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Establish Feedback Loops in an Electrical Engineering Core Course with Adaptive Release

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Objective and Motivation

Analysis and Design of Control Systems is a core course in most Electrical Engineering programs in the United States. This course typically includes topics such as fundamental mathematical background on complex numbers, logarithm calculations, establishing and solving differential equations, Laplace Transform, and new knowledge on stability criteria and controller design. In addition, this course integrates theoretic analysis and real-world applications to prepare students for their senior design projects. However, at our university, a substantial mathematical foundation is required and the lack of this preparation in our student population has been a main source of challenge, resulting in lower student interest, many D and F grades, and substantial withdrawal (DFW) rates in our classes.

To address this, we have created an innovative teaching approach to increase students' performance by differentiating instruction to each student based on his/her understanding of key knowledge points in the lectures measured through an adaptive assessment system. In this approach, we designed a series of online quizzes according to lectures and adaptively assigned exercises/homework to students with respect to their mistakes in their quizzes. For students who did not meet a specific knowledge point, a video lecture was assigned to reinforce the lecture material and a follow-up quiz was designed to examine the improvement in understanding. Instructors would modify the following-up lectures based on the students' performance in quiz grades in a timely manner and form a fundamental knowledge-point-based feedback loop for instruction. Feedback loops on exam preparation and self-evaluation system were established by pre-exam preparation survey (input), adaptive load for preparation, exam results (output), and post-exam survey (feedback). With this adaptive release mechanism, students were able to review the knowledge points before exams, improve understanding of specific topics with extra work, and efficiently review the course material for exam preparation.

This paper presents an evaluation of our course design. Achievement data of 87 students have been collected and analyzed by an evaluation model associating attendance of each student, time spent on exam preparation and homework, number of office-hour visits, and study groups attended for exam preparation, to outcomes of the course. Our results showed a significant increase in engagement of students and remaining enthusiasms of students partially due to the increase in direct interaction between instructor and individual student by this adaptive release mechanism. In the previous teaching cycles, an average of 18% DFW rate was observed in this course. With the adaptive release, there was no withdraw from the class and DFW rate was reduced to 10%.

Background

An electrical engineering course, entitled "Analysis and design of control systems", has been adopted as a core course by most Department of Electrical Engineering, Systems Engineering, and Aerospace Engineering worldwide. The knowledge covered in this course has served as keystones to electrical circuits, electronics, manufacturing line, and process control when automation is involved. One outcome of the course is to produce highly trained manpower in automation and control engineering ready to take up the challenges in industrial research/design.

This course is broadly-based with prerequisite knowledge of 1) mathematical modeling skills obtained from general physics (freshman level course), general chemistry (freshman level course), and network theory (sophomore level course); 2) differential equation solving skills obtained from Calculus (freshman level course); and 3) Laplace transform and complex numbers obtained from Engineering Analysis (junior level course). This course integrates students' knowledge base established in the first 3 years in college. This course also serves as a gateway to senior level courses for automation and control. At least three technical electives are developed based on the knowledge given in this course. Furthermore, this is the only course providing a viewpoint for *Systemic Design and Implementation* in undergraduate engineering education which supports a better understanding of digital signal processing, communication systems, and senior design for senior students. Therefore, this course is critical for a student to attain both academic and practical skills for their future career. However, this course has been facing a significant D-grade, F-grade, or withdrawals rate (averaged at 18%) during the past years. This high DFW rate is caused partially by three reasons.

First, students enrolled in the course have ***different preparation levels*** illustrated by the grade distribution of a prerequisite test. During the past 3 years, prerequisite test covering complex numbers, logarithm calculation, solving 1st order differential equation, and Laplace transform has an average of 45/100. This course requires a C or above grade in prerequisite courses, which creates some challenges. First, there may be a long time gap between enrollment time of prerequisite courses and the time taking this course. As a normal design, students should take calculus I and II to solve a differential equation in the first year of college study, Engineer Analysis 1 and II to understand complex numbers and Laplace transform to solve differential equations in the second year. Thus, they can have Analysis and Design of Control System in the 3rd year. However, not every student follows this schedule. Some students are part-time students and have an extended program plan. Some students have to re-take these prerequisites several times to have a passing score. Therefore, when they register for this core course, they may forget some concepts and fundamental knowledge. Furthermore, a passing grade of C for prerequisite courses means the students may have acquired only 70% of course material, while finishing the prerequisite courses but not the understanding of knowledge needed before enrollment in this course. In addition, this 70% knowledge may not be the materials required by this core course.

