AC 2008-1884: A NEW TOOL TO ASSESS THE VALUE OF ACTIVE AND PROBLEM-BASED LEARNING IN ENHANCING ENGINEERING STUDENT SELF-EFFICACY

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A New Tool to Assess the Value of Active and Problem-Based Learning in Enhancing Engineering Student Self-Efficacy

Abstract:

Self-efficacy, or belief in one's own ability to learn, is a key predictor of success for engineering students. I have developed and evaluated a scenario-based, task-specific on-line assessment instrument, the Self-Efficacy Assessment Survey (SEAS), and evaluated its use for pre- and post-assessment of students in a first year Introduction to Engineering course. Through a combination of the SEAS and other quantitative and qualitative assessment tools, incorporation of problem-based and active learning activities are found to enhance student self-belief in their ability to learn engineering-related material and accomplish certain engineering-related tasks. Use of scenario-based questions to measure student confidence levels (as has been done in the SEAS) provides a unique mechanism to gain insight into student self-efficacy, though questions must be carefully designed to limit the impact of extraneous factors on student responses.

Background:

Engineering coursework has historically suffered from a perception of being rather uninteresting, mathematically weighty, and dominated by memorization of equations and rote theories. This perception has resulted in difficulties in recruiting underrepresented groups to the engineering field (and retaining them), and in motivating students and maintaining high retention rates in general, especially through the first two years of engineering education. This is especially true when course activities are not designed to enhance self-efficacy (defined as a student's ability to believe that he or she can play a leading role in building his or her own learning gains)[1]. In fact, belief in self has been shown to be the single greatest predictor of student success, especially in science, technology, engineering and mathematics (STEM), at all grade levels. Only after a strong belief in one's intelligence has been established do other factors become significant.[2]

Pedagogical development efforts for engineering coursework has in many cases lagged behind developments in other educational areas, and has not taken advantage of our increased understanding of student learning styles and of new techniques that are being employed to enhance student engagement in the humanities and in some natural sciences. However, recently (within the past 10 years) growing importance has been assigned to designing and implementing courses and programs that embody a more active and holistic approach to engineering education.

In addition to active learning approaches, it is equally important to develop methods for students to assess their own learning and, through survey and interview tools, to evaluate the impact of these courses and projects in enhancing student confidence in their ability to learn. The basis of evaluation is the degree to which students feel these courses enhance their views of lifelong learning, including providing them with the tools and self-efficacy to teach themselves, as well as the degree to which students understand how specific coursework contributes to a comprehensive approach to engineering problem solving. Hence, improved assessment, including self-assessment, better enables courses and programs to be optimized to meet STEM learning objectives.

Pedagogical methods that enhance student engagement (including problem-based learning, active learning, real-world examples, and hands-on applications) strongly support improvements in student self-belief. In particular, the adoption of active learning strategies in college science courses has been shown to enhance students' self efficacy.[3,4,5] Wilke found that incorporation of active learning into less than 50% of the total class periods for a physiology course for nonmajors, including group inquiry-based problem-solving activities, case studies accompanied by discussion, and various forms of written feedback, resulted in significant enhancement in student self-belief in learning abilities.[5] Student self-belief and confidence are also linked to the goals of willingness and ability to engage in life-long learning, which are key educational outcomes required by the accreditation process for university engineering programs (as delineated by ABET, the Accreditation Board for Engineering and Technology). In his 1991 book on lifelong learning, P. Candy concluded that self-belief and confidence in their learning ability helps students be proactive in assessing their own learning needs, and in acquiring information, guidance, and instruction that help meet those needs.[6] Clearly, a proactive, independent, and confident attitude will make lifelong learning a natural pursuit for the successful engineering student throughout his or her career.

