Linking Student Learning Outcomes to Instructional Practices – Phase III

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Abstract *– More than ever, today's engineering colleges are concerned with and attuned to improving the processes and outcomes of educating tomorrow's engineers. To that end, ABET's "3a through k" criteria identified eleven learning outcomes expected of engineering graduates. Based on a rigorous review of the literature, the first phase of our work found four additional student outcomes desired by the engineering education community, and suggested that an engineering graduate also ought to demonstrate 1) ability to manage a project (including a familiarity with business, market-related, and financial matters), 2) a multidisciplinary systems perspective, 3) an understanding of and appreciation for the diversity of students, faculty, staff, colleagues, and customers, and 4) a strong work ethic. During Phase II of this project, we identified several assessment instruments that might measure those outcomes and began searching for instructional "best practices" thought to promote the 15 desired learning outcomes. This paper, based on Phase III of the project, provides empirical evidence from and identifies the gaps in higher education and engineering education journal articles that link instructional best practices with the 15 desired student outcomes in engineering education.*

I. Introduction

This work is Phase III of a continuing effort to identify a comprehensive summary of and the links between the student learning outcomes desired by engineering education stakeholders and the most effective teaching and learning strategies associated with those outcomes. In Phase I of this project we identified, through a thorough review of engineering education literature, an additional five learning outcomes not specifically included in ABET's 3a though k criteria [1]. Although many more outcomes were mentioned in the literature, each of the five learning outcomes was cited at least 16 times, which was also the number of times the least cited ABET EAC criterion was referenced in the same body of literature [2]. As work on the project continued, we reconsidered a fifth additional learning outcome, "logical thought processes and critical thinking," and concluded that it is, indeed, imbedded in ABET EAC criterion 3e. The final list of 15 student learning outcomes determined to be foundational for engineering graduates includes the 11 ABET 3a through k criteria and the four outcomes listed in Table 1.

In Phase II of this project, we reviewed 58 published resources to identify any valuable assessment tools used to measure the 15 student learning outcomes named in Phase I. In total, we found 65 assessment tools (listed in the Frontiers in Education paper associated with Phase II of this project [3]) that measured at least one of the 15 learning outcomes. Many of the assessment tools named in the paper are generic in nature (e.g., student presentations, alumni surveys, student portfolios), although some examples are of specific inventories or instruments (e.g., "Team Knowledge Test," "Freshman Engineering Perception Test," "Profile of Nonverbal Sensitivity"). A clear result of the work done for Phase II indicates that no single assessment tool

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exists to measure engineering students' progress towards achieving more than one or two – much less all 15 – of the identified foundational student learning outcomes.

Table 1. 15 Foundational Technical and Non-Technical Student Outcomes

Engineering graduates must have:	
ABET Criteria 3a-k	
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 of the need for, and an ability to engage in life-long learning
j)	A knowledge of contemporary issues
k)	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
"Plus CASEE's four"	
l)	An ability to manage a project (including a familiarity with business, market-related, and financial matters)
m)	A multidisciplinary systems perspective
n)	An understanding of and appreciation for the diversity of students, faculty, staff, colleagues, and customers
o)	A strong work ethic

The goal of Phase III of this project, discussed in this paper, is to identify instructional *principles* and *practices* that contribute to students' attainment of 15 foundational, technical and non-technical student learning outcomes. This paper identifies ten such principles and then presents some of the empirical evidence in the engineering education literature that discusses in more detail the studies conducted and instructional *practices* related to each principle.

II. Ten Principles of Effective Instruction

During a literature search for the best instructional practices thought to contribute to the 15 student learning outcomes identified in Phase I, ten principles of effective instruction repeatedly emerged. Although a number of authors used different wording for similar concepts, this paper cites three sources as the primary tools for organizing the ten principles and uses their "language." The three sources (Chickering and Gamson [4], Bransford et al [5], and the American Psychological Association's "learner-centered psychological principles" [6]) were chosen based on their prominence in engineering education circles, how familiar engineering educators already are with these concepts, and of course, their appropriateness. The ten principles of effective instruction include:

1) Encouraging student-faculty interaction
2) Developing reciprocity and cooperation among students
3) Communicating high expectations
4) Providing prompt feedback
5) Using active learning techniques
6) Emphasizing time on task
7) Respecting diverse talents and ways of thinking
8) Building on correct pre-existing understandings; dispelling false preconceptions
9) Providing factual knowledge, facilitating understanding of the facts and ideas in context of a conceptual framework, and organizing knowledge that facilitates retrieval and application
10) Encouraging students' motivation to learn

The remainder of this paper defines each of the ten principles of effective instruction, provides brief summaries of the empirical research about how each of the principles affects or is expected to affect the 15 identified student outcomes, and presents specific examples of instructional practices related to each instructional principle. For a detailed accounting of specific instructional methods that directly address Outcomes 3a through k, see Felder and Brent's Appendix C [7]. We highly recommend readers review Felder and Brent's appendices as they are quite thorough and, therefore, we will not duplicate their work in this paper.