The second reason for high DFW rate is ***different engagement levels*** of students. The attendance rate for each lecture for the past 3-years ranged from 50% - 95%. A follow-up survey on average time spent on this course also diverged from 4-12 hours/week with an average of 6.6 hours/week. In addition, the time they spent on this course significantly diverged based on coordination with other events: due date of course load (homework and exams) for this course, course load for other courses, and personal events. An expected time spending on a 3-credit course is12 hours per week including 3 hours in lecture given by the instructor, 1-hour in recitation given by a teaching assistant, and 8 hours in self-guided study on review, homework, and projects for this 3-credit course. Therefore, the average time our students spent on this course was below the expectation.

The high DFW rate is also associated with ***different achievement levels*** of students. Students with a high GPA generally illustrate enthusiasm in maintaining their GPA and are more willing to communicate with instructors and are comfortable asking for help from instructors and teaching assistants. In addition, students with a high GPA also demonstrated a willingness to spend more time on this course and an effective study habit to maintain their GPA. On the other hand, a student with a lower GPA was more likely to be categorized as a high-risk student in midterm grades.

To address an individual student's needs caused by different preparation, engagement, and achievement levels, an adaptive release mechanism was proposed to enhance students' performance in the Fall semester of 2017[1-3]. The adaptive release modules were designed to test students' understanding on course materials and then adaptively guide students who did not reach the learning goal for the material in recitation by a teaching assistant, via extra video lectures online, or with further explanation of examples in PowerPoint presentations.

The adaptive release mechanisms were also integrated into feedback loops for both instructor and students to improve the effectiveness of teaching and learning. Feedback loops have been proposed to improve teaching and learning for two decades. The importance of feedback loops for effective communications, writing, and collaborative learning has been reported extensively [4-10]. Most reports emphasized the role of feedback loops in the assessment of the teaching-learning process. However, little has been reported to establish instructional development for engineering courses.

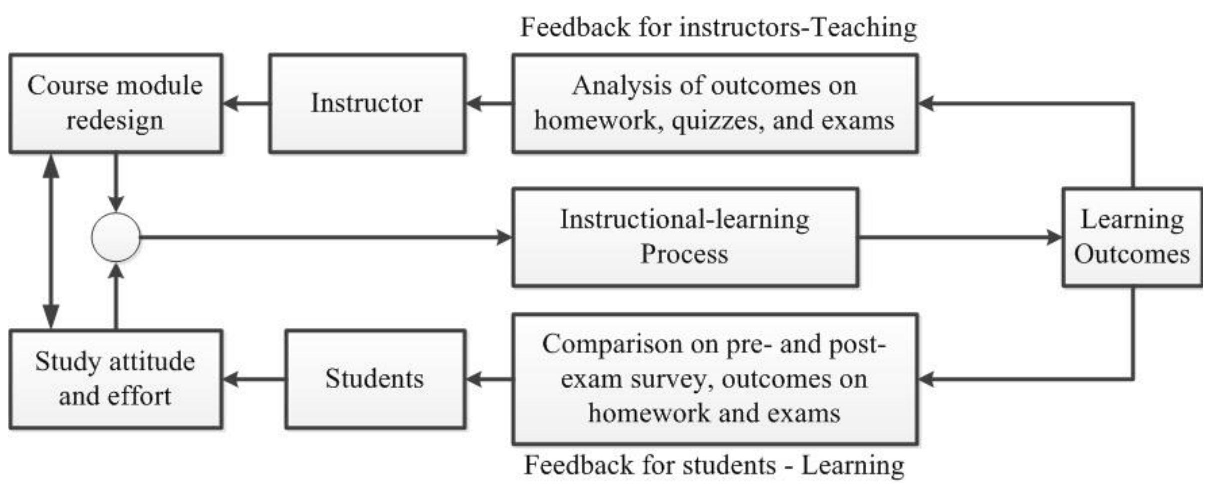

Figure 1. The architecture of feedback loops for course redesign with two independent and complementary parts: an instructor-teaching feedback loop and a student-learning feedback loop.