1. Development of assessment tools:

Many assessment tools have been developed for undergraduate engineering courses and programs, many of them in response to the assessment and feedback loop requirements of the ABET guidelines for accreditation of engineering degree programs. The 2008-2009 ABET Accreditation Policy and Procedure Manual states that "Assessment is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes and program educational objectives."[7] Assessment should be designed to provide actionable feedback; in other words, the feedback provided should help program coordinators and instructors evaluate whether students are learning in agreement with the stated educational objectives of courses or programs. Self-assessment should be part of that process (in addition to general evaluation of student performance in problem-based tasks by the instructor and outside (objective) evaluations of student knowledge and understanding), since student perception of their own learning progress is a key factor in overall student success and retention.

Traditional assessment tools are often insufficient for evaluating something as difficult to clearly delineate as self-efficacy, so new tools must be used in addition to them. This is especially true as we incorporate active learning techniques and other methods (including real-world examples and new approaches such as studio methods) intended to enhance student comprehension of engineering and technology principles. Care must be taken, however, in development of assessment tools to ensure that they provide a meaningful measure of student learning. For example, Frank Pajares in "Self Efficacy Beliefs in Academic Settings"[8] writes:

> *"In many cases, the problem is one of mismeasurement of self-efficacy, a problem that has plagued research in this area... In part, the problem is this: Because judgments of self-efficacy are task and domain specific, global or inappropriately defined self-efficacy assessments weaken effects.*
> *Various researchers have assessed general academic self-perceptions of competence… The problem with such assessments is that students must generate judgments about their*

academic capabilities without a clear activity or task in mind. As a result, they generate the judgments by in some fashion mentally aggregating related perceptions that they hope will be related to imagined tasks. Domain-specific assessments, such as asking students to report their confidence to learn mathematics or writing, are more explanatory and predictive than omnibus measures and preferable to general academic judgments, but they are inferior to task-specific judgments because the subdomains differ markedly in the skills required."(p.547)

Thus, any assessment tool developed, if it is to be of value to both instructors and students, must include specific examples related to the skill set the course is intended to provide. I believe that student responses to these skill set-specific examples also reflect students' belief in their abilities to learn and solve problems in areas beyond traditional engineering applications.

2. Course Design to enhance student self-belief in learning ability:

There are many references regarding the value of problem-based, active learning environments for improvement of student comprehension and engagement.[9,10,11] The results of a recent study by Braxton, et al., suggest that development of an active learning approach in courses directly enhances student perception of learning gains, which in turn helps students to view their academic experience as more rewarding, and for a number of related reasons, enhances student retention.[12] My overarching premise in course design is that an active learning and problem-based learning approach, incorporating real-world examples and experiences, will enhance student self-efficacy.

Approximately eight years ago, a freshman level introductory course was developed for the Engineering Science (ESG) degree program at Stony Brook University (SBU) in order to better prepare students for upper level coursework and introduce them to both the nature of the coursework and the structure of the B.E. program itself. In recent years, active learning components have been developed and enhanced for this class, ESG100, "Introduction to Engineering Science". ESG 100 has evolved into a modular course, with four primary components/activities designed as follows:

- Skills for success in learning and living engineering:
    - The students read and discuss selections from the book "Stuff You Don't Learn in Engineering School" by Carl Selinger (IEEE Press/John Wiley and Sons, 2004). The module also includes lectures on the engineering programs at SBU, professionalism in engineering, and a discussion of skills for academic success in an engineering program.

- Team design project: Building a "mousebot"
    - This project requires students to work, in groups, from a set of instructions (which in fact have some omissions and lack some details which the students were required to find independently) to build a small light-sensing robot from a recycled computer mouse. The parts were very inexpensive, and students found some in discarded electronics. Certain aspects are completely left up to students' ingenuity and

development, such as the design of the wheels, the internal architecture of the "mousebot", and the design of the "drive train" and choice of materials for structural support and connections. With only a minimal introduction and some background on basic electronics, student teams need to master the required skills (including reading electronic schematics and "pin outs" (which they had to find independently on the internet); soldering; cutting and dremeling plastic parts; and assembly techniques). The final projects are shown as part of a "robotics day" event at the University, and students develop reports and reflection papers on the project.

