TEACHING MASTERY IN STATICS USING THE STEMSI ONLINE LEARNING ENVIRONMENT

Franco Capaldi, Ph.D.
capaldif@merrimack.edu
Merrimack College
315 Turnpike Street, North Andover, MA, 01845

In this paper, we will convey lessons learned from a "flipped" mastery based Engineering Statics course. Statics is a foundation course upon which much of the Civil and Mechanical engineering curriculum is based. A poor understanding of even a portion of the topics covered in statics leads to poor performance in later courses. In a traditional classroom, a student might pass a course by achieving a C by understanding roughly 70% of the course material. However, this missing 30% might consist of critical material which is needed in later courses. Allowing students with a poor foundation to continue leads to propagation of student misunderstanding. In the mastery approach adopted in this paper, passing the course requires students to demonstrate mastery in each of 12 subtopics within statics. Sequential mastery in each topic was strictly enforced. For example, students with a poor understanding of vectors are unable to continue to a more advanced topic until they improve their ability to perform vector math. The STEMSI infinitely explorable online learning environment makes mastery learning practical in both small and large classrooms and has now been tested with classes containing over 150 students. Students learn at their own pace accessing online videos, practice problems, and assessment tests. Mastery learning has made a clear difference in student outcomes including significant improvements in vector mathematics, visualization, and promoted a better understanding of vector notation. Students have also demonstrated improved abilities to draw free body diagrams and analyze problems in mechanics. We will discuss practical aspects of the mastery classroom including the administration of exams, development of written skills, engineering solution presentation formats, and methods to achieve knowledge integration. Mastery learning has proven to be a significant improvement over the traditional classroom experience for students of all levels. We will also discuss our first attempts to expand this mastery concept to higher level engineering courses.

Key words: Online, Mastery, Statics, Engineering, Teaching,

Introduction:

Over the past decade, there has been a rapid improvement in “smart” computer tutoring systems. Computer systems are ideally suited to aid students who have difficulty visualizing structures. By allowing interaction, students may change the view angle to discern the three dimensional nature of the problem. In addition, the software may be used to guide a student through the solution process.

While students have different learning styles, and professors often have different teaching styles, it is becoming increasingly clear that effective assessment and immediate student feedback can produce beneficial results in the classroom [1]. Computer systems are ideally suited for such immediate feedback. They can also be used to present interactive case-based problems [2]. Systems have emerged which are capable of analyzing student response and providing targeted feedback to students when their response is incorrect. Systems such as ARCHIMEDES [3], Statics Tutor [4], Shaping Structures: Statics [5], BEST Statics [6], M-Model [7] and many others have emerged to provide students with modern computational learning tools [8] [9]. However, as noted by St. Clair and Baker [10], there remains room for improvement. None of these software solutions provides both an online distribution mechanism and a flexible entry system capable of handling a variety of problem types and vector notation.

An informal discussion with students who were currently using online homework systems revealed that students disliked using these systems for several reasons. Students find it difficult to ask the professor questions regarding the online solution and methodology. There is no record of effort involved or of partial progress made in the solution of the problem. Determining the exact format expected by the software is difficult. An informal discussion with professors using the online software systems indicated that many professors found that scores for online homework did not correlated with student exam scores.

Software description

The SGS system is designed as a homework or exam problem delivery system. A student logs into the system over the internet and is directed to an assignment. The student is presented with a problem statement, a three dimensional interactive figure, and an empty solution area. The student can then click on icons to add text, equations, or diagrams to the solution. Each time an equation or diagram is entered into the system, the student receives feedback on the correctness of the entry.

The SGS system allows students the ability to interact both graphically, and through equations with a problem. Students can explore the three dimensional figure presented along with the program to determine how parts are connected or to explore the three dimensional geometry, Figure 1. Student entry is accomplished using the toolbar shown in Figure 2. Clicking these icons allows a student to enter an equation, a new diagram, or text into the solution area. The system automatically grades problems and identifies student weakness.