Design and Development

The objective of the course redesign is to establish a feedback loop to examine the teaching-learning effectiveness. Tools for this course design include adaptive release, student surveys, and educational observations. Assessment of this course redesign includes teaching-learning effectiveness based on student performance on average of final exams, DFW rate, and teaching evaluation.

The overall architecture of feedback loops for this course redesign is described in Figure 1. There are two independent and complementary feedback loops: a feedback loop for the instructor and a feedback loop for students. Learning outcomes include both outcomes of student performance, teaching evaluation on the instructor, and student's surveys on course preparation and effort.

Specifically, the input of feedback loop for instructor will be course modules. The instructional process will give the output as outcomes of online quizzes, homework, and exams. The output will be analyzed to modify and redesign course modules and instructional material. It's worth to note that this feedback loop was integrated with the adaptive release mechanism.

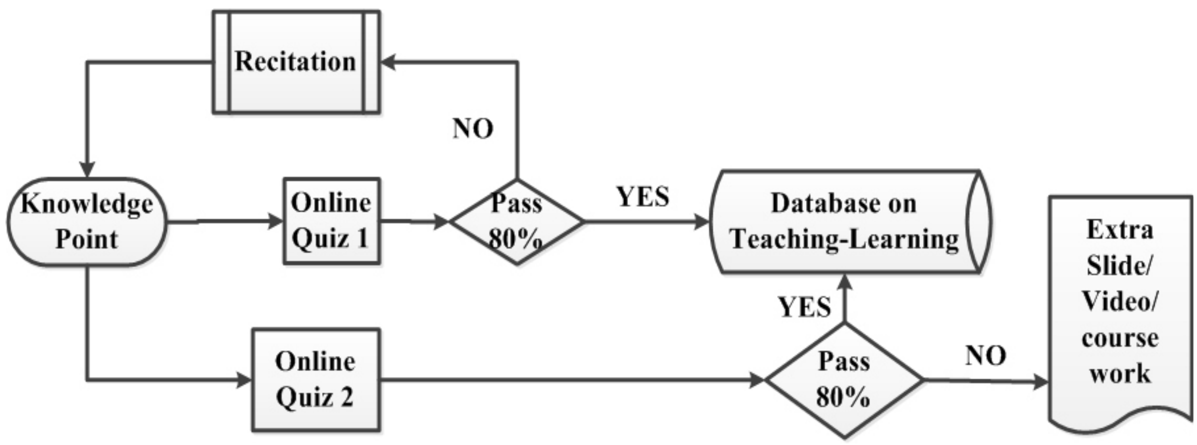

Figure 2. An illustration of a teaching feedback loop for a knowledge point with online quizzes and adaptive release.

An illustration of a teaching feedback loop for each knowledge point is shown in Figure 2. After a lecture was given for a specific knowledge point, an online quiz was assigned right after the lecture to test the understanding of the knowledge point. An online quiz with 5-10 problems examined concept, definition, and applications for the knowledge point at a fundamental level. If a student answered the problems with greater or equal to 80/100 correct response rate, the student passed this quiz. Otherwise, the student was requested to attend a recitation session organized by a teaching assistant to reinforce understanding. A second online quiz was given after the recitation for the same knowledge point with a passing score of 80/100 also. Upon passing, the correct response rate and understanding levels of students were saved to a database for teaching-learning analysis. If a student did not pass the 2nd online quiz, the instructor would provide extra videos or slides to help the student. Overall, 90% of students passed the 2nd quiz. The instructor would modify the following-up lectures based on the students' performance in quiz grades in a timely manner and form a fundamental knowledge-point-based feedback loop for instruction.

The input of the feedback loop for students includes prerequisite test and pre-exam survey for exam preparation. Students identify their special need and integrate these needs into the learning process. The output of the student learning feedback loop includes post-exam survey, outcomes on quizzes, homework, and exams. The feedback loop is closed by comparing the pre-exam survey and the post-exam survey so students can figure out their study focus to improve learning.

Development of the course modules includes reconstructed course perquisites, lecture presentations, homework assignments, in-class quizzes, videos related to special topics, online quizzes developed with Respondus, and adaptive release in Blackboard.

