

DEFINING, TEACHING AND ASSESSING LIFELONG LEARNING SKILLS

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Abstract - Lifelong learning skills have always been important in any education and work setting. However, ABET EC 2000 recently put a new focus on these skills in engineering education. Outcome 3i states the expectation that engineering graduates must have “a recognition of the need for, and an ability to engage in lifelong learning”. The paper first defines a set of attributes / skills, which are necessary for students to develop as lifelong learners. It is postulated that the “recognition of the need” requires skills in the affective domain, while the “ability to engage” requires skills in the cognitive domain. Next, the paper offers course design elements, which help students develop lifelong learning skills. Finally, the paper presents a method for assessing these skills. Assessment of data from a variety of engineering courses at San Jose State University are presented and analyzed. This assessment method can be used for any of the eleven outcomes in ABET EC 2000, criterion 3.

Index Terms – Assessment, course design, lifelong learning.

INTRODUCTION

The need to stay current has always been important for all professionals. However, this need is becoming more and more pressing as new technological advances continue to transform the workplace at a very rapid pace [1]. In the mid-eighties the “half-life” of an engineer’s technical skills – that is, how long it takes for half of everything an engineer knew about his/her field to become obsolete – was estimated to vary from 7.5 years for mechanical and 5 years for electrical, to 2.5 years for software engineers [2]. Most experts would agree that these numbers are probably smaller today.

Assuming that the graduate school option has been exhausted, engineers can stay current throughout their career by attending short courses, workshops, seminars and conferences in their own as well as in new, emerging fields. However, it is not practical to expect that all the new knowledge we will ever need at some point in our careers can be acquired through these venues. Sooner or later, one will have to search the worldwide web, go to the library or the bookstore, and eventually sit down with a book, an article or some other reference to learn on his/her own. It is in this context that lifelong learning skills need to be defined, taught, and practiced. This is consistent with

Candy’s view [3] that “lifelong learning takes, as one of its principal aims, equipping people with skills and competencies required to continue their own self-education beyond the end of formal schooling”.

This paper will present and discuss:

- A definition of lifelong learning skills.
- Course design elements that address lifelong learning skills.
- A method for assessing the effectiveness of an engineering program in teaching students lifelong learning skills.

The definition, most of the course design elements and the assessment method are generic enough to be used in any field, even outside of engineering.

A DEFINITION FOR LIFELONG LEARNING

Outcome 3i of ABET EC 2000 [4] states that engineering graduates should have “a recognition of the need for, and an ability to engage in lifelong learning”. The first obvious challenge in addressing this outcome is the definition of lifelong learning itself. What exactly constitutes lifelong learning? How can one distinguish a graduate who is a lifelong learner from someone who is not? What are the attributes of lifelong learners?

Felder and Brent [5, p.19] suggest that each outcome be analyzed into *elements* – different abilities specified in the outcome – and that a set of *attributes* be defined for each element – actions that explicitly demonstrate mastery of the abilities specified. For outcome 3i the two obvious elements are:

- Recognition of the need for lifelong learning.
- Ability to engage in lifelong learning.

One of the key differences between these elements is that the first one requires skills in the affective domain, while the second one requires skills in the cognitive domain.

Recognition of the Need

In Bloom’s taxonomy of educational objectives there are five levels of competency in the affective domain [6]. Mastery of each level can be demonstrated through certain actions, examples of which are given below:

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- Level 1: *Receiving* (a stimulus). Students go to class, participate in class activities.
- Level 2: *Responding* (to a stimulus). Students study for their courses, carry out assignments.
- Level 3: *Valuing* (an object or a behavior). Students are committed to their education, have positive attitudes about their coursework.
- Level 4: *Organization* (of values into a system). Students balance their responsibilities effectively; begin to formulate a systematic approach to learning.
- Level 5: *Characterization* (by a value complex). Students work independently and diligently, practice cooperation when working in teams, act ethically. Their value system reflects consistently in their behavior.

It is fair to say that the affective domain represents attitudes and values, which strongly influence the behavior of the learner. Without these one cannot possibly develop skills in the cognitive domain. It could be argued that level 4 (organization) represents the minimum level of mastery students must possess when they graduate, to develop as lifelong learners.

