USING FUNDAMENTAL SKILLS EXAMS IN CORE TECHNICAL CLASSES AT THE UNITED STATES AIR FORCE ACADEMY

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As future leaders, United States Air Force Academy students will face many challenges and problems requiring unique solutions. The classroom provides their initial attempt at providing solutions to ambiguous problems. Our goal in the math department is to develop the thought processes and skills necessary to allow students to become good problem solvers. There are four primary elements that we believe are essential in order for students to develop higher order thinking skills--understanding the broader concepts behind mathematical constructs, constructing mathematical models, communicating mathematical ideas, and the developing of fundamental skills.

Understanding concepts is the student's ability to understand the ideas that motivate a particular mathematical construction and when the application of this idea might be appropriate. A student with a developed understanding of big picture concepts is able to answer the questions of "Why?" and "When?" in reference to the given topic. Our primary instrument to measure conceptual understanding is via short writing assignments, more involved homework assignments, and, to a lesser degree, in-class tests or quizzes. Constructing models of (sometimes) ill-posed problems requires examining a real-world scenario and translating this problem from spoken/written language into mathematical language. Students must understand what mathematical ideas are at work in the problem, what simplifying assumptions they must make, and how these work together so that they can formulate a tractable mathematical statement. Most of our students find this a difficult process and are often relieved when they begin the process of solving their new model. Our primary assessment instruments of this construction (and solution) process are group and individual projects. And to a lesser degree, we also utilize extended homework problems and in-class exams to further understand students' grasp of modeling. Having the ability to communicate technical ideas in an intelligent yet practical way is essential in today's world. Students must be able to articulate their understanding to themselves and to other people. Students must be able to interpret and articulate the results of the modeling process to themselves and others. Thus we view verbal and written communication as important acts of self-reflection and self-assessment and we ask our students to do this on short writing assignments, longer projects with both written and verbal communication component, and oral examinations.

Fluency in basic, fundamental skills enhances student proficiency in higher order thinking process. For us, 'fundamental skills' involve the kinds of procedures students must simply memorize. For example, we consider the short-cut derivative process of changing x^2 to $2x$ a fundamental skill. Certainly, a student might be able to understand the important concept of 'instantaneous rate of change' apart from memorizing this skill, but the ability to compute basic things enables a student to gain a perspective and understanding that may not be apparent when examining the notion of 'derivative' from afar. In short, we want students to understand the "Why?", the "When?" and the "How?" of a mathematical construct. Our primary assessment instrument of the "how?" of mechanical skills are Fundamental Skills Exams (FSEs).

Our hope is that each student will pass an FSE with 100% accuracy. However, due to technical issues discussed below, the students are considered proficient with a score of 80% or better. Our FSEs are administered using an online software application. The software is also the method by which students do all homework assignments for most of our calculus courses. By doing homework prior to taking an FSE, students are able to practice in the environment in which they will test. We also provide students practice FSEs prior to their first test date. Since most students, particularly incoming freshmen, may not be comfortable with the various syntax idiosyncrasies, we allow the 80% proficiency rate rather than 100%, although strong consideration is being given to raise the proficiency rate to 90 or 100%. Students are given four attempts to pass an FSE. Again, most calculus courses consist of two FSEs, so students can have up to eight attempts, four per FSE. The first attempt, for both FSEs, is given to the entire course at once. Successive attempts are scheduled as necessary. Students are issued laptops at the start of the school year with wireless capabilities, which allow them to connect to the online application in class. A class typically consists of 20 or so students, and each student is given a randomized version of the FSE. The questions are all the same, however the numbers used and the order of each question varies by student. Each FSE consists of 10 questions with no partial credit awarded; therefore correctly answering eight to ten questions will result in a passing score. A student who passes the first attempt receives 100% of the assignment points (usually 5-10% of the course), 80% for passing the second attempt, and 60% for the third. Currently, no points are awarded for passing the fourth and final attempt.

