learning than about collaborative (cooperative) teaching. Educators need to pay more attention to this if collaborations like ours are to become more frequent and productive.

Finally, we can reflect on what's next for our students. Our principal concern is the very few ways in which the rest of our undergraduate curriculum builds on this kind of first semester. Focus groups of students who met some months after the first year’s collaborations mentioned this explicitly[1]. Getting widespread commitment to the PD vision will require considerable time and effort by faculty and a variety of administrative support mechanisms. And even then, implementation at other levels will probably require exceptionally creative and adaptive teaching[6].

Acknowledgments: The authors are grateful to many UVa colleagues, especially T. C. Scott, Edmund P. Russell, Richard D. Jacques, Kristin A. Gildersleeve, William J. Thurneck, and C. J. Livesay for their involvement this year's paired sections of TCC 101 and ENGR 164.

Bibliographic Information

1. Pfaffenberger, B., J. P. O'Connell, S. Carlson, T. C. Scott, and M. A. Shields (1996). Teaching professional development in the first-year writing course. ASEE Annual Conference, Session 2653, Washington, DC, June.

2. Peterson, G.D., (1995). ABET Engineering Criteria 2000. Accreditation Board for Engineering and Technology, Inc., Baltimore, MD.

3. Shields, M.A., (1997). Enhancing cross-cultural understanding among engineering students: The Technology and Human Development Project. ASEE Annual Conference, Session 2660, Milwaukee, June.

4. Briggs, K.C., and I. Briggs Myers, (1977). Myers-Briggs Type Indicator Form G Booklet. (1984). MBTI Form G Profile Report. Consulting Psychologists Press, Palo Alto, CA.

5. Board of Trustees of the Leland Stanford, Junior, University, (1994). Strong Interest Inventory of the Strong Vocational Interest Blanks. Consulting Psychologists Press, Palo Alto, CA.

6. Woods, D. R. and P. E. Wood (1996). The future of engineering education: A Canadian perspective. Presented to the New Approaches to Undergraduate Education VIII Conference, Kingston, ON, July 23-27.

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