- Research in engineering: The future of energy and building a gas fuel cell
  - This project required students, again in teams, to build a simple gas fuel cell using graphite electrodes in salt water. The cell could be "charged" with a nine volt battery, providing bubbles of hydrogen and chlorine adhering to the electrode surfaces which would then recombine driving the chemical reaction which provided a potential difference across the electrodes. Teams would modify the number and configuration of electrodes, as well as the solution chemistry, to try to develop higher or more persistent voltages, and finally prepare a report on their "research" and designs. A brief introduction to materials engineering is included in this module.

- Learning from engineering disaster
  - Students see films and read accounts of famous (and lesser known) catastrophic engineering failures and discuss the nature of the failure, the responsibility for and causes of the failure, and how engineered devices and systems can be better designed to avoid failure. The ethical implications of engineering failures are also discussed, and students individually research and report on a recent engineering failure (of their own choosing), providing a brief failure report and presentation.

Modules 2 and 3 (the "mousebot" and fuel cell) have been recently redesigned to expand the opportunities for active (hands-on) and problem based learning. For example, students are encouraged and directed to optimize the designs by customizing construction and materials, and a "studio" approach has been incorporated into nearly one quarter of the classes for the course. This allows student groups to freely explore ideas and develop skills with supervisory assistance from the professor and a teaching assistance. Student response to module 2, in particular, reflects improvements in "self-efficacy" brought about by this lesson module. Samples of responses to the "mousebot" project, excerpted from the final reflection papers, bear this out:

> *"Personally, it was the first time I had built a working robot and I'm glad we did it … we were able to see first hand the engineering design process at work. We also realized it's necessary to have broad knowledge in engineering and that working in groups can increase that knowledge so that you can successfully complete the task assigned to you." (male student, engineering science major)*

> *"I believe that it [the project] helped me develop skills in listening and voicing my opinion when I felt that I had something that could contribute to what we were doing." (male student, underrepresented ethic group, possible engineering major)*

"Many people had never soldered prior to this project, but now probably feel comfortable doing so." (female student, bioengineering major)

"The skills I learned I can use no matter what profession I decide to follow. This project gave me a chance to experience new things." (female student, non-engineering major)

"Basically before the project …I didn't believe we had the necessary skills to complete the project, but we somehow pushed through it and in the end I think we did much better than we thought we would have done." (male student, mechanical engineering major)

"It was a little hard to work as a team at first… we were all strangers to each other. Some of us were also strangers to the college environment…I learned about the tools I never knew how to use before that will in turn help me in my future. I also felt that by organizing meetings and work times that I got a taste of what life will be like after college in the real world … trying to get the project done." (male student, engineering science major)

"Something else I learned from doing this project was what exactly goes into making an electrical circuit. I've studied basic circuitry in my physics classes, but I never actually had a hands-on experience with building a practical circuit until now." (male student, engineering science major)

"This mousebot project was a lot harder than I thought it would be, but it was also a lot of fun and I learned a great deal from it. By the end of this project, I had this great feeling of pride and accomplishment. I was so proud that my group and I had created something that worked." (female, history major)

"I thought the "mousebot" project … would be nothing more than an easy "A" and I would not learn much from it; however, it turns out this project taught me more about engineering and design than I had ever known, and it especially taught me that hands-on experience doing a project is immeasurable in comparison to a homework discussing engineering principles." (male student engineering science major)

While evidence from reflection papers and student reports clearly provides one form of assessment concerning student perception of learning gains and confidence in their ability to meet learning objectives, use of an assessment tool which can provide numerical data on student perception of self-efficacy is needed.   Below we discuss results from a popular on-line assessment tool, the Student Assessment of Learning Gains, and a tool developed by the author, the Self-Efficacy Assessment Survey (SEAS), to see how such data can be developed and interpreted, and how this in turn leads us to improvements in the assessment tools themselves.

