AC 2010-774: APPLICATIONS AND CONFIDENCE INVENTORIES FOR ASSESSING CURRICULAR CHANGE IN INTRODUCTORY ENGINEERING MATHEMATICS INSTRUCTION

Lisa Schneider, Cornell University

Lisa Schneider has been the Director of Engineering Learning Initiatives in Cornell University's College of Engineering since December 2002. Learning Initiatives' programs enhance the educational environment of the College by providing opportunities for collaborative learning, undergraduate research, teaching skill development, peer instruction, and leadership development. Schneider received her PhD in Sociology from Cornell in 1997. Before taking this position, she taught Sociology as an assistant professor at Hobart and William Smith Colleges from 1997-1999, and then served for three years as Senior Director of Research and Evaluation at PowerUP, a national nonprofit organization dedicated to expanding technology access and providing youth development resources for underserved youth.

Maria Terrell, Cornell University Math Dept.

Applications and Confidence Inventories for Assessing Curricular Change in Introductory Engineering Mathematics Instruction

Abstract

This project stems from a collaborative effort by engineering and mathematics faculty at a research university to enhance engineering students' abilities to transfer and apply mathematics to solve problems in engineering contexts. A recent curriculum innovation resulting from these efforts involves the integration of collaborative, applied, problem-solving workshops into the first-semester engineering mathematics course. This paper will summarize the project team's work to develop two instruments - one to gauge students' abilities in using mathematics in engineering contexts; and the other to gauge students' self-efficacy perceptions related to studying engineering and to learning and applying mathematics – that can be used to assess the effects of this innovation and others like it. The paper will report on the processes being used to develop and adapt the two instruments, the Mathematics Applications Inventory (MAI) and the Engineering and Mathematics Perceptions Survey (EMPS). The project is funded by the National Science Foundation, Directorate of Education and Human Resources, Course, Curriculum, and Laboratory Improvement (CCLI) Program, Grant # DUE-0837757.

The paper will also report the preliminary results of the pilot administration of both instruments in Fall 2009. A sample of first-year engineering students responded to the online EMPS instrument, completed an initial open-ended version of the MAI, and participated in in-depth interviews about their responses to the MAI. The paper will include preliminary analyses of the resulting data, including associations between EMPS responses and MAI performance, patterns in students' responses to the problems on the MAI, common areas of difficulty related to the application of specific mathematical topics, and patterns of responses and performance by other background and status variables such as gender, race, SAT scores, and level of mathematics preparation.

Forthcoming project work includes the use of data from the pre-test and post-test pilot administrations and the in-depth student interviews to inform the development of the MAI into a multiple-choice inventory and to inform any necessary revisions of the EMPS. Administration of both inventories to the full class of first-year engineering students is scheduled for Fall 2010. Findings will be used to help assess the effect that integrating collaborative, applied, problem-solving workshops into the first-semester engineering mathematics course has on students' abilities and attitudes about using mathematics. It is also intended that the resulting developed, tested, and validated instruments will be appropriate for the assessment of related innovations in engineering and mathematics instruction at other institutions.

Goals and Objectives

The aim of this project is to assess the effects of integrating engineering applications into core mathematics courses for engineers. We expect this innovation will 1) enhance students' *understanding* of mathematics as representative of physical phenomena and their *skill* applying mathematics to solve problems involving physical quantities and relationships; and 2) enhance students' *confidence* about their understanding of mathematics and their ability to use mathematics to succeed in engineering.

The challenges of assessing learning outcomes in education in general are significant, if not daunting. Over the past decade engineering educators have developed a framework for defining the notion of "learning outcomes" and have established a list of eleven learning outcomes essential for ABET accreditation. The first of those outcomes, which addresses the basic scientific knowledge needed by engineers, includes: *An ability to apply knowledge of mathematics, science and engineering.* The emphasis of this outcome is on:

> *Formulation and solution of mathematical models describing the behavior and performance of physical, chemical, and biological systems and processes; and use of basic scientific and engineering principles to analyze the performance of processes and systems.* (Besterfield-Sacre et al., 2000)

Central to the framework is the understanding that true learning cannot be measured without observable behavior. Each learning outcome must reflect the integration of the cognitive and the behavioral – the knowing and the doing.