The main advantage of this system is that it can evaluate any and all possible intermediate steps required to solve a problem. As a trivial example, if a problem asked a student “What is 2 + 3 + 4?”, a student might not know the answer right away but might enter “2 + 3 = 5”. The system would then identify this as a correct entry. Instead of being a system that presents content, it is a system that understands a subject and can provide immediate feedback regarding student hypotheses even when they are not anticipated by the instructor, Figure 2. For a mathematics course, this means the system would understand the mathematical operators and relevant equations and operations. In statics, the system understands reaction, internal, and external forces and fields and other related topics. In other words, the system can interpret student responses in the context of a given subject. It can determine that a student is requesting a particular type of information such as the internal stress in a beam and compute this information on the fly. As such, this system provides an infinitely explorable learning environment or an environment where student interaction is not predetermined by the instructor but can consist of any relevant subject material which the system can recognize.

Teaching students to be creative problem solvers is difficult. In many engineering courses, students learn “recipes” which they apply over and over. When they are working on homework in the evening with their classmates, the instructor is not present and it may be easier to take a standard approach to a problem than to try something which might be wrong. This system provides students a 24 hour instructor which is capable of analyzing any potential solution or solution path. Students can form hypotheses and test them immediately at any time and from anywhere. This is a significant deviation for many of them. In fact, during preliminary studies at Merrimack College, students had to be taught to take advantage of the system. Students who take an incorrect approach focus on the final answer and often are reluctant to go back to earlier intermediate steps. This results from previous interaction with other online systems which can evaluate a final result but not an intermediate step. Students had to be encouraged to provide the entire solution through the SGS system. By doing this, they test intermediate steps as they progress through a problem and ensure that they understand the solution process and do not propagate algebra errors in their solution.

Mastery Learning

A previous study conducted at Merrimack College [11] showed that students using the SGS system performed better on coursework than those who did not. Two sections taught by the same instructor were split into a control and treatment group. The treatment group performed their homework online using SGS while the control group received identical homework except that it was completed on paper. Students were given identical midterms and finals and a direct comparison between the results showed that the treatment group performed about 1 grade level (10 points) better than the control group even when normalized for initial level of competency.

As part of the study described in this paper, students at Merrimack College used the STEMSI software to engage in mastery learning. The topic of Statics was broken up into the following 12 subtopics: Introduction, Math, Vectors, Forces, Equilibrium, Moments, Rigid Bodies, Trusses, Frames and Machines, Internal Forces, Centroids, and Moments of Inertia.

Within the software, students access a series of video lectures and pdf documents aimed at introducing and explaining particular topics. Each lecture is indexed and searchable, students can find videos on particular topics as needed or watch a series of related videos at one time. All videos were viewed by students outside of the classroom and viewing statistics are visible to the instructor.

Classroom time was reserved for problem sessions. Students solve a set of engineering problems both online and in written format. Online problems are distributed to the students such that each student has a variant of the same problem. Solutions are unique, but methodology for solving the problems is the same. Students are encouraged to discuss methodology with other students. The instructor spends time moving from student to student answer questions and monitoring student progress.

Students are required to prove proficiency in each of the 12 subtopics. Students can complete assessment exams during any class period. If a student fails to achieve mastery of a topic, they can retake the exam during another class period. An integrated midterm and final forces students to revisit previous topics and ensures that they maintain a reasonable schedule in terms of topic mastery. Theoretically, a bright and self-motivated student could achieve proficiency in all topics within 12 lecture periods.