<u>Assessment tools used to evaluate Introduction to Engineering Science</u>

1. Student Evaluation of Instructor and Course

The “Student Evaluation of Instructor and Course” is a traditional “scantron” style assessment tool used to evaluate all couses at SBU for many years. This tool is primarily useful for evaluating student perceptions of instructor performance and their reactions to the coursework. Questions typically involve whether the instructor is prepared, clearly presents the topic, conveys enthusiasm, shows concern, makes objectives clear, holds office hours, gives appropriate assignments, and evaluates fairly. Students are asked for general comments on the course (what is good or bad about it) and whether they would recommend the course/instructor. While this is useful information, this tool has limitations. It is always applied at the end of a course, so changes in student perception are not considered (nor should they necessarily be for this type of evaluation). More importantly, it does not evaluate, except indirectly through comments, how students feel about how well they learned the material presented. Although we can use this student feedback method to recommend changes in teaching if there is a glaring deficiency, it has little use for judging student learning gains and perceptions of self-efficacy.

2. Student Assessment of Learning Gains (SALG):

Certain tools have been specifically developed to provide student self-assessment of learning gains in engineering coursework. One that has proved very useful for improving engineering coursework is the Student Assessment of Learning Gains (SALG) online survey. The SALG instrument was initially designed by Elaine Seymour (University of Colorado) in 1997 and has been modified and evaluated by a number of researchers over the past decade.[13] As stated on the SALG website at the Wisconsin Center for Education Research (which provides links to a number of assessment tools, primarily for science-based courses), the SALG is designed as a supplemental tool to traditional classroom evaluations. Its purpose is to provide faculty with “information about what students feel that they have gained from particular aspects of their classes, and from the class overall”. As in the case of the Student Evaluation of Instructor and Course scantron form described above, Seymour found that traditional institutional evaluations lacked specific information on student learning gains, except as inferred from answers to the few open-ended questions provided on the forms. Interviews with students confirmed the lack of correlation between students’ evaluation of their instructor’s preparation or performance and the amount of material they felt they had learned in the course or their general gains in skills and understanding.

The SALG post-assessment survey targets students’ self-belief in learning ability in a general way only, not through using task- or even discipline-specific examples. As the current version of the SALG (which is available online for instructors) offers great flexibility through user modification of the questions asked (i.e., it is designed to be adaptable for specific courses and materials), the SALG can be modified to assess student confidence and self-efficacy. In addition, by providing an online format with statistical reporting, the user can quickly see what students feel about the extent to which they have learned and met course objectives. In the following section (“Results from Survey Tools”), I provide data obtained from the pre- and post- SALG surveys I used with the Fall 2007 offering of Introduction to Engineering Science.

3. The Self-Efficacy Assessment Survey (SEAS)

As the unmodified SALG addresses general learning gains, I developed the SEAS to study the usefulness of incorporating STEM-specific scenarios that I believed would reflect student self-belief in their learning ability in science, technology, and mathematical areas. By using questions with a "clear task or activity in mind", as described in the quote from Pejares's study cited earlier in this manuscript, I hoped to avoid some of the "mismeasurement" issues for assessment of self-efficacy.[8] The majority of the questions (as shown in Table 4 in the following section) represent mini-scenarios or narratives that require the student to reflect on his or her willingness, confidence, or likelihood to acquire or use technical skills to solve a problem. I made the survey available to the students in an online format supported by the Blackboard software site used for the course. For each question, students chose a response based on a "likert" scale (measuring positive or negative response to a statement).[14] An example of a question with possible responses would be:

You want to transfer a film from your new digital video camera to your computer and email it to your relatives in a format they can view. How comfortable do you feel in figuring out how to do this (given some time with manuals, etc.)?

__ *very comfortable* __ *somewhat comfortable* __ *a little comfortable*

__ *not very comfortable* __ *not comfortable at all*

For purposes of statistical analysis, the student responses can be assigned values from 5 to 1, respectively.