Further, research has shown that what students think about their learning experiences (attitudinal outcomes) is also a critical component in understanding student performance, especially in the first year (Besterfield-Sacre, Atman, and Shuman, 1997; Besterfield-Sacre, Moreno, Shuman, Atman, 1999; Hutchison-Green, Follman and Bodner, 2008; Hutchison et al., 2006). Our goal is to develop two instruments to assess the student learning and attitudinal outcomes resulting from innovations in content and teaching methodology in our first year calculus courses for engineers. The instruments will be designed to gather data on 1) students' *abilities* to apply mathematics to represent physical quantities and relationships, both before and after their participation in the problem-solving workshops; and 2) students' *confidence* in their abilities to successfully use mathematics to represent physical quantities and relationships, both before and after their participation in the problem-solving workshops.

The need for research on, and development of, assessment instruments and metrics to inform engineering education practice has been well documented. In 2006, the Engineering Education Research Colloquies (EERC) presented five research areas to serve as the foundation for the new discipline of Engineering Education (Steering Committee of the National Engineering Education Research Colloquies, 2006a, 2006b). Our evaluation of this curricular change will contribute to three of those areas: Engineering Learning Mechanisms, Engineering Learning Systems, and Engineering Assessment.

Engineering Learning Mechanisms: We are eager to gain insight into how engineering students develop problem solving competencies in the context of mathematical modeling. The questions we will investigate related to this area are:

1) What experiences with engineering applications of mathematics, or mathematical modeling in general, do students have before they enter college? What is their level of cognition (that is, the ability to understand and use abstraction), mathematical skill, and confidence at entrance?

2) Does regular participation in problem solving engineering applications workshops enhance students' *understanding* of mathematics as representative of physical phenomena and their *skill* applying mathematics to solve problems involving physical quantities and relationships?

Engineering Learning Systems: We are eager to learn about the effect that instructional culture has on student learning, retention and transfer of knowledge within the engineering curriculum. The third question we are interested in exploring is:

3) Does regular participation in collaborative engineering applications workshops enhance students' confidence about their understanding of mathematics and their ability to use mathematics to succeed in engineering?

Engineering Assessment: The main work of this project will be to produce two assessment instruments to measure the effects of our curriculum innovation on engineering students' abilities and confidence in applying mathematics to physical phenomena and problem-solving. Our aim is to develop instruments that can be widely used to inform approaches to mathematical instruction for engineering students and to ultimately improve the effectiveness of engineering educational practice.

Related studies have demonstrated the benefits of integrating math, science, and engineering instruction in the early years of the engineering curriculum (Carr, 2003; Froyd and Ohland, 2005; National Academy of Engineering, 2005; Olds and Miller, 2004), of providing active, collaborative learning environments in engineering courses (Felder, Felder and Dietz, 1998; Johnson, Johnson and Smith, 1998a, 1998b; Prince, 2004; Springer, Stanne and Donovan, 1999; Terenzini et al., 2001), of attending to student attitudes and beliefs regarding their own ability to succeed in engineering (Besterfield-Sacre, Atman, and Shuman, 1997; Besterfield-Sacre, Moreno, Shuman, Atman, 1999; Hutchison-Green, Follman and Bodner, 2008; Hutchison et al., 2006; McKenna and Hirsch, 2005; Ponton et al., 2001), and of improving mathematics instruction by attending to students' understanding of central concepts (Bingolbali, Monaghan and Roper, 2007; Epstein, 1997; Ferrini-Mundy and Graham, 1991; Schoenfeld, 1997). We plan to add to this research base on the effects of curriculum innovation on student learning outcomes, and to provide tools to improve our collective ability to specify, detect, and understand those outcomes.