Conclusions:

Student comments, observation of student behavior by the author, and performance on mastery exams have led the author to the following conclusions:

- Online homework does not develop necessary written problem presentation skills. Written solutions must be included in the mix of assignments.
- Giving each student a related but different problem during class fostered the greatest student interaction. Students could discuss solution methodology while still needing to complete their own independent work.
- Requiring mastery in preliminary topics such as math and vector notation greatly improved student understanding in later more advanced topics.
- Maintaining a list of course milestones (such as dates by which students should have finished a mastery exams) helps students to pace their time and allows students to progress together through the course. Also, by testing individual topics continuously during the course, cramming for exams is no longer an issue.
- Including several exams which integrate groups of subtopics is necessary to encourage students to review previous topics and connect concepts from various parts of the course.

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Figure 1. Three dimensional interactive figures allow students to visualize problems, vectors, motion, and trajectories.

Figure 2. Feedback is provided for all possible intermediate steps.

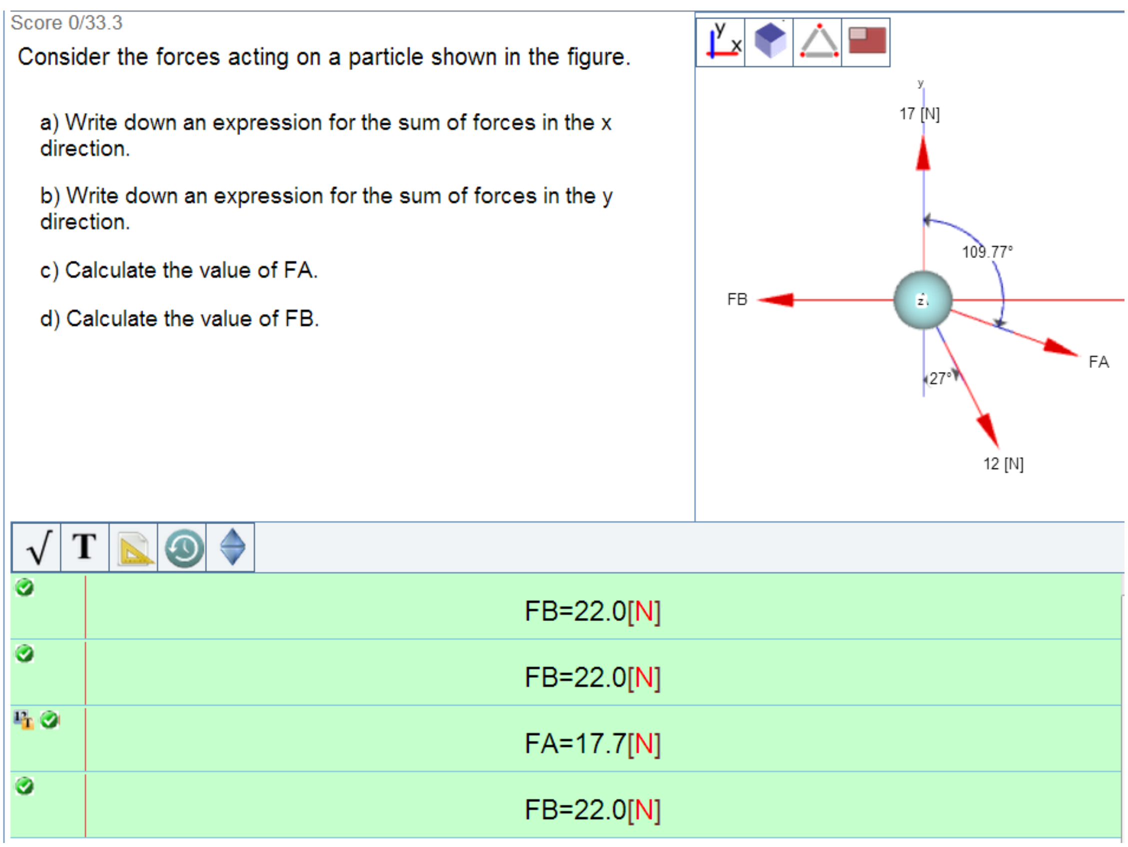

Figure 3. Mastery Learning Topics