Most scenarios were task-specific, except for a few that directly asked about students' confidence level in learning calculus, chemistry, and physics, and how confident they were that they understood the learning objectives of the program and could complete their degree program successfully in a timely fashion. While some specific scenarios could be directly correlated to material discussed in class, other scenarios were included in order to address general technical literacy issues or other concepts outside of the class learning objectives but which could be solved, if students were confident in their own ability to seek out additional information and help. The example given above is one such question. Another key difference between the surveys is that the SALG survey uses different pre- and post-course questionnaires, while the SEAS used the same questions for the pre- and post-test.

Both surveys (SALG and SEAS) include similar demographic data that can provide additional insight into the students' surveys and perhaps help to explain some aspects of the survey results. Both surveys were administered as both pre- and post-tests through anonymous online technologies using a password-protected method. Unfortunately, due to technical problems, the post-test for the SALG was only available to a small group of students, which strongly limits the statistical significance of changes to responses to questions from the pre-test.

Results from SALG and SEAS survey tools:

The following table summarizes data collected for ESG 100:

Data description	***Data type***	***Who is involved***	***Date of collection***	***Purpose***
Student Assessment of Learning Gains (SALG)	Pre-survey of student learning and self-efficacy	ESG 100 (59 first year university students, engineering interest) 55 responses	September, 2007 (completed)	Assess student self-efficacy prior to course
Self-Efficacy Assessment Survey (SEAS)	Pre-survey of self-efficacy	ESG 100 31 responses	September, 2007 (completed)	Assess student self-efficacy prior to course
Student Assessment of Learning Gains (SALG)	Post-survey of student learning and self-efficacy	ESG 100 6 responses	December, 2007 (completed)	Assess student self-efficacy following application of problem-based, active learning in course
Self-Efficacy Assessment Survey (SEAS)	Post-survey of self-efficacy	ESG 100 45 responses	December, 2007 (completed)	Assess student self-efficacy following application of problem-based, active learning in course
Survey of learning goals	Post-survey questionnaire	ESG 100 30 responses	December, 2007 (completed)	Assess whether learning goals of class were met
Student evaluation of instructor and course (SUNY survey)	SCANTRON evaluation of course	ESG 100 40 responses	December, 2007 (completed, data not to be available until mid-Spring)	Very general information on student impression of instructor and course

Table 1: Assessment data collection plan

Note that a significant amount of data cited in table 1 is still being analyzed. Further analysis of this data will be made available at the time of the ASEE national meeting.

The following tables provide a selection of questions and responses from the SALG survey for the Introduction to Engineering Science class. I modified the SALG (as much as possible within its given format) to address course-specific questions.

Presently, I am confident that I can understand (1=not confident/5=extremely confident) (55 responses) Mean score (standard deviation)

What an engineer is	3.85 (0.8)
How one becomes an engineer	3.67 (0.84)
The learning goals of the Engineering Science program	3.67 (0.93)
The interdisciplinary nature of modern engineering	3.65 (1.11)
How engineers think about problems	3.58 (1.03)
How engineers come up with new design concepts	3.33 (1.16)
The role of engineers in addressing societal issues	3.76 (1.02)
Some basic ways scientists and engineers solve problems	3.83 (0.95)
How technological developments are achieved	3.45 (0.98)
Articles in the media about new technological development	3.67 (0.96)
The importance of life-long learning	4.15 (0.91)
How engineers learn from mistakes	4.18 ((0.82)
The nature of engineering ethics	3.93 (0.9)
What it means to be a professional engineer	3.56 (1.01)

Table 2: Results of SALG pre-test

It is clear from the responses cited in table 2 that at the beginning of the course, students felt least comfortable with concepts of design, technological improvements, and (to a lesser extent) problem solving, and most comfortable with issues of lifelong learning and learning from mistakes and ethics (although there is a fairly large distribution in the responses). These results are particularly interesting, as the students' brief reflection papers at the end of the course on whether they felt the learning objectives were met indicated that they perceived the greatest learning gains in lifelong learning, ethics, learning from mistakes, as well as design. Thus the SALG's more general questions concerning what students think they know may be somewhat inaccurate and representative of the possible "mismeasurement" of self-efficacy identified earlier.