Local Background

Entering engineering students at our university have median SAT Math scores of approximately 750 and Verbal scores of approximately 685. Credit for the equivalent of first semester calculus is expected at entrance (i.e., the equivalent of a 4 or 5 on the AB Advanced placement examination). The first mathematics course for half of the entering class is the equivalent of second semester calculus, for the other half it is multivariable/vector calculus or higher. By all the usual measures we have a very able and motivated group of students. Yet engineering faculty at our institution have reported consistently that students in introductory engineering courses have difficulty using even elementary mathematics to represent quantities and relationships between them. This inability to use the mathematics that they have apparently learned has been all the more perplexing since the core engineering mathematics courses are taught jointly by mathematicians and faculty in engineering.

We believe this mismatch between students' apparent background and their depth of understanding and ability to apply concepts to new problem situations is by no means unique to our institution. Many schools face it, and some new understanding of why this is happening, and some evaluation of whether a particular intervention improves things, will have wide implications nationally.

In 2006 the Dean of the Engineering College at our institution formed a Curriculum Task Force. The task force was charged with developing recommendations for changes in the college's core curriculum that would reflect and implement the Undergraduate Studies Objectives of the college:

- Enhance the undergraduate educational environment and experience.
- Enhance the engineering undergraduate curriculum and implement procedures for assessment and change.
- Become a leader in the education of women and underrepresented minority engineers.

As the result of the task force's work, the faculty of the College of Engineering voted in 2006 to adopt curriculum reform efforts that had as a primary objective to link first year core courses in mathematics and physical sciences with engineering applications. In Spring 2007 the Department of Mathematics curriculum committee, in cooperation with faculty and administrators from Engineering, approved a plan to infuse first semester engineering mathematics with collaborative, problem-solving workshops. The first set of materials was written by teams of engineers from across the college and by pure and applied mathematicians.

In the Fall 2007 pilot implementation effort, applied problem-solving was integrated into the first course in the required engineering math sequence by transforming one of the two weekly teaching assistant-led recitation sections into a collaborative problem-solving workshop. All sixteen sections of the course received the workshop innovation. As such, all 392 students enrolled in the course participated in the workshops. The problems for the workshops were developed by engineering faculty teaching the 200-level engineering courses in which basic calculus is routinely applied, and then reviewed and revised by a liaison committee of mathematics and engineering faculty. The workshops were facilitated by the section teaching assistants along with upper-class undergraduate engineering students serving as course assistants. The teaching assistants and course assistants received training on facilitating active, collaborative problem-solving. The training was developed and led by engineering faculty and staff, drawing on other successful collaborative learning efforts in the college.

In the workshops students are instructed to work in groups on the applied problems. Teaching assistants and course assistants facilitate the group work and provide guidance where necessary. Students are encouraged to discuss and grapple with the problems together with their group members and to help each other to collectively reach a solution.

Based on the initial evaluation of this pilot semester we recognized the need to both revise some of the materials and to conduct a more careful assessment of the effect on students' confidence and ability to use the mathematics they were learning. During the summer of 2008 designated engineering and mathematics faculty members worked together to revise the workshop problems in response to evaluation findings. The bulk of the revisions involved clarifying the problem descriptions and instructions, providing stronger ties to course material, and shortening problems so that they could be completed within the fifty-minute workshop sections.

After the Fall 2008 implementation of the workshops, evaluation feedback reflected the positive effect of those revisions. However, feedback also indicated that the workshop schedule was still too ambitious – suggesting that fewer problems should be assigned per workshop and that fewer workshops should be scheduled per term. Further refining of the materials by the mathematics course staff prior to the Fall 2009 implementation primarily involved selecting the best problems to use for a scaled back workshop schedule, involving nine workshops per semester rather than fourteen, and one problem per workshop rather than two.

During the Fall 2009 semester we ran a pilot pre- and post-test administration of the first draft of both assessment instruments – one measuring students' abilities to use mathematics in applied problem-solving (MAI); and the other to gauge students' self-efficacy perceptions related to studying engineering and to learning and applying mathematics (EMPS). The instrument development and pilot-test administration processes are described in the following sections.