For curriculum design and assessment purposes, the following actions were selected as possible measures of students' recognition of the need for lifelong learning:

- 3i-1: Willingness to learn new material on their own.
- 3i-2: Reflecting on their learning process.
- 3i-3: Participation in professional societies' activities.
- 3i-4: Reading engineering articles / books outside of class.
- 3i-5: Attending extracurricular training or planning to attend graduate school.

Ability to Engage

In the cognitive domain, there are six levels of competency [7]. Again, mastery of each level can be demonstrated through certain actions, examples of which are given below:

- Level 1: *Knowledge*. Students recognize or recall information (ex. repeat verbatim definitions or principles).
- Level 2: *Comprehension*. Students understand the meaning of information, so they can explain it to others (ex. share their own examples of how a principle applies in certain situations).
- Level 3: *Application*. Students use information appropriately to solve well-defined problems.
- Level 4: *Analysis*. Students deal with ambiguity in new, ill-defined situations by formulating models and seeing relationships.
- Level 5: *Synthesis*. Students combine elements in novel ways to generate new products or ideas.
- Level 6: *Evaluation*. Students judge the worth of ideas, theories and opinions, choose among alternatives, and justify their choice based on specific criteria.

In the cognitive domain level 4 (analysis) represents the minimum level of mastery students must possess when they graduate, to develop as lifelong learners. The following nine were selected as representative of the skills necessary to engage effectively in lifelong learning in engineering:

- 3i-6: Observe engineering artifacts carefully and critically, to reach an understanding of the reasons behind their design.
- 3i-7: Access information effectively and efficiently from a variety of sources.
- 3i-8: Read critically and assess the quality of information available (ex. question the validity of information, including that from textbooks or teachers).
- 3i-9: Categorize and classify information.
- 3i-10: Analyze new content by breaking it down, asking key questions, comparing and contrasting, recognizing patterns, and interpreting information.
- 3i-11: Synthesize new concepts by making connections, transferring prior knowledge, and generalizing.
- 3i-12: Model by estimating, simplifying, making assumptions and approximations.
- 3i-13: Visualize (ex. create pictures in their mind that help them "see" what the words in a book describe).
- 3i-14: Reason by predicting, inferring, using inductions, questioning assumptions, using lateral thinking, and inquiring.

Obviously, the list of attributes given above is not comprehensive. Rather, it is intended as a starting point in the study of outcome 3i and it may have to be revised during the assessment process.

COURSE DESIGN TO ADDRESS LIFELONG LEARNING SKILLS

It was mentioned in the previous section that attributes 3i-1 through 3i-5 can be viewed as attitudes rather than skills and as such, they present a different kind of challenge in course design. How do we teach attitudes? And how do we measure changes in attitudes? Comprehensive and satisfying answers to these questions are not easy to offer. However, there are course elements, which greatly contribute to shaping students' attitudes towards learning and help them recognize the need for lifelong learning. Examples from a variety of engineering courses at SJSU are given below.

E 10: Introduction to Engineering

- (3i-2) The course includes an "engineering success" component [8], which explicitly discusses learning in the university environment, strategies for maximizing performance in engineering courses, preparation for exams, and reasons for pursuing a graduate degree.
- (3i-3) Representatives from the student chapters of professional societies discuss the benefits of membership in their societies. Students receive course points if they join and participate in the activities of their societies.

- (3i-2) Students explore their learning styles by taking the Learning Styles Inventory [9] and the Jung Typology Test [10]. These tests help them to identify strengths and weaknesses in their learning process. Subsequently, the students develop strategies to help them overcome their weaknesses and become more balanced in their learning approach.

ME 111: Fluid Mechanics & AE 162: Aerodynamics

- (3i-4) Students select an article in a periodical related to the course subject, summarize it in one page and make a short presentation in class. This assignment is designed to make the students aware of the various publications in the field and help them see how the concepts they learn apply in more complex, real world problems.
- (3i-1) Students take responsibility to study a particular topic on their own and demonstrate their knowledge by solving assigned problems. Interaction with the instructor, as well as with other students is encouraged but no lectures are given on this topic.
- (3i-2) Students reflect periodically on their learning process. They identify their strengths and weaknesses and develop a routine that works best for them. They discuss challenges and highlights for them in the course.