Although the SALG post-test results only reflected the views of a few students, a comparison of student confidence in skills developed appears to show mixed results in their areas of confidence (with significant improvement in problem solving skills, team work, and finding data in journals). Again, the low number of post-test SALG responses limits the usefulness of this data. The SALG study is being conducted again for a new course in order to analyze the effectiveness of the tool as a predictor of student gains in self-efficacy.

Presently, I am confident that I can (1=not confident/5=extremely confident)
Mean score (standard deviation)

Skill	**Pre-test results**	**Post-test results**
Solve problems	3.78 (0.9)	4.2 (1.1)
Write papers	3.84 (0.94)	3.8 (1.79)
Design experiments	3.24 (0.94)	4 (1.41)
Critically review articles	3.69 (0.96)	3.8 (1.79)
Work effectively with others	4.07 (0.92)	4.6 (0.89)
Find data or articles in journals or elsewhere	3.84 (0.9)	4.75 (0.5)
Take additional courses in this subject area	3.78 (1.03)	4.4 ((0.89)

Table 3: Results of pre-test (55 responses) and post-test (6 responses, due to technical difficulties), in SALG survey of skills gained

Finally, table 4 shows the pre-and post-course results for sample questions from the SEAS for the Introduction to Engineering Science first year course. As indicated, the average score for each question is shown, along with the standard deviation.

Average response (5= very comfortable/confident/likely; 4 = somewhat; 3 = a little; 2 = not very; 1 = not at all) and standard deviation on SEAS test

Question	**pre-test % (31 responses)**	**post-test % (45 responses)**
1. You want to transfer a film from your new digital videocamera to your computer and email it to your relatives in a format they can view. How comfortable do you feel in figuring out how to do this (given some time with manuals, etc.)?	4.46 (0.71)	4.63 (0.83)
2. You want to find a chemical repellant for ticks which contains the fewest hazardous chemicals. How confident are you that you can research the ingredients on the label and find out their possible health effects?	3.96 (0.80)	4.30 (0.72)
3. Certain materials for clothing can be damaged in a dryer. Your coat has a material listed on the label which you have never heard of, and no washing instructions. How likely are you to try to find out whether you can put your coat in the dryer (without destroying it) without just dropping it off at the dry cleaner (and hoping for the best)?	3.86 (0.93)	4.03 (1.02)
4. Your boss at the local convenience store asks for your help in trying to figure out why the laser scanner is not working right. This could involve working with a technician, going through the manual and testing the device and perhaps making adjustments. How comfortable are you with helping out in this situation?	4.23 (0.93)	4.03 (0.89)
5. You are reading the news on line and you see a story on a major bridge collapse in which people were killed. There is a link to a technical description of the bridge and how it might have failed. How likely are you to go to that link and read the information?	4 (1.11)	4.1 (1.06)
6. How comfortable would you be if your friend or family member asks you to give them a quick summary of the information on the bridge and explain to them what went wrong?	4.03 (1.03)	4.25 (0.94)
7. You are asked to write a paper on DNA sequencing for your biology or engineering class, and you must reference at least ten technical papers in journals in the library. How comfortable do you feel with this assignment?	3.46 (0.93)	3.83 (0.77)