A. Encouraging Student-Faculty Interaction

Learning is enhanced through socially supported interactions with others [8], and data from a number of studies of undergraduate learning suggest that student-faculty interaction is significantly and positively related to college grade point average, degree attainment, graduating with honors, and enrollment in graduate school [9-12]. In addition, a recent study concluded that faculty interaction is significantly and positively associated with gains in engineering students' design and professional skills [13].

Instructor-student interaction can happen in various ways and degrees of intensity. For instance, faculty may interact with students both in and out of the classroom, discuss course-related topics, and offer academic advice. Out of class conversations on substantive matter, and faculty-supervised internships or research opportunities provide excellent and effective opportunities to interact with students [14]. Transmitting, by verbal or non-verbal communication, an attitude that values students' opinions and contributions, learning students' names, arriving at class early and staying late, and being enthusiastic about course content [15] are ways in which faculty may foster student-instructor interaction.

B. Developing Reciprocity and Cooperation Among Students

Similar to student-faculty interactions, several researchers have posited that peer interaction enhances undergraduate students' learning experiences [4, 16-18]. Relating specifically to engineering education, Colbeck et al's research found that group work helped students enhance their leadership skills and effectively divide tasks among group members [19]. Results of a study at the Colorado School of Mines suggested students who participated in a first-year program that fostered a learning community graduated at significantly higher rates than their peers. Peer mentoring and participating in learning communities, both of which foster reciprocity and cooperation among students, contributed to students' retention and positive experiences in their engineering major [20].

Using collaborative and cooperative instructional activities are ways to foster reciprocity and cooperation among students. Johnson et al [18], McKeachie [17], and an increasing number of higher education scholars have written about specific collaborative and cooperative instructional strategies and techniques. Readers interested in implementing these types of activities in their classrooms might also reference Felder and Brent's section on cooperative learning in the engineering classroom [7].

C. Communicating High Expectations

Research suggests setting high but attainable goals increases students' academic performance [4, 15, 16, 21]. In addition, endorsing formidable goals can affect not only individual students' performance, but permeate the institutional climate of an entire department or university. Little research has been published on the effects of faculty expectations on engineering students' academic performance, however, engineering faculty can adhere to generic recommendations including: preparing a list of challenging educational objectives; developing goals that are demanding yet attainable; and requiring students to spend a significant, but not overwhelming, amount of time on coursework, etc.

D. Providing Prompt Feedback

Providing feedback to students is a valuable tool in encouraging student learning, particularly when introducing new material or concepts [4, 14-16, 22]. Bjorklund et al found that prompt and detailed feedback from faculty contributed significantly to student gains in design and professional skills in a first-year design course [13]. Faculty can provide feedback both formally (e.g., graded exams or lab work) and informally (e.g., verbally correcting a students' misperceptions during a class discussion). Faculty ought to avoid confrontational strategies in the classroom, and rather make efforts to provide feedback in a constructive, supportive, and timely manner.

Vines and Rowland [23] applied the concept of feedback mechanisms in electrical engineering applications to create their Instructional Feedback model, which suggests that faculty implement many "sensors" (e.g., homework, group projects, exams, minute papers) to gauge students' progress through any one course. The authors' model compares instructors to "actuators" that provide correction to the system (i.e., student progress) by providing frequent and detailed feedback. They also suggest faculty apprise students of their progress or shortcomings several times during a course, in order to give students the opportunity to change their approach or study habits to learn more successfully. Also vital to the process, instructors ought to check periodically to see if students made changes based on their feedback.

E. Using Active Learning Techniques

The National Research Council, among others, asserts that the practice and activities in which people engage while learning shape what is learned [8]. Further, education researchers have found that engaging in active learning techniques rather than listening to lectures helps students, in many cases, to learn and retain more information [4, 6, 15-17]. In his study comparing effect sizes for results of various studies of active learning, Prince found support for using active learning (including cooperative, collaborative, and problem-based learning) techniques in the classroom [24].