ME 195 A, B: Senior Design Project & AE 170 A, B: Aircraft / Spacecraft Design

- (3i-3, 5) Students attend monthly seminars offered by engineers and other experts from the local industry.
- (3i-3) Students attend monthly meetings of the local chapters of their professional societies.
- (3i-3) Students participate in national design competitions and / or present their designs at regional student conferences.

Some examples from the same courses on how students develop their “ability to engage” are given below:

E 10: Introduction to Engineering

- (3i-6) Reverse engineering project: Students work in teams to disassemble a device, sketch each component and describe its function. They discuss the desirable properties of the materials used and any expected failure modes. Finally, they make suggestions on how the device could be improved and made more readily recyclable [11].
- (3i-12) Students use a rational approach and mathematical modeling to solve simple estimation problems from a variety of fields [12].

ME 111: Fluid Mechanics & AE 162: Aerodynamics

- (3i-10, 11) These skills are inherent in any learning process, whether guided or not. However, students are challenged further in developing these skills, by taking responsibility to study a particular course topic on their

own and demonstrate their knowledge by solving assigned problems.

AE 170 A, B: Aircraft Design

- (3i-7, 8) In addition to working on their design projects, students are given several sets of design questions [13] to research in a variety of sources. They are required to answer these questions in writing and cite appropriately all their references.
- (3i-12, 14) Students make a number of assumptions as they try to predict the performance of their airplanes. Often these assumptions need to be revised in the latter stages of the project, sometimes resulting in major design changes. When they design a particular component students use lateral thinking to visualize how it will affect other components of the airplane.

ASSESSMENT PROCESS

The assessment process is illustrated in figure 1. Three outcome indicators [5] are used to assess the effectiveness of the mechanical and aerospace engineering programs at SJSU in each of the 11 outcomes (3a-3k, [4]):

- a. Student work (assignments, tests, reports, etc.)
- b. Student course reflections
- c. Student surveys.

Although most of the required courses in our curricula incorporate instructional methods and appropriate content that address several of the 11 outcomes, only a subset of these courses (typically 3-4) are selected to assess each outcome. Course coordinators are the first to analyze the indicators from their courses. Based on the evidence collected and the prescribed performance targets, they write a short analysis on how effective the course has been in improving students’ skills in each of the outcomes addressed by their course (see examples in the next session). Coordinators then make recommendations for necessary changes / improvements in their course.

For each outcome the department has a designated “*champion*”, a faculty member whose responsibility is to assess the particular outcome and make recommendations to the department for curriculum changes, should the evidence reveal inadequate student performance in the particular outcome. Outcome champions look at the analyses and the evidence submitted by course coordinators and write their own statement on how well each program prepares students in the skills of the particular outcome.

The courses selected for assessment of lifelong learning skills in the two programs are the following:

- E10: Introduction to Engineering (ME & AE)
- ME111: Fluid Mechanics (ME & AE)
- AE162: Aerodynamics (AE)
- ME195 A & B: Senior Design Project (ME)
- AE 170 A & B: Aircraft or Spacecraft Design (AE)

The following performance targets [5] have been set in the department:

- In each class that addresses a particular outcome, at least 70% of the students must total 70% or higher in all assignments and test questions that pertain to this outcome. It is assumed that all grading is criterion referenced.
- In student surveys, at least 70% of the respondents must agree that the particular course / program improved their lifelong learning skills, as defined previously.

ASSESSING LIFELONG LEARNING SKILLS

The following two subsections present examples of course coordinators' analysis for two of the selected courses.

E10: Introduction to Engineering

As was mentioned earlier, this course includes an "engineering success" component [8], which explicitly discusses learning in the university environment. In addition, students solve several estimation problems, making rational assumptions and using mathematical modeling. They also work in teams on two open-ended, hands-on design projects.

In fall 2002 twelve sections of E10 were offered, each with an approximate enrollment of 50 students. In 5 of these sections, taught by three instructors, a total of 203 students received passing grades. The cumulative scores of these students on all the assignments and exam questions that pertained to lifelong learning was as follows:

- 111 students (55%) received 70% or higher.
- 60 students (29%) received between 50-69%.
- 32 students (16%) received below 50%.