Implementation

Implementation of the course redesign was stringently under the design blueprint as shown in Figures 1 and 2. A total of 10 course modules, including the linear property of the system, Laplace transform, Sensitivity analysis, Time domain analysis, Property of closed-loop system, Stability analysis, Root locus analysis, Bode plot, Nyquist analysis, and Controller design, were redesigned during the semester. Each course module has at least 1 online quiz assigned with the adaptive release. Among all redesigned course modules, the module on Laplace transform is one of the fundamental requirements for this course. In addition, Laplace transform is widely used in Electrical Engineering courses. Therefore, an example of course module on Laplace transform was presented as follows.

Course Modules on Laplace Transform

1. Module Objectives:
   - Objective 1: Review properties of Laplace transform
   - Objective 2: Present Laplace transform of 6 basic time domain functions: delta function, unit step function, ramp function, exponential function, sinusoid functions (sin ωt and cos ωt)
   - Objective 3: Apply Laplace transform and inverse Laplace transform to solve ordinary differential equations.
2. Lectures and Readings:
   - Chapter 2 in Textbook: RC. Dorf, and RH. Bishop, *Modern Control Systems,* 12th Edition, Addison-Wesley 2010
   - Lecture presentations by the instructor
3. Tools
   - Adaptive release in Blackboard
   - Recitation
   - Video
4. Assessments
   - In-class quiz and group discussion
   - Online quiz in Blackboard
   - Homework assignment
   - Exam 1 (problems 1 and 2)

- Final exam (Problem 1)

5. Deadlines
   - In-class quiz and group discussion (during the class with lecture)
   - Online quiz in Blackboard (within 2 days of lecture)
   - Homework assignment (1-week post-lecture)
   - Exam 1 - problems 1 and 2 (4 weeks post-lecture)
   - Final exam - Problem 1 (14 weeks post-lecture)

The online quiz with 14 questions for adaptive release was designed for two online quizzes using Respondus. Each quiz will have 7 problems randomly chosen from the 14 questions.

1. How many basic factors are included in the transfer function $X(s) = \frac{5(s+3)(s+4)}{s(s+2)(s+6)}$?

2. How many basic factors are there in transfer function $\mathrm{F}(s) = \frac{s^4+8s^3+16s^2+9s+6}{s^3+6s^2+11s+6}$?

3. What's the order of the differential equation $\ddot{y}(t) + 4\dot{y}(t) = 5y(0), y(0) = \dot{y}(0) = 1$?

4. How many basic factors are there in transfer function $F(s) = \frac{s^2+2s+3}{(s+1)^3}$?

5. What's the highest order of basic factors when taking partial fraction expansion for $\mathrm{F}(s) = F(s) = \frac{s^2+2s+3}{(s+1)^3}$?

6. Given the function $G(s) = \frac{4s}{(s+1)(s-1)^2}$, how many basic factors will you get using partial fraction expansion?

7. Given the partial fraction expansion as follows, $\frac{4x}{(x-1)^2(x+1)} = \frac{A}{x-1} + \frac{B}{(x-1)^2} + \frac{C}{x+1}$, what's the value of parameter A, B, and C?

8. Given the partial fraction expansion as follows, $\frac{1-x+2x^2-x^3}{x(x^2+1)^2} = \frac{A}{x} + \frac{Bx+C}{x^2+1} + \frac{Dx+E}{(x^2+1)^2}$, what's the value of parameter A, B, C, D, and E?

Evaluation

Evaluation of the course aims to answer three questions:

1) Does adaptive release improve student performance by identifying the special needs of each student?
2) Do feedback loops help to maintain effective instructor-student interaction?
3) Do feedback loops help to improve student performance?

The evaluation plan includes the following items:

1. Prerequisite test on background knowledge in the first lecture;
2. In-class quiz and group discussion every week (also serve as attendance list);
3. Homework (7 assignments) for every other week starting from week 2;
4. Exam 1 and Pre-exam survey for Exam 1 at week 6;
5. Exam 2 and Pre-exam survey for Exam 2 at week 9;
6. Survey for adaptive release at week 15;
7. Survey on teaching from week 13-15;

8. Final exam and Pre-exam survey for final Exam at week 16.
9. Three classroom observations at week 8, 9, and 10 by evaluators from the Department of Education at the University of Texas at San Antonio.