In a study on active learning in engineering classrooms, Terenzini et al [25] found that when compared to students in lecture-based courses, students engaged in collaborative, active learning techniques made significant, positive gains in design skills, communications skills, and group skills. McKenna and Agogino also found support for using active learning techniques when middle and high school students who used computer simulations and Legos to build pulleys and levers showed significant improvement in mechanical reasoning on pre- and post-tests [26].

Many effective active learning instructional strategies exist, and it is imperative that faculty implement strategies best suited to their course content and students' abilities. For further discussion about and suggestions for active learning techniques, see Wankat [15], Felder and Brent [7], and McKeachie [17].

F. Emphasizing Time on Task

Consensus states the more time students spend on the task of learning, the more students will learn [4, 15-17]. This concept does not imply, however, that the period of learning must occur continuously for several hours. Indeed, while total amount of time on task is important, it is also helpful to break up long class periods with activities, breaks, and repetition of material already covered [15, 22]. Very little research has focused specifically on time-on-task for engineering majors, yet opportunities to do so are available as engineering students can spend a great deal of time in classrooms, laboratories, and even study or homework groups.

G. Respecting Diverse Talents and Ways of Thinking

Though mentioned by Chickering and Gamson [4], discussion about the different ways women and men undergraduates learn began in the higher education research sphere with the publication of Baxter-Magolda's longitudinal study of college students' "ways of knowing" [27]. Her study examined students' intellectual development from their first year in college through one year after college graduation and the gender-related patterns of intellectual development and "knowing." In brief, she found that women were more likely to use relational ways of knowing, which are characterized by being open, responsive, connected, and flexible. In contrast, men generally engage in impersonal or objective ways of knowing, which are distinguished by logical, algorithmic procedures that result in separateness and abstraction

Many researchers, in recent years, have examined the differences between and similarities in the educational experiences, processes, and intellectual development of various groups of students (e.g., women, men, white students, students of color, non-native English speakers) [e.g., 28, 29]. Findings suggest learners have different strategies, approaches, patterns of abilities, and learning styles that are a function of the interaction between their heredity and their prior experiences [8].

In their assessment of the effects of using integrated virtual learning systems to teach students about programmable logic controllers, Hsieh and Hsieh [30] found, for example, that continued use of animations to illustrate command functions contributed to students' understanding of complex concepts. Similarly, Ellis [31] found that using a tutorial with animation fosters a greater degree of learning than using text-only instruction when teaching Boolean algebra. Although virtual experiences or laboratory experiments should not replace physical experiments, many faculty are looking for ways to best reach students of all backgrounds and learning styles. Therefore, best practice would suggest that, to the extent that it is possible, content and delivery style ought to be adapted to students' cultural background and learning styles, which would ensure greater academic success for many students.

H. Building on Correct Pre-existing Understandings; Dispelling False Preconceptions

Learners use what they already know to construct new understandings. Similarly stated, learning with understanding is facilitated when new and existing knowledge is structured around the major concepts and principles of the discipline [8, 22]. Therefore, faculty ought to give pre-tests in some classes to assess with what misconceptions and accurate preconceptions their students come to class.

In addition to pre-testing, concept mapping [32] and implementing knowledge surveys [33] may also be helpful to investigate students' understanding of certain concepts, document misconceptions about a topic and development over time. Besterfield-Sacre et al's study found that concept maps designed for their study were sensitive enough to detect growth in engineering students' knowledge integration from sophomore to senior year [34].

I. Providing Factual Knowledge, Facilitating Understanding of the Facts and Ideas in Context of a Conceptual Framework, and Organizing Knowledge that Facilitates Retrieval and Application

Faculty, as educators with expert knowledge of their fields, can facilitate students' learning by providing access to course-specific facts, helping learners situate facts and ideas in the context of the broader field, and guiding students on the ways new information and ideas can be applied to other situations [5].

Although research examining these processes is scarce in the engineering education literature, a few sources provide examples of instructional strategies that seem to adhere to these concepts. For example, Wankat suggests faculty teach inductively by introducing new topics or concepts with simple, specific examples [15]. Additionally, researchers have been working on Project 2020 (based at Embry-Riddle Aeronautical University), a project that links recent discoveries in brain science and their relevance to education and learning. They suggest faculty put "meaning before detail" by beginning a new subject with hands-on activities, analogous metaphors to describe new concepts, and common sense examples [35]. They further contend that “learning though discovery” (e.g., solving ill-structured or open-ended problems) facilitates pattern recognition and knowledge retrieval.