Obviously, the 70% target in student performance was not met in these 5 sections and the results are expected to be similar in the other sections as well. This is not a surprise. It is frequently discussed among E10 instructors, that freshmen do not adequately appreciate the "engineering success" content of the course. For example, in a previous study on the effectiveness of E10, a large percentage of students felt they already knew how to study and prepare for exams simply because they made it successfully through high school [14]. As a consequence, they did not care to spend any time on these topics, either in class or outside of class. The challenge here lies in finding more effective ways to convince our freshmen that they need to improve their study skills beyond the level developed in high school.

Student survey results from 10 sections are shown in table 1. Overall, the 70% target is met in one skill only (3i-12), although in some sections the target was met in several skills. For most skills the results are close to the target and they reveal that freshmen tend to be much more confident than is warranted by their actual performance in the course, as reflected by their grades.

In summary, approximately 55% of the students finish E10 with improved lifelong learning skills, as evidenced by their performance on specific course assignments and tests. On the other hand, it should be mentioned that other course assignments, which also contribute to the development of lifelong learning skills, were not included in the scoring, because they were considered under different outcomes (ex. design project scores were considered under outcome 3c).

AE 170 A: Aircraft Design I

Most of the lifelong learning skills defined earlier are inherent in open-ended, design projects, like the ones required in AE170A&B. Nevertheless, students are given an additional assignment to practice lifelong learning skills. Seven (7) sets of design questions are posted on the course website and each student must search individually several references, including the worldwide web, for answers. Moreover, the students are tested on these questions during their oral presentations. In fall 2002, the scores on this assignment ranged from 73% to 88% for the top 5 students, and from 25% to 54% for the other two students in the class.

The results of the surveys (table 1) show very high level of student confidence in all areas except participation in professional society activities. In the next course offering students will be asked to attend several local meetings, as part of a series of assignments, and report back to class on their learning experience.

Overall, the students increased their lifelong learning skills as evidenced by (a) their work on their projects, (b) their output on the design questions, and (c) the confidence level shown in their survey responses.

CONCLUSION

This paper presented a definition of lifelong learning skills, course design elements for addressing these skills, and a method for assessing the effectiveness of a course and a program in regards to outcome 3i. A preliminary analysis of the available data for several courses shows that both the mechanical and the aerospace engineering programs are on a good track towards satisfying this outcome, although much work needs to be done still at the freshman level to ensure that course performance targets are met. The results from the aerospace engineering capstone design course show that by the time they graduate, most students have recognized the need and acquired most of the skills necessary to continue their own self-education.

In general, when performance targets are not met, course design and instructor effectiveness must first be evaluated. On the other hand, if student performance does not meet the targets, student abilities and motivation also need to be considered. A concern has been raised repeatedly, that today's students enter the university less motivated and prepared than in the past. If this is true, is it realistic to set the performance targets at the 70% level for 70% of the students? If not, what would be appropriate targets? Should

we perhaps be satisfied if only 50% or 60% of the students meet the 70% performance level? Or should course standards be lowered to meet higher performance targets? What would be acceptable with ABET? Eventually, every engineering school will have to grapple with these questions and generate their own answers.