Instrument Development:

Mathematics Applications Inventory (MAI)

The Mathematics Applications Inventory, MAI, is intended to measure the level at which first year undergraduate engineering students can apply basic mathematical tools for expressing rate of change (variable and constant-ratios and derivatives) and accumulation (finite sums of products or infinite sums of products-definite integrals) in physical contexts. The key mathematical concepts for the MAI were identified through a modified "Delphi study" of elementary mathematics applications in engineering courses involving faculty from across all engineering and physical science disciplines at Cornell. Based on that study, and in consultation with experts in mathematical diagnostic testing and educational assessment instrument validation, test items were developed.

The initial set of test items includes five open ended questions with a total of 11 sub-questions. Student responses to the open ended questions will be used to refine the questions and to develop a set of distracters for the multiple choice version of the instrument. The questions are intended to be accessible to students who have completed the equivalent of first semester single variable differential and integral calculus, equivalent to an AB advanced placement course, in high school. The questions focus primarily on applications in which the independent variable is not time. This was a necessary consequence of avoiding applications which were too similar to Advanced Placement test problems. The MAI questions are designed to be more conceptual and less computational, although some questions do require some elementary computations. The mathematical concepts represented on the MAI from pre-calculus are average of numbers, average rate of change, fractional change, reasoning from and about graphs/graphical displays, asymptotic behavior, signed numbers (arithmetic with positive and negative numbers). The mathematical concepts from introductory calculus include the derivative, the definite integral, the fundamental theorem of calculus.

A more detailed description of the MAI development process can be found in the forthcoming paper dedicated to the topic, *Assessing Engineering Students' Ability to Use the Mathematics They Have Learned* (Terrell, Terrell, and Schneider, 2010).

Engineering and Mathematics Perceptions Survey (EMPS)
The Engineering and Mathematics Perceptions Survey, EMPS, is intended to measure the confidence of first year undergraduate engineering students in their abilities to do well in mathematics courses, to apply the mathematics they have learned to solve word problems, and to succeed in the engineering curriculum. It also is intended to measure students' sense of positive connection to other engineering and university students, and the value students place on learning mathematics. The EMPS is adapted from the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument developed as part of the NSF-funded Assessing Women in Engineering (AWE) project (Assessing Women in Engineering (AWE) Project, 2007).

The LAESE was designed to measure undergraduate students' self-efficacy related to succeeding in the engineering curriculum, as well as feelings of inclusion in the academic environment, ability to cope with setbacks or challenges related to the college environment, and expectations about engineering career success and math outcomes. The original use of the instrument was focused on self-efficacy among undergraduate women engineering students, and specifically on the relationship of self-efficacy and the other related constructs to students' persistence in engineering (Marra et al., 2004). Following its development in 2003, the LAESE was used as the primary instrument for a longitudinal multi-institution study of self-efficacy among male and female engineering students at five institutions across the United States. Validity and reliability were analyzed for all items and subscales and found to be acceptable (Marra and Bogue, 2006; Marra et al., 2007).

For our purposes, we retained four of the six subscales included in the LAESE instrument: engineering self-efficacy I (five items), engineering self-efficacy II (six items), feelings of inclusion (four items), and math outcomes expectations (three items). We created our own subscale intended to measure math applications self-efficacy (three items). We also retained LAESE items asking students their perceptions about the amount of work required to get the grades they want in college versus the amount of work required to get the grades they wanted in high school, and about their confidence that they will complete an engineering degree. For the post-test survey (administered in the final week of the semester), we added a question asking students to estimate the final grade they expect to receive in their first-semester math course, and to rate how confident they are about their estimate.

Pilot-test administration

For the Fall 2009 pilot-test administration we obtained a sample of first-year engineering students enrolled in the first-semester engineering calculus course, *Calculus for Engineers.*

Students in this course would be participating in the collaborative, applied problem-solving workshops throughout the semester. As a control group, we also obtained a sample of first-year engineering students who already had credit for the first calculus course (through AP or advanced course credit), and thus were immediately entering the second course in the engineering calculus sequence, *Multivariable Calculus for Engineers*. This course does not have a collaborative, applied problem-solving component.