J. Encouraging Students' Motivation to Learn

Scientific research on education suggests students' motivation to learn and sense of self affect what is learned, how much is learned, and how much effort will be put into the learning process [8]. Therefore, faculty ought to encourage students' motivation to learn [5]. One way to promote students' motivation to learn is to use emotions to increase attention and retention [33]. Hersam et al. found that active, collaborative instructional techniques and problem-based learning increased students' enthusiasm for and interest in nanotechnology [35].

In addition to using emotion to encourage student motivation, faculty can improve student motivation by allowing students to define their own learning goals [5]. In a discussion of indicators of engaged, effective learning, Jones et al. describe characteristics of students who are responsible for their own learning:

> In engaged learning settings, students are *responsible for their own learning*; they take charge and are self-regulated. They define learning goals and problems that are meaningful to them; have a big picture of how specific activities relate to those goals; develop standards of excellence; and evaluate how well they have achieved their goals. They have alternative routes or strategies for attaining goals--and some strategies for correcting errors and redirecting themselves when their plans do not work. They know their own strengths and weaknesses and know how to deal with them productively and constructively. Engaged learners are also able to shape and manage change. [36, p. 8]

In a study of engineering students working in teams, Colbeck et al. found that students held differing individual learning goals, even when working in teams [11]. Their differing goals led to various level of motivation to participate in teams. For example, most students that wanted to earn good grades or learn the material or processes of the lessons generally worked harder than their teammates that sought only to pass the course. Faculty, therefore, should encourage students to set goals regarding content and skills they would like to learn in a certain course. The goals they set should be positive, realistic, measurable, and clear. In sum, faculty ought to support students as they set specific goals, sub-goals, and deadlines, and monitor their own progress.

III. Instructional Principles Related to Student Outcomes: Research and Gaps

While we hope the preceding information on desired outcomes for engineering students and instructional principles may be helpful to the reader, this section endeavors to “tie it all together” by illustrating which of the instructional principles, based on our review of the literature, are related to particular student outcomes. To more easily visualize these relationships, Table 2 is provided below. While we tried to be reasonably thorough in our presentation of available research, we acknowledge that it is likely we neglected to include some research linking the identified instructional practices and student outcomes.

Table 2. Instructional Principles Related to Student Outcomes

Instructional Principles	**Related Student Outcomes (ABET 3a-k) plus four**	
	Evidence found in engineering education research	**Expected relationship**
1. Encouraging student-faculty interaction	3b, 3c, 3f	All
2. Developing reciprocity and cooperation among students	3g, L	3d, 3g, L, N
3. Communicating high expectations		All
4. Providing prompt feedback	3b, 3c, 3f	All
5. Using active learning techniques	3b, 3c, 3d, 3e, 3g, 3k	All (except 3j)
6. Emphasizing time on task		All
7. Respecting diverse talents and ways of thinking	3a, 3b, N	All (especially N)
8. Building on correct pre-existing understandings; dispelling false preconceptions	3a	All (especially those related to design)
9. Providing factual knowledge, facilitating understanding of the facts and ideas in context of a conceptual framework, and organizing knowledge that facilitates retrieval and application		All (especially those related to design)
10. Encouraging students' motivation to learn		All (especially 3i)

The first column of Table 2 lists the instructional principles described in this paper. Columns two and three list student outcomes (ABET 3a through k "plus 4") associated with each instructional practice. More specifically, the second column lists outcomes, shown in the literature, that result from students engaging in teaching and learning strategies associated with each instructional principle. Column three lists outcomes *expected* to result from students engaging in teaching and learning strategies associated with each instructional principle, however, no evidence was found to substantiate these assumptions. For example, engineering education research has shown that student-faculty interaction contributes to students' gains in design and professional skills [13]; however, one could expect that through interacting with faculty, students ought to make gains in all of the identified outcomes. As noted in Table 2, many opportunities exist for scholars to conduct novel and needed research examining the extent to which these principles and outcomes are related, and exactly which instructional best practices contribute to students achieving each of the identified outcomes.

IV. Conclusions

Although not explicitly addressed in the course of this paper, several engineering colleges have developed during recent years "engineering entrepreneurship" courses and minors. While these courses and programs are not instructional principles or practices, per se, they do address several of the 15 student outcomes outlined in the beginning of this paper, including ABET 3d, 3f, 3 h, and having the ability to manage a project and a multidisciplinary systems perspective. Research assessing the impact and effectiveness of these programs is beginning to appear in the literature [e.g., 37, 38] and the engineering education community will likely see more of these programs and their assessments in the near future.