8. Your alarm clock falls on the floor and stops working (you probably knocked it over so it would stop telling you to wake up!). How likely are you to try to fix it yourself? Assume you have a very limited budget.	3.8 (1.40)	4.23 (1.05)
9. Your cell phone falls on the concrete and the back flies off, battery falls out, etc. How likely are you to try to put it back together?	4.8 (0.40)	4.66 (0.65)
10. The phone no longer works. How likely are you to try to figure out what is wrong with it on your own?	3.74 (1.18)	3.85 (1.07)
11. Your PC has some sort of problem which is preventing it from communicating with your printer. How comfortable would you be with trying to troubleshoot the problem on your own?	4.33 (0.99)	4.30 (0.87)
12. You are asked to give a presentation in one week on how an ATM works. What is your reaction to this assignment?	3.76 (1.01)	3.98 (1.03)
13. You are asked to write a report for next week on the pros and cons of alternative energy sources. What is your first reaction?	4.02 (0.80)	4.44 (0.67)
14. You are asked to teach a middle school (5th or 6th grade) class about how technology can help doctors identify and treat illness. You have one week to prepare. How confident do you feel about doing this?	3.83 (0.82)	4.12 (0.87)
15. You are going for a job interview at a bank, and are told that they might ask some questions about your ability to learn their software and electronic filing system. How comfortable do you feel about that part of the interview?	4.06 (0.86)	4.10 (1.04)
16. How comfortable are you with your ability to learn calculus?	4 (0.98)	4.05 (0.97)
17. How comfortable are you with your ability to learn chemistry?	3.97 (0.92)	4.05 (0.80)
18. How comfortable are you with your ability to learn physics?	3.9 (0.99)	3.95 (1.12)
19. How comfortable do you feel that you know and understand what learning goals are expected of you in your degree program at Stony Brook University?	4 (0.79)	4.12 (0.71)
20. How comfortable do you feel that you will be able to graduate from Stony Brook University (in a reasonable amount of time) with a degree which includes math, science or technology coursework?	4.3 (0.87)	4.25 (0.89)

Table 4: Summary of SEAS responses

While statistical analysis indicates only one question with a "significant" difference in the means (a p value from an unpaired t test of less than 0.05) and two additional questions with nearly significant differences (p values between 0.05 and 0.07), the SEAS reveals some interesting trends that can be used both to understand student self-efficacy changes and to improve the assessment tool itself.

The question which showed a statistically significant increase in the mean value of response is number 13, asking students how comfortable they would feel faced with the prospect of having to prepair a report on alternative energy sources. There is a connection between the knowledge content represented by this question and the material taught in class, but the overlap is partial. The only "alternative" energy source discussed in class was the hydrogen fuel cell, so the question does represent an extension of student belief in their ability to research additional STEM information and prepare a report. The other two questions with responses indicating near significant increases (as determined by the t test with p values less than 0.07) are numbers 2 (researching the ingredients on the label of an insecticide to identify possible toxicity) and 7 (writing a paper on DNA sequencing which requires library research involving technical journals). In both cases, these are not specific tasks undertaken in class; however, the research activities in class (involving projects requiring research of technical causes of engineering failures and chemical processes occurring in a fuel cell) could help to generate the enhancement in confidence indicated.

While other responses do not show statistically large changes in student self-belief or comfort level, possible trends can be identified. As a group, the non-task-specific questions, concerning comfort with ability to learn foundation coursework for engineering (calculus, physics, and chemistry), show a small positive increase in students' confidence in their learning ability in these areas. No statistically significant trend is seen in responses to the last two questions, on comfort with knowing learning goals and graduating on time. This may reflect factors outside the course, including both exposure to a broad range of very difficult classes throughout the semester, as well as gaining an understanding of how naturally difficult coursework for an engineering degree may be.

For nearly all of the 15 "scenario" self-confidence questions, the results were showed small positive increases. Taken as a whole, this trend can be judged to be significant. Scenario questions involve students' self-confidence in the ability to explain an engineering failure, write a research paper (in an unfamiliar area), write a technical report, and research certain materials and prepare a lecture on technology for middle school students. These scenarios closely reflect some of the class activities, although each represents an extension of learned skills beyond what was done in class (especially in the case of teaching technology to middle school students). In retrospect, having additional questions/scenarios which directly address the course learning objectives would no doubt have been more useful in assessing student learning gains as well as student self-belief. The survey does appear to indicate increases in student self-efficacy and self-confidence in engaging in technical, engineering-related tasks following the course. However, the indications show some inconsistencies in correlating student perception of performance or eagerness to engage in diverse technical tasks to the learning goals of the class and the degree program.