Of the 322 first-year engineering students enrolled in *Calculus for Engineers* we generated a random sample of 50 students and supplemented that with a purposive sample of 21 additional students selected to ensure a strong representation of female and underrepresented minority students (Black, Hispanic, and Native American) and students with lower math SAT scores. Of the 353 first-year engineering students enrolled in *Multivariable Calculus for Engineers* we used the same procedures to generate a random sample of 50 students and to supplement that with a purposive sample of 21 additional students selected to ensure a strong representation of female students, underrepresented minority students, and students with lower math SAT scores.

In the first week of Fall 2009 semester classes the students in the samples were contacted via e-mail. We described the project and invited them to participate. They were asked to first complete the online EMPS. Those who submitted their online EMPS responses were then e-mailed the location for the written MAI administration. Sample members were offered $20 for the completion of both the EMPS and the MAI. Of the 142 sample members, 75 completed the online EMPS pre-test. Of those, 51 showed up to take the written MAI pre-test.

The MAI responses were reviewed immediately after the test administration, and 14 of those who took the MAI were asked to attend a one-on-one interview with one of the researchers about the MAI items and their responses. The interviews were completed 48-72 hours after the MAI administration. In the interviews, students were asked four questions about each of the MAI items:

1) How confident were you in your response to this question?

2) Is this question similar to problems you have solved in some other setting? If yes, please describe the setting.

3) Talk me through your answer to this question.

4) Did you have other ideas about how to solve the problem that you did not write down?

Pre-test respondents were asked to complete the instruments again in the last week of the Fall 2009 semester. Those who had completed the MAI pre-test were asked to again complete the online EMPS and the written MAI post-test, and were offered $30 for their post-test participation. Those who had only completed the online EMPS during the pre-test were asked to respond to the online EMPS post-test, and were offered $10 for their post-test participation. Of the 51 students who had completed both the EMPS and MAI pre-test, 35 fully participated in the post-test, again completing both the EMPS and MAI post-test. Seven others from that group completed only the EMPS post-test and did not show up for the MAI post-test. Of the 24 who had completed only the EMPS pre-test, 12 completed the EMPS post-test. Thus, 54 of the initial 75 EMPS respondents completed the EMPS post-test; 35 of the initial MAI respondents completed the MAI post-test.

Preliminary Results

Preliminary analyses of the quantitative data included exploring the associations between EMPS responses and MAI performance, changes from pre- to post-test administration, and patterns of responses and performance by other background and status variables such as gender, race, SAT scores, and level of mathematics preparation. The relatively low numbers of respondents for the Fall 2009 pilot inhibit meaningful comparisons by gender and race. However, some significant differences by course in the factors associated with MAI performance are observed. For these analyses, we are comparing those enrolled in Math 1910, *Calculus for Engineers*, the first course in the engineering mathematics sequence, and the one which includes engineering mathematics workshops integrated into the course, with those enrolled in Math 1920, *Multivariable Calculus for Engineers*, the second course in the sequence, which does not include workshops.

Tables 1 reports demographic frequencies, by gender and by racial/ethnic status, for the two samples, with respondents grouped by course enrollment. Table 2 illustrates the distribution of scores, by course, for the variables we focus on in these preliminary analyses.

Table 1: Demographic Frequencies by Course

	Math 1910 Respondents		**Math 1920 Respondents**	
	Frequency	Percent	Frequency	Percent
Male	23	59%	22	62.9%
Female	16	41%	13	37.1%
Total	39	100%	35	100%
White	12	30.8%	15	42.9%
Asian	10	25.6%	7	20%
Hispanic	8	20.5%	6	17.1%
Black	4	10.3%	2	5.7%
International	2	5.1%	2	5.7%
Native American	1	2.6%	1	2.9%
Not Reported	2	5.1%	2	5.7%
Total	39	100%	35	100%

Table 2: Scores Distributions by Course

	N	Minimum	Maximum	Mean	Std. Dev.
SAT Math - 1910	39	640	800	725.90	48.92
SAT Math - 1920	**35**	**580**	**800**	**739.43**	**63.94**
SAT Math 2 - 1910	33	600	800	738.18	62.27
SAT Math 2 - 1920	**32**	**600**	**800**	**735.94**	**63.85**
SAT Phys - 1910	18	580	800	699.44	68.47
SAT Phys - 1920	**15**	**640**	**800**	**742.67**	**57.63**