This work completed for this paper is part of a continuing effort to identify a comprehensive summary of the student learning outcomes desired by engineering education stakeholders, the most effective instructional strategies associated with those outcomes, and determination of the extent to which faculty and students are engaged in those strategies. The next phase of this project is the development of a set of survey instruments that will assess the extent to which engineering faculty and students are engaged in "best practices" in engineering education. Faculty and students at five CASEE-affiliated institutions will review and provide feedback regarding potential survey items during spring 2005. After the surveys have been refined, we will pilot test the instruments in spring 2006. At the conclusion of this project, CASEE intends to make the survey instruments available to engineering colleges nationwide.

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References

[1] Cupp, Stephanie, M., P. D. Moore, and N. L. Fortenberry. "Linking Student Learning Outcomes to Instructional Practices – Phase I." *Annual Conference and Exposition Proceedings,* Session 1630, Washington, DC: American Society for Engineering Education, 2004.

[2] Accreditation Board for Engineering and Technology, Inc. 2003-2004 Criteria for Accrediting Engineering Programs, Baltimore, MD: Accreditation Board for Engineering and Technology, Inc., 2002.

[3] Moore, Paolo Davidian, S. M. Cupp, and N. L. Fortenberry. "Linking Student Learning Outcomes to Instructional Practices – Phase II." *Annual Frontiers in Education Conference,* Boulder, CO: ASEE/IEEE, 2003.

[4] Chickering, Arthur W. and Z. F. Gamson (Eds.). "Applying the Seven Principles for Good Practice in Undergraduate Education." *New Directions for Teaching and Learning*, Vol. 47, 1991.

[5] Bransford, John D., A. L. Brown, and R. R. Cocking, eds. 2000. "How People Learn: Brain, Mind, Experience, and School." National Academy Press, Washington, DC.

[6] "Learner-Centered Psychological Principles: A Framework for School Redesign and Reform." American Psychological Association, 2004. Available at <http://www.apa.org/ed/lcp.html>. Accessed 11/30/2004.

[7] Felder, Richard, and R. Brent. "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria." *Journal of Engineering Education*, v92, no. 1, 7-25.

[8] National Research Council. 2002. *Scientific Research in Education.* Washington, DC: National Academy Press.

[9] Astin, A. W. *What matters in college: Four critical years revisited.* San Francisco: Jossey-Bass, 1993.

[10] Tinto, V. "Linking learning and leaving." In Braxton, J. M. (Ed.). *Reworking the student departure puzzle*. Nashville: The Vanderbilt University Press, 2000.

[11] Colbeck, Carol L., A. F. Cabrera, and P. T. Terenzini, "Learning professional confidence: Linking teaching practices, students' self-perceptions, and gender." *The Review of Higher Education*, 24, 2, 2000, 173-191.

[12] Pascarella, E. T and P. T. Terenzini, *How college affects students*. San Francisco: Jossey-Bass, 1991.

[13] Bjorklund, Stefani A., J. M. Parente, and D. Sathianathan. "Effects of Faculty Interaction and Feedback on Gains in Student Skills." *Journal of Engineering Education*, v93, no.2, 2004, 153-160.

[14] Kuh, G. D. and Hu, S. "The effects of student-faculty interaction in the 1990s." *The Review of Higher Education,* 24, 3, 2001, 309-332.

[15] Wankat, P.C. 2002. *The Effective, Efficient Professor*. Boston: Allyn & Bacon.

[16] Scorcinelli, M. D. "Research Findings on the Seven Principles," *New Directions for Teaching and Learning,* v47, 1991, 13-25.

[17] McKeachie, W. J. 1999. *Teaching Tips: Strategies, Research, and Theory for College and University Teachers.* 10th ed. Boston: Houghton Mifflin.

[18] Johnson, D.W., R.T. Johnson, and K.A. Smith. 1998. *Active Learning: Cooperation in the College Classroom.* 2nd ed. Edina. MN: Interaction Book Company.

[19] Colbeck, Carol L., S. E. Campbell, and S. A. Bjorklund. "Grouping in the Dark: What Students Learn from Group Projects." *Journal of Higher Education*, v 71, no. 1, 2000, 60-83.