A descriptive analysis of these data was used to show the results of this adaptive release and feedback loop approach in this course.

Table 1. Statistics of student enrollment, average, and standard deviation of grades for the redesigned course, average and standard deviation of students' GPA before the enrollment of the course, DFW rate, and attendance rate

TERM	# of Enrollment	AVG Course Grade	SD Course Grade	AVG GPA	SD GPA	DFW Rate	Attendance Rate
Fall 2015	34	2.0	0.97	3.02	0.45	21.00	60%
Fall 2016	33	2.39	0.85	3.05	0.48	15.00	79%
Fall 2017	20	2.75	0.98	3.09	0.35	10.00	90%

Results

With the adaptive release and feedback loop established in the class, significant improvements in student performance, active student response, and instructor-student interaction have been observed in the three class observations conducted in the Fall 2017 semester. The instructor has supervised the same course in Fall semesters in 2015, 2016, and 2017. The course redesign was conducted during the Fall semester of 2017. Statistics on student preparation and grades for this redesigned core course were analyzed in Table 1.

The time percentage of student and instructor activities were illustrated in Figure 3. One average from three observations of student and instructor activities in Spring 2017 semester (before the course redesign) and in Fall 2017 (after the course redesign) are illustrated in Figure 3. Results show a decrease in the instructor presenting information through lectures, while students are receiving information directly from the instructor. Figure 3 also shows an increase in students actively engaging in class, while the instructor increasingly guides in-class activities and/or discussions. These small group activities resulted in more time for the instructor to administer them, but also resulted in an increase of student engagement in class.

Two surveys for the overall course have been conducted on the evaluation of adaptive release and overall teaching before the end of the semester between weeks 13-15. The survey on adaptive release showed that 37.8% of students agreed that adaptive release supported the learning process while 13.4% of students disliked the adaptive release as shown in Figure 4. In addition, about 9.8% students liked the adaptive release for easy access, 19.5% liked the feedback mechanisms, and 8.5% liked the question types of adaptive release. About 5% of students give extra suggestions to improve the adaptive release while only 3.7% of students liked the current format. There are 2.4% of students who expressed a neutral opinion. Overall, 75% of the student population favored the adaptive release and feedback mechanisms.

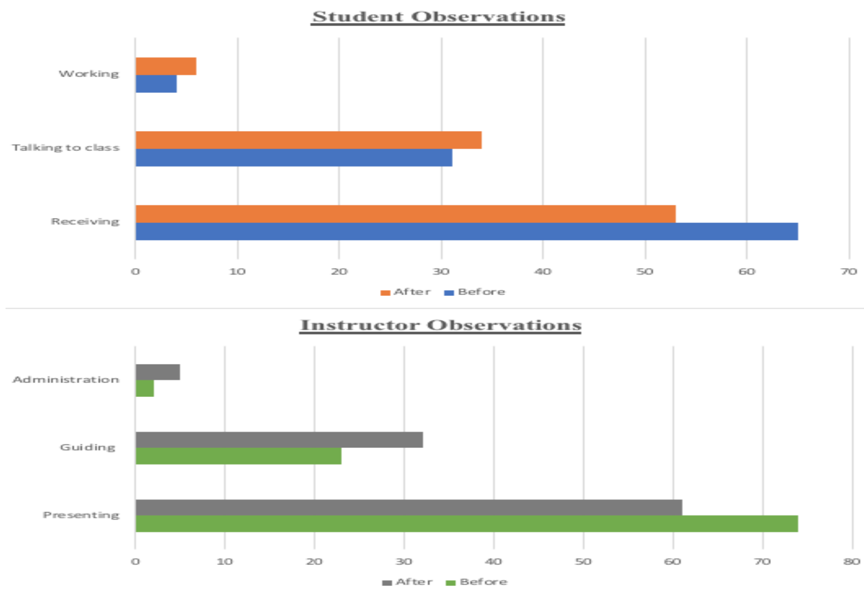

Figure 3. One sample observation of student (orange) and instructor (blue) activities as percentage of class time. Summation of percentage of activities of students and instructor will be 100%, respectively.