Pre MAI score - 1910	28	.00	10.00	5.57	2.76
Pre MAI score - 1920	**22**	**2.00**	**11.00**	**6.84**	**2.52**
Pre Eng Self-Eff I - 1910	38	2.00	7.60	5.61	1.11
Pre Eng Self-Eff I - 1920	**35**	**3.80**	**7.40**	**5.95**	**.860**
Pre MathApp Self-Eff I - 1910	37	4.33	7.00	5.95	.626
Pre MathApp Self-Eff I - 1920	**35**	**4.00**	**8.00**	**6.23**	**.903**
Post MAI score - 1910	18	3.00	11.00	6.14	2.01
Post MAI score - 1920	**16**	**2**	**11**	**8.06**	**2.75**
Post Eng Self-Eff I - 1910	29	2.20	6.40	4.73	1.14
Post Eng Self-Eff I - 1920	**24**	**2.60**	**7.00**	**5.50**	**1.12**
Post MathApp Self-Eff I - 1910	27	2,67	7.00	5.36	1.07
Post MathApp Self-Eff I - 1920	**24**	**3.00**	**7.00**	**5.83**	**1.00**
Final Grade – 1910	29	.00	4.30	2.67	1.07
Final Grade - 1920	**24**	**1.00**	**4.30**	**2.77**	**.980**

Tables 3 and 4 report the relevant correlation coefficients to demonstrate some interesting differences observed by course and from pre-test to post-test. Two interesting preliminary findings emerge. One involves the association between pre-college performance on relevant SAT tests with performance on the MAI. The other involves the association between students' self-efficacy perceptions regarding their ability to succeed in engineering and mathematics with their performance on the MAI.

Table 3: Math 1910 students: Correlations with MAI performance

	MathSAT	**Math2SAT**	**PhysSAT**	**Engineering SelfEff I**	**Math App SelfEff**	**Final grade**
Pre-test	.341 (28)	.392 (24)	.700** (13)	.316 (28)	-.086 (28)	NA
Post-test	.113 (18)	.333 (15)	.202 (7)	.587** (18)	.539* (17)	.511* (18)

Pearson correlation coefficients are reported.
N for each cell appears in parentheses.
*Correlation is significant at the .05 level (2-tailed)
** Correlation is significant at the .01 level (2-tailed)

Table 4: Math 1920 students: Correlations with MAI performance

	MathSAT	**Math2SAT**	**PhysSAT**	**Engineering SelfEff I**	**Math App SelfEff**	**Final grade**
Pre-test	.435* (22)	.510* (20)	.395 (13)	.176 (22)	-.067 (22)	NA
Post-test	.739** (16)	.768** (14)	.717 (7)	.148 (16)	.034 (16)	.834** (16)

Pearson correlation coefficients are reported.
N for each cell appears in parentheses.
*Correlation is significant at the .05 level (2-tailed)
** Correlation is significant at the .01 level (2-tailed)

When considering the observed differences in the effect of SAT test performance, it is important to remember that, on average, students enrolled in Math 1910 have a lower level of pre-college mathematics preparation relative to those enrolled in Math 1920. For 1910 students, performance on the Physics SAT test is significantly correlated with performance on the MAI at pre-test, but not at post-test. For this group, performance on Math SAT tests is not significantly correlated with MAI performance at either time. On the contrary, for those enrolled in Math 1920, performance on the Math SAT and the Math2 SAT is significantly correlated with MAI performance at both pre- and post-test, while performance on the Physics SAT is not significantly correlated.