[20] Olds, Barbara and R. Miller, "The Effect of a First-Year Integrated Engineering Curriculum on Graduation Rates and Student Satisfaction: A Longitudinal Study." *Journal of Engineering Education*, v93, no.1, 2004, 23-35.

[21] Carson, B. H. "Thirty Years of Stories: The Professor's Place in Student Memories." *Change,* 28, 6, 1996, 11-7.

[22] Boudtedt, Aileen. 2003. "A Special Report on the Next Revolution in Higher Education," Project 2020, Embry-Riddle Aeronautical University.

[23] Vines, D. L., and Rowland, J. R. "An instructional feedback model for improved learning and mentoring." Paper presented at the annual meeting of Frontiers in Education, 1995.

[24] Prince, Michael, "Does Active Learning Work? A Review of the Research," *Journal of Engineering Education*, v93, no.3, 2004, 223-231.

[25] Terenzini, Patrick T., A. F. Cabrera, C. L. Colbeck, J. M. Parente, and S. A. Bjorklund. "Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains," Journal of Engineering Education, v90, no. 1, 123-130.

[26] McKenna, Ann F. and Alice M. Agogino. "Supporting Mechanical Reasoning with a Representationally-Rich Learning Environment." *Journal of Engineering Education*, v93, no.2, 2004, 97- 104.

[27] Baxter Magolda, Marcia. 1992. *Knowing and Reasoning in College: Gender-Related Patterns in Students' Intellectual Development.* Jossey-Bass.

[28] Laeser, Melissa, B.M. Moskal, R. Knecht, and D. Lasich, "Engineering Design: Examining the Impact of Gender and the Team's Composition,"*Journal of Engineering Education*, v992, no.1, 2003, 49-56.

[29] Colbeck, C. L., Cabrera, A. F., & Terenzini, P. T. (1999). Teaching for professional competence and confidence: The link between instructional practices and learning gains for female and male students. In Designing the Future of Science and Engineering Education. Proceedings of the 1999 Frontiers in Education Conference. Washington, DC: IEEE Computer Society.

[30] Hsieh, S. and P. Yee Hsieh. "Integrated Virtual Learning System for Programmable Logic Controller." *Journal of Engineering Education*, v93, no.2, 2004, 169-178.

[31] Ellis, Timothy. "Animating to Build Higher Cognitive Understanding: A Model for Studying Multimedia Effectiveness in Education." *Journal of Engineering Education*, v93, no.1, 2004, 59-64.

[32] Zelik, M., "Concept Mapping," *Field-tested Learning Assessment Guide (FLAG),* <http://www.flaguide.org/cat/minutepapers/conmap1.htm>, accessed December 2004.

[33] Nuhfer, Edward and D. Knipp. "The Knowledge Survey: A Tool for All Reasons." *To Improve the Academy, v21*, 59-78.

[34] Besterfield-Sacre, Mary, J. Gerchak, M. Lyons, L. J. Shuman, and H. Wolfe, "Scoring Concept Maps: An Integrated Rubric fro Assessing Engineering Education." *Journal of Engineering Education*, v93, no.2, 2004, 105-115.

[35] Boustedt, Aileen, "New Brain Discoveries Challenge Traditional Education." Embry-Riddle Aeronautical University. Available at http://homepage.mac.com/yogitrish/ERAU_Project2020/documents/NSFProject2020Summary_000.pdf. Accessed December, 2004.

[36] Hersam, Mark, C., M. Luna, and G. Light. "Implementation of Interdisciplinary Group Learning and Peer Assessment in a Nanotechnology Engineering Course." *Journal of Engineering Education*, v93, no.1, 2004, 49-57.

[37] Jones, B.F., G. Valdez, J. Nowakowski, and C. Rasmussen, 1995. "Plugging In: Choosing and Using Educational Technology." Washington, DC: Council for Educational Development and Research, and North Central Regional Educational Laboratory. Available online: http://www.ncrel.org/sdrs/edtalk/toc.htm

[38] Ohland, Matthew, W., Frillman, S. A., Zhang, G., Brawner, C. E., and Miller III, T. K. "The Effect of an Entrepreneurship Program on GPA and Retention," *Journal of Engineering Education*, v93, no. 4, 293-301.

[39] Carlson, Lawrence, J. Sullivan, S. Poole, and M. Piket-May. "Engineers as Entrepreneurs: Invention and Innovation in Design and Build Courses." Paper presented at the Frontiers in Education annual conference, San Juan, PR, November 1999. Available at < http://fie.engrng.pitt.edu/fie99/papers/1140.pdf>.

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