We currently utilize Fundamental Skills Exams (FSEs) in Differential Calculus (Calc 1), Integral Calculus (Calc 2), and Multi-variable Calculus (Calc 3). In these courses, we define a 'fundamental skill' as a one (or two) step process found in basic algebra, derivative, and anti-derivative processes. For example, in Differential Calculus, we expect students to start the course with a solid understanding of algebra, which will aide in their ability to leave the course with a mastery of basic derivative skills. So we give two FSEs in this course—one covering basic algebra skills that they should have learned in prior courses, and another assessing student ability to perform basic derivative operations. Sample questions are shown below:

Differential Calculus Algebra FSE Sample Question:

Solve for x using logs where

$4 = e^{5x}$

Differential Calculus Derivative FSE Sample Question:

Find the derivative of

$f(x) = \sin^2(10x)$

Success in Integral Calculus requires basic proficiency in taking derivatives, so we give the students an FSE covering derivatives learned in Differential Calculus. We then require a student to demonstrate proficiency on a second FSE covering anti-derivatives. In Multi-variable Calculus, we similarly give two FSEs: prerequisite FSE covering derivatives and anti-derivatives and a second FSE covering skills germane to Mult-variable Calculus.

The figures below are examples of the cumulative passing rates for FSEs administered during the 2005-2006 academic year. The cumulative passing rate increases per attempt, and generally reaches 99-100% by the fourth attempt, although numbers for the fourth attempt are not shown. The passing rate reaches 90% rather quickly for honors classes and Calculus 3—courses typically taken by technical students. Students in Fall Calculus 2 or Spring Calculus 1 are those who are either not technically inclined, or did not have sufficient calculus background prior to coming to USAFA, these students have the lowest initial passing rate, yet are also close to 100% near the third attempt. Based on the numbers, the cumulative passing rate tends to reach 100% by the final attempt. We are quite interested to see if the students continue to reach 100% if the proficiency rate is raised above 80%.

Cumulative Passing Rates for FSE#2 Fall 2005

	Calc 1	Calc 2	Hon Calc 2	Hon Calc 3
Attempt 1	91%	46%	88%	93%
Attempt 2	94%	74%	98%	100%
Attempt 3	95%	93%	99%	N/A

FIGURE 1

Cumulative Passing Rates for FSE#1 Spring 2006

	Calc 1	Calc 2	Calc 3
Attempt 1	49%	82%	89%
Attempt 2	66%	97%	98%
Attempt 3	93%	99%	99%

FIGURE 2

Figure 3 shows the passing rates at 80%, 90%, and 100% proficiency for each FSE attempt. These numbers are important as we continue to assess whether or not to raise the passing proficiency rate to a score above 80%.

Passing Rates & Scores for Calculus 1 FSE #1 Fall 2005

	ATTEMPT1	ATTEMPT2	ATTEMPT3
FSE 80% Score	44%	38%	82%
FSE 90% Score	19%	16%	50%
FSE 100% Score	1%	14%	5%

FIGURE 3

FSEs have tremendous benefits to the students, faculty, and other departments. First off, the administering of FSEs allows the burden of learning to be placed on the students. As USAFA continues its shift toward a learning-centered classroom, requiring students to learn this material outside of class time will benefit the students in becoming learning-centered, thereby alleviating a portion of their dependency on the instructor. Although the material tested on the second FSE is taught in class, the onus of passing the first FSE is entirely on the student. Therefore, they will either need to learn or refresh themselves on topics they should have seen prior to their current course. As a result, instead of focusing on prerequisite material, instructors can devote more class time to in-course material and developing higher-level thinking skills. The high standard for passing an FSE (80% or better) will require students to truly have a firm grasp of the material thereby enhancing their ability to deal with difficult concepts. Also, by testing material from prerequisites the students will start to understand the importance of learning material the right way the first time, rather than doing a "brain-dump" at the end of a semester. This makes students much more sound mathematically so that as they enter high-level technical courses they are better students, and other departments do not have to spend time reviewing basic math skills.

As our use of FSEs continues to evolve we will look at several aspects of the FSE and how it is administered. A highly debated topic is the 80% pass rate. In the near future, we will make the decision on whether or not to raise the pass rate and not allow for syntax errors. Raising the score will lower the cumulative pass rate, but perhaps students will feel even more of a burden to meet the standard that we set. We are also looking into those problems that students miss most often to determine whether or not these problems are more difficult or poor FSE questions. Currently, the department categorizes each question as hard, medium, or easy. However, student performance will help us to better determine categorization, as well as allow us to measure our current categorization. We'll also evaluate the correlation between factors such as a student's grade in the course and their FSE grade. Any correlations will allow us to determine the effectiveness of using the FSE as a true gateway exam in particular for those students who are not able to pass an FSE but have a passing grade in the course.

For more information regarding FSE administration or any of the above discussed information please contact the authors.