While those differences in associations with SAT test performance for the two groups are presumably highlighting differences in preparation and experience, the observed relationships between self-efficacy perceptions and MAI performance appear to be indicating differences by course in the alignment of students' perceptions of their abilities with their actual performance. For the students in Math 1910, who are experiencing the collaborative, problem-solving, engineering math workshops throughout the semester, their perceptions of their own abilities to successfully apply mathematics to solve problems becomes more aligned with their actual ability to do so, as demonstrated by the positive and significant correlation between the math applications self-efficacy measure and their MAI performance at post-test. Their overall engineering self-efficacy follows suit, also exhibiting a positive and significant correlation with MAI performance at post-test. These associations are not present at pre-test. For the students in Math 1920, associations between self-efficacy perceptions and MAI performance are not present at pre-test, and are still non-existent at post-test. This change over the course of the semester, for the 1910 students, in the alignment of students' perceptions of their abilities with their actual performance, suggests that the workshops in Math 1910 may be enhancing students' awareness of their own learning, and of what is involved and what will be required of them in relation to "applying mathematics" and "succeeding in engineering." The experience is perhaps providing students a realistic picture of what will be required of them as an engineering student and where they stand in relation to those requirements. This preliminary finding will certainly be further explored in the coming terms.

The correlations between MAI performance and final course grade for both courses are also instructive. This will be explored further to determine the extent to which the MAI is capturing the same problem-solving abilities that are required to do well in the course, versus the extent to which the MAI focus on applications measures problem-solving abilities that are distinct from the abilities required to perform well in the course.

Next Steps

Using findings about student performance on the MAI, patterns of understanding and misunderstanding of the items, and common errors – both from the pilot test responses to the open-ended MAI and from the one-on-one student interviews - refinement of the MAI questions and the development of the instrument into a multiple-choice inventory was accomplished. This process will be more fully documented in the forthcoming paper, *Assessing Engineering Students' Ability to Use the Mathematics They Have Learned* (Terrell, Terrell, and Schneider, 2010).

The multiple-choice version of the MAI and a slightly revised version of the EMPS are being administered in Spring 2010 to approximately 350 students enrolled in Math 1920 (almost all of whom were in the Fall 2009 Math 1910 class). The greater numbers of respondents expected during Spring semester will allow a fuller assessment of the validity and reliability of the instrument items and subscales to be performed. Findings will inform instrument revisions and refinement before a full administration to the entering class of engineering students in Math 1910 and 1920 will be implemented in Fall 2010.

The more comprehensive data obtained during Fall 2010 will be used to help assess the effect that integrating collaborative, applied, problem-solving workshops into the first-semester engineering mathematics course has on students' abilities and attitudes about using mathematics. It is also intended that the resulting developed, tested, and validated instruments will be appropriate for the assessment of related innovations in engineering and mathematics instruction at other institutions.

References

Assessing Women in Engineering (AWE) Project. 2007. Longitudinal Assessment of Engineering Self-Efficacy (LAESE) instrument. AWE Survey Instruments. Retrieved August 2009 from http://www.engr.psu.edu/awe/secured/director/diversity/efficacy.aspx .

Besterfield-Sacre, M.E., C.J. Atman and L.J. Shuman. 1997. Characteristics of Freshman Engineering Students: Models for Determining Student Attrition and Success in Engineering. *Journal of Engineering Education*, 86(2), 139-149.

Besterfield-Sacre, M. E., M. Moreno, L. J. Shuman, C. Atman. Comparing Entering Freshman Engineers: Institutional Differences in Student Attitudes. 1999. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, June 1999.

Besterfield-Sacre, M. E., L. J. Shuman, H. Wolfe, C. Atman, J. McGouty, R. L. Miller, B. Olds. 2000. Defining the Outcomes: A Framework for EC- 2000. *IEEE Transactions on Education*, 43 (2): 100-110.

Bingolbali, E., J. Monaghan, and T. Roper. 2007. Engineering students' conceptions of the derivative and some implications for their mathematical education. *International Journal of Mathematical Education in Science and Technology* 38 (6): 763-777.

Carr, S.H. 2003. Engineering First at Northwestern University: Where are we in 2003? *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, June 2003.

Epstein, J. 1997. Cognitive Development in an Integrated Mathematics & Science Program. *Journal of College Science Teaching*, 27: 194–201.

Felder, R. M., G. N. Felder and E. J. Dietz. 1998. A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students. Journal of Engineering Education, 87 (4): 469-480.