Some questions showed little statistical variation in response, and some of these (in retrospect) appear to be "bad" questions. For example, questions involving repair of a cellular phone (question 9) or PC (question 11) likely do not reflect much change since there is probably a general sense that any complicated problem will be dealt with by warranty, etc. Also, simple issues concerning computers and even phones are likely to already be within the skill set of an average engineering college student, so assessing self-confidence for these scenarios might not be very useful. Finally, the most negative trend (the response that showed the largest drop in self-confidence) concerned comfort in helping to repair a piece of equipment (question 4). The responses might well reflect students' increased understanding of the complexity of electronics based on their experiences in class.

The demographics of the respondents should also be noted. For both the pre- and post-assessments, respondents were about 80% male, and about 75% intended to become or continue as engineering majors. Interestingly, the increase in respondents to the post-assessment was largely a result of greater numbers of students from Hispanic and Asian ethnicities responding to the post-assessment. There does not appear to be any clear reason for this difference.

Revisions of the SEAS

While the initial study involved survey questions of generalized tasks incorporating science, technology, engineering and mathematics, revisions are planned to include content that is more closely aligned with class activities. In this way, measurements of self-belief can be more closely correlated to actual content knowledge gained through the active learning methods used. For example, the SEAS will be used with a course in biologically inspired engineering design. The active content incorporated into the course will involve discussions of case studies in design as well as group inquiry-based problem solving activities in drawing ideas from nature for engineering designs. Hence an improved SEAS survey question (scenario) will directly address student comfort levels in their ability to understand how engineers can look to nature for design ideas to solve problems in a specific area (e.g. energy), whether or not that area is the exact problem area discussed in class. The new model for assessment can be described graphically as:

Learning goal → Knowledge content → Active learning approach → SEAS scenario

In addition to the scenarios created which directly analyze knowledge content gained, selected general SEAS scenarios (typical of the questions in table 4) can be retained. In this way, the assessment can test for self-confidence for learning and applying STEM knowledge as well as for knowledge and skills directly targeted in classroom activities. To aid in development of the SEAS for a particular course, a table with the four headings (learning goals/knowledge content/active learning approach/SEAS scenario) will be used. In addition to statistical design to acquire more significant data, this step will ensure that both general self-efficacy and specific course content are correlated and assessed.

Conclusions:

A new assessment tool, the Self-Efficacy Assessment Survey (SEAS) has been designed and evaluated. While statistical data analysis is still being conducted (and will be presented at the ASEE national meeting), a number of important conclusions can be reported:

i.) Both general student feedback (in reflection papers and comments) and self-assessment survey tools indicate that active learning, problem-based content in an introductory engineering course enhance student engagement. These activities also enhance student self-efficacy, particularly in task-specific areas closely related to course content.
ii) Use of scenario-based questions to measure student confidence levels (as has been done in the SEAS) provides insight into student self-efficacy. New SEAS survey scenarios will be designed to map more directly to course learning goals and active learning content.
iii) Relating responses to scenario-based, task-specific questions to overall self-efficacy gains in STEM areas requires careful design of questions to focus on effects which can be correlated to class activities. This is difficult as there can be many external factors (other academic as well as non-academic issues) that may play a role in determining student comfort and confidence in approaching engineering-related problem solving in the real-world. This, of course, is the primary challenge of assessment tool design efforts in general.
iv) Future work will address ongoing modification of survey questions to assess the impact of both course design as well as other factors which affect the complex issue of self-efficacy. Clearly, combinations of new online methods such as SEAS and the user-modified SALG which provide quantitative data with qualitative information from student reflection papers have provided the best insight so far into the correlation between course design and overall perceptions of student self-efficacy.
v) Finally, I have observed that there is a proportional tendency between the amount of assessment done and students' negative impression of the value of assessment ("assessment burnout"). This has taught me an important cautionary lesson for future assessment efforts. Also, the more "informal" and directly linked to classroom activities an assessment method is, the less likely the tendency for students to find it to be annoying or useless, and hence more useful the assessment tool.

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