OUTCOME ASSESSMENT FLOW CHART

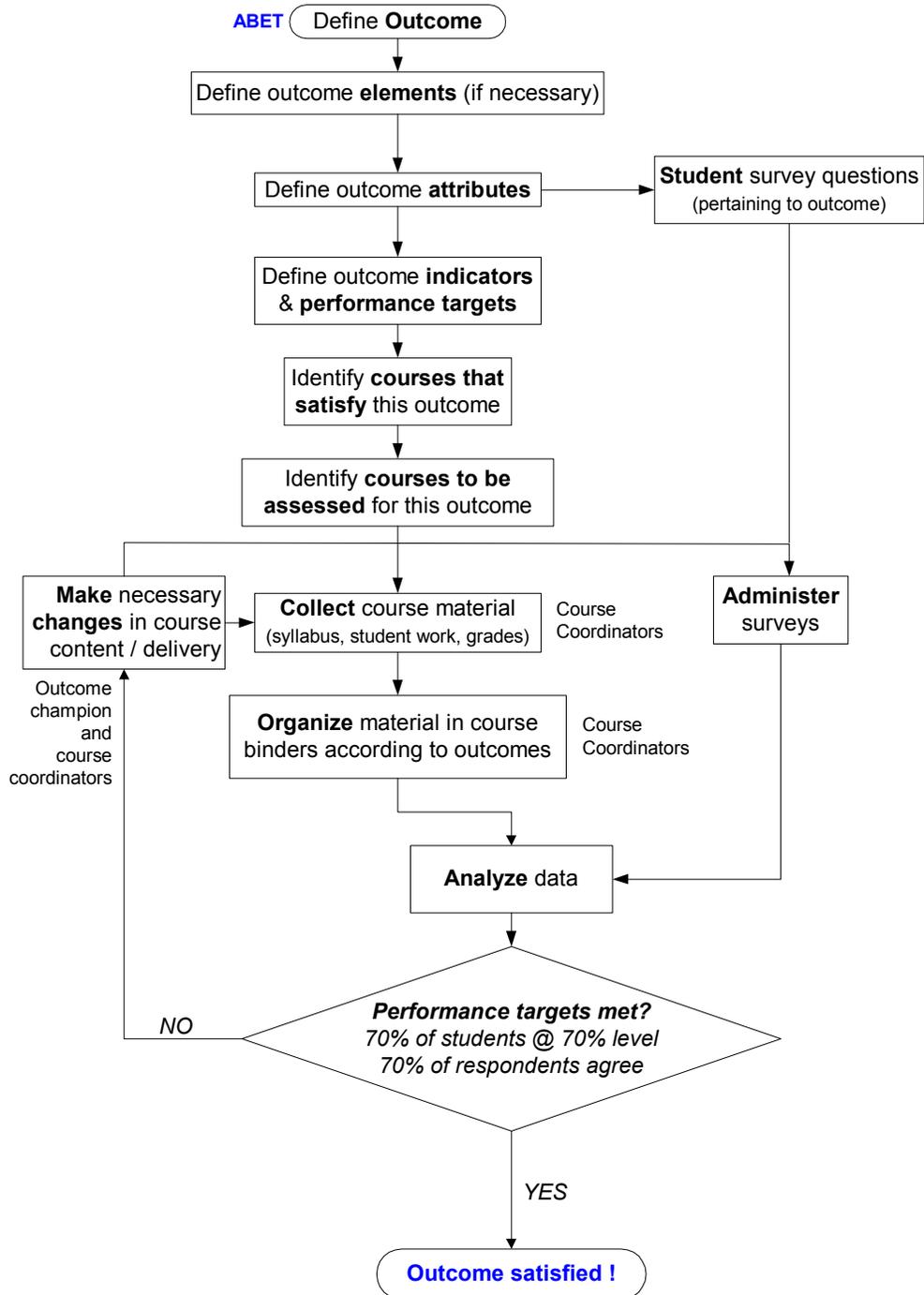


FIGURE 1
OUTCOME ASSESSMENT FLOWCHART

TABLE 1
RESULTS OF STUDENT SURVEYS FROM 3 COURSES, INDICATING STUDENT OPINION
ON HOW WELL EACH COURSE IMPROVED THEIR LIFELONG LEARNING SKILLS.
[Red color indicates that the 70% target was not met]