Ferrini-Mundy, J. & K. G. Graham. 1991. Research in Calculus Learning: Understanding of Limits, Derivatives and Integrals, in Kaput & Dubinsky (eds.).

Froyd, J.E. and M.W. Ohland. 2005. Integrated Engineering Curricula. *Journal of Engineering Education*, 94 (1): 147-164.

Hutchison-Green, M. A., D. K. Follman, and G. M. Bodner. 2008. Providing a Voice: Qualitative Investigation of the Impact of a First-Year Engineering Experience on Students' Efficacy Beliefs. *Journal of Engineering Education* 97 (2): 177-190.

Hutchison-Green, M. A., D. K. Follman, M. Sumpter, and G. M. Bodner. 2006. The factors affecting first-year engineering students' self-efficacy beliefs. *Journal of Engineering Education* 95 (1): 39-47.

Johnson, D., R. Johnson and K.Smith. 1998a. *Active Learning: Cooperation in the College Classroom,* 2nd ed. Edina, MN: Interaction Book Co.

Johnson, D., R. Johnson and K.Smith. 1998b. Cooperative Learning Returns to College: What Evidence is There That it Works? *Change,* 30 (4): 26-35.

Marra, R. M., C. Moore, M. Schuurman, B. Bogue. 2004. Assessing Women in Engineering (AWE): Assessment Results on Women Engineering Students Beliefs. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, 2004.

Marra, R. M. and B. Bogue. 2006. Women Engineering Students' Self Efficacy – A Longitudinal Multi-Institution Study. *Proceedings of the Women in Engineering Programs and Advocates Network (WEPAN) Conference*, 2006.

Marra, R.M., B. Bogue, K. Rodgers, and D. Shen. 2007. Self Efficacy of Women Engineering Students? Three Years of Data at U.S. Institutions. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, 2007.

McKenna, A. F. and P. Hirsch. 2005. Evaluating Student Confidence in Engineering Design, Teamwork and Communication. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* 2005.

National Academy of Engineering. 2005. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, D.C.: National Academies Press.

Olds, B. M. and R. Miller. 2004. The effect of a First-Year Integrated Engineering Curriculum on Graduation Rates and Student Satisfaction: A Longitudinal Study. *Journal of Engineering Education* 93 (1): 23-35.

Ponton, M. K., J. H. Edmister, L. S. Ukeiley, and J. M. Seiner. 2001. Understanding the role of self-efficacy in engineering education. *Journal of Engineering Education* 90 (2): 247-251.

Prince, M. 2004. Does Active Learning Work? A Review of the Research. *Journal of Engineering Education,* 93 (3).

Schoenfeld, A.H. 1997. Student Assessment in Calculus. *Report of the NSF Working Group on Assessment in Calculus*, MAA Notes (43).

Springer, L., M. Stanne and S. Donovan. 1999. Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering and Technology: A Meta-Analysis. *Review of Educational Research,* 69 (1): 21-52.

Steering Committee of the National Engineering Education Research Colloquies. 2006a. The National Engineering Education Research Colloquies. *Journal of Engineering Education* 95 (4): 257-258.

Steering Committee of the National Engineering Education Research Colloquies. 2006b. The Research Agenda for the New Discipline of Engineering Education. *Journal of Engineering Education* 95 (4): 259-261.

Terenzini, P., A. Cabrera, C. Colbeck, J. Parente and S. Bjorklund. 2001. Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains. *Journal of Engineering Education*, 90 (1): 123-130.

Terrell, M., R. Terrell, and L. Schneider. 2010. Assessing Engineering Students' Ability to Use the Mathematics They Have Learned. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, June 2010 (forthcoming).

My motivation for writing the first edition of Introductory Econometrics: A Modern Approach was that I saw a fairly wide gap between how econometrics is taught to under-graduates and how empirical researchers think about and apply econometric methods. I became convinced that teaching introductory econometrics from the perspective of pro-fessional users of econometrics would actually simplify the presentation, in addition to making the subject much more interesting. Based on the positive reactions to earlier editions, it appears that my hunch was cor-rect.