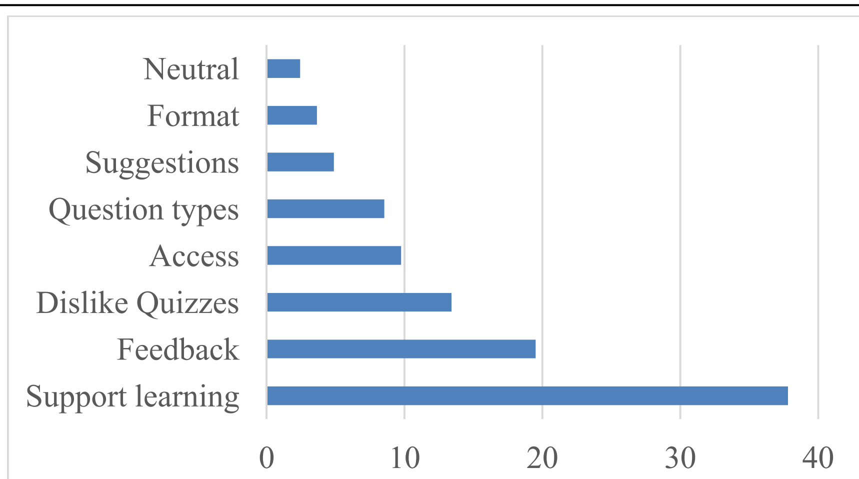

Figure 4. Student survey on adaptive release. Through open-ended questions, students shared their experiences and overall feelings toward the adaptive release, the strengths and weaknesses of the design, and recommendations for future improvements.

Conclusion

An electrical engineering core course was re-designed with adaptive release and feedback mechanisms. There were significant improvements in student performance with increased average course grades from 2.0 (fall 2015) and 2.39 (Fall 2016) to 2.75 (Fall 2017) with A accounting for 4. In addition, the DFW rate was reduced from 21% in 2015 and 15% in 2016 to 10% in 2017, respectively. Student surveys also illustrated a positive impact of the adaptive release on student performance. The observations of the course demonstrated a proactive attitude of students evidenced by higher attendance rate, increased interaction among students and between instructor and students. Overall, this work presented an effective and promising direction for practice in improving engineering education with adaptive release and feedback loops in instruction.

Acknowledgment

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References

[1] F. Martin and J. C. Whitmer, "Applying learning analytics to investigate timed release in online learning," *Technology, Knowledge and Learning,* vol. 21, pp. 59-74, 2016.

[2] J. Mott, "Envisioning the post-LMS era: The open learning network," *Educause Quarterly,* vol. 33, pp. 1-9, 2010.

[3] Y. Xie, F. Ke, and P. Sharma, "The effect of peer feedback for blogging on college students' reflective learning processes," *The Internet and Higher Education,* vol. 11, pp. 18-25, 2008.

[4] P. Black, C. Harrison, C. Lee, B. Marshall, and D. Wiliam, "Working inside the black box: Assessment for learning in the classroom," *Phi Delta Kappan,* vol. 86, pp. 8-21, 2004.

[5] D. Boud and E. Molloy, "Rethinking models of feedback for learning: the challenge of design," *Assessment & Evaluation in Higher Education,* vol. 38, pp. 698-712, 2013.

[6] S. Gielen, E. Peeters, F. Dochy, P. Onghena, and K. Struyven, "Improving the effectiveness of peer feedback for learning," *Learning and Instruction,* vol. 20, pp. 304-315, 2010/08/01/ 2010.

[7] P. M. Lightbown and N. Spada, "Focus-on-Form and Corrective Feedback in Communicative Language Teaching: Effects on Second Language Learning," *Studies in Second Language Acquisition,* vol. 12, pp. 429-448, 2008.

[8] D. J. Nicol and D. Macfarlane-Dick, "Formative assessment and self-regulated learning: a model and seven principles of good feedback practice," *Studies in Higher Education,* vol. 31, pp. 199-218, 2006/04/01 2006.

[9] H. J. Parkin, S. Hepplestone, G. Holden, B. Irwin, and L. Thorpe, "A role for technology in enhancing students' engagement with feedback," *Assessment & Evaluation in Higher Education,* vol. 37, pp. 963-973, 2012/12/01 2012.

[10] D. Woods, R. Felder, A. Rugarcia, and J. Stice, "The Future Of Engineering Education Iii. Developing Critical Skills," *Change,* vol. 4, pp. 48-52, 2000.