NS: Not sure	D: Disagree	E10 (N=256)			ME 195 A (N=28)			AE 170 A (N=7)		
<i>In this course:</i>		Agree	NS	D	Agree	NS	D	Agree	NS	D
3i-1: I was encouraged and taught how to learn new material and find information on my own.		164 (64%)	66 (26%)	26 (10%)	25 (89%)	2 (07%)	1 (04%)	6 (86%)	0	1 (14%)
3i-3: I was encouraged to participate in professional society activities and events.		138 (54%)	71 (28%)	47 (18%)	14 (50%)	9 (32%)	5 (18%)	1 (14%)	1 (14%)	5 (71%)
3i-5: I became aware that to stay current in today's world, I must continue my education by attending short courses, workshops, seminars, conferences and/or graduate school.		161 (63%)	67 (26%)	28 (11%)	21 (75%)	2 (07%)	5 (18%)	6 (86%)	1 (14%)	0
<i>This course has increased my ability to:</i>										
3i-6: Observe engineering artifacts carefully and critically.		129 (50%)	93 (36%)	34 (13%)	21 (75%)	3 (11%)	4 (14%)	5 (71%)	0	1 (14%)
3i-7: Access information from a variety of sources.		165 (64%)	71 (28%)	20 (08%)	27 (96%)	0	1 (04%)	6 (86%)	0	0
3i-8: Read critically and assess the quality of information available.		160 (63%)	68 (27%)	28 (11%)	26 (93%)	1 (04%)	1 (04%)	5 (71%)	1 (14%)	0
3i-9: Categorize and classify information.		132 (52%)	99 (39%)	25 (10%)	24 (86%)	2 (07%)	2 (07%)	5 (71%)	1 (14%)	0
3i-10: Analyze new content by breaking it down, asking key questions, comparing and contrasting, recognizing patterns, and interpreting information.		174 (68%)	67 (26%)	15 (06%)	25 (89%)	2 (07%)	1 (04%)	5 (71%)	2 (29%)	0
3i-11: Synthesize new concepts by making connections, transferring prior knowledge, and generalizing my understanding.		176 (69%)	63 (25%)	17 (07%)	26 (93%)	2 (07%)	0	5 (71%)	2 (29%)	0
3i-12: Model by estimating, simplifying, making assumptions and approximations.		199 (78%)	44 (17%)	13 (05%)	28 (100%)	0	0	5 (71%)	0	2 (29%)
3i-13: Visualize (ex. create pictures in my mind to help me "see" what the words in a book describe).		172 (67%)	61 (24%)	23 (09%)	23 (82%)	3 (11%)	2 (07%)	5 (71%)	0	2 (29%)
3i-14: Reason by predicting, inferring, using inductions, questioning assumptions, using lateral thinking, and inquiring.		168 (66%)	69 (27%)	19 (07%)	24 (86%)	3 (11%)	1 (04%)	6 (86%)	0	1 (14%)

REFERENCES

- Otala, L., "Studying for the Future: Lifelong Learning in Europe, the U.S., and Japan", *ASEE Prism*, October 1993, pp.22-29.
- Smerdon, E.T., "Lifelong Learning for Engineers: Riding the Whirlwind", *The Bridge*, vol.26, no. 1-2, Spring/Summer 1996, also available at <<http://www.nae.edu/nae/naehome.nsf/weblinks/NAEW-4NHMJL?opendocument>>
- Candy, P., "Self-Direction for Lifelong Learning: A Comprehensive Guide to Theory and Practice", *Jossey-Bass*, San Francisco, 1991.
- Criteria for Accrediting Engineering Programs, Effective for Evaluations During the 2003-2004 Accreditation Cycle, *Engineering Accreditation Commission, Accreditation Board for Engineering and Technology*, <<http://www.abet.org/criteria.html>>
- Felder, R.M., Brent, R., "Designing and Teaching Courses to Satisfy the ABET Engineering Criteria", *ASEE Journal of Engineering Education*, vol.92, no.1, January 2003, pp.7-25.
- Bloom, B.S., Karthwohl, D.R., Massia, B.B., "Taxonomy of Educational Objectives, Handbook 2, Affective Domain", *Addison Wesley*, New York, 1984.
- Bloom, B.S., "Taxonomy of Educational Objectives, Handbook 1, Cognitive Domain", *Addison Wesley*, New York, 1984.
- Schiavone, P., "Engineering Success", *Prentice Hall Engineering Source series*, 2nd ed., 2002.
- Learning Styles Inventory: <http://www.ncsu.edu/effective_teaching/ILSdir/ilsweb.html>.
- Jung Typology Test: <<http://www.humanmetrics.com/cgi-win/JTypes2.asp>>.
- Reverse engineering project: <<http://www.engr.sjsu.edu/nikos/courses/engr10/reversengr.htm>>.
- Estimation problems: <<http://www.engr.sjsu.edu/nikos/courses/engr10/fermi.htm>>.
- Aircraft design questions: <<http://www.engr.sjsu.edu/nikos/courses/ae170/exam.htm>>.
- Mourtos, N.J., Furman, B.J., "Assessing the Effectiveness of an Introductory Engineering Course for Freshmen", *Proceedings, ASEE/IEEE Frontiers in Education Conference*, 2002.