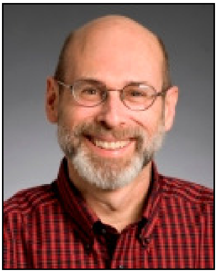
STATICS FOR ENGINEERS: FROM DIAGNOSIS OF STUDENTS DIFFICULTIES TO A STATICS CONCEPT INVENTORY AND AN OPEN COURSE



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An engineering education seeks to develop in students a broad range of skills. One skill is the ability to utilize scientific principles to design new systems and to make sense of existing ones. By the time students begin studying engineering at the university level, they have already had exposure to some scientific principles and some experience in applying them. Engineering education seeks to broaden that exposure to new principles and ideas, but also to deepen student understanding of ideas that already seem familiar. Given the wide range of learning resources (e.g. textbooks, web-sites) that are available to students, what effective role can the instructor play in the process of broadening and deepening student understanding?

Typically, instructors have minimal familiarity with how students conceive of the ideas and principles of the given subject and what students are thinking when trying to solve problems. This is perhaps the greatest obstacle to instructors that hope to intervene and help redirect students along more useful pathways. The author and colleagues have grappled with some of the challenges to offering students feedback and suggestions for improvement in Statics, the first engineering mechanics course that addresses equilibrium of solid bodies subjected to forces. In particular, we have wondered: what stumbling blocks and incorrect understandings prevent students from principled approaches to problems? Can we pose particular questions to effectively gain insight into our students' conceptions? Finally, how do we embed such questioning into on-going instruction so students can benefit directly and we can have something closer to continuous monitoring?

Our methodology for approaching these challenges started with field studies: the gathering and analysis of the work product of students engaged in solving Statics problems. The analysis consisted in placing errors made my students into distinct identifiable categories, and then recognizing concepts or clusters of concepts that are at issue in each type of error. Essentially we were identifying the most troublesome areas for students, with a particular focus on difficulties apart from mathematical analysis. But, instructors cannot on a routine basis identify the difficulties of their students by deconstructing their solutions to problems. Instead, with the picture of student difficulties coming into better focus, we sought to devise narrow questions, each focusing on whether a student possess one of the commonly observed misunderstandings. Interviews of students pondering such questions provided ideas for enticing incorrect answers, and those “distractors” suggested by interviews were combined with errors found from field studies. Collections of questions were gathered and administered as tests over a period of five years to thousands of students in many institutions, facilitated by a web-based implementation. The results were analyzed in ways that enabled the questions to be continually refined, resulting in a standardized test: the Statics Concept Inventory (also known as the Concept Assessment Tool for Statics).

Nearly concurrent with this effort, we sought out approaches that would make the accuracy of their understandings more visible to students themselves. This included prominently an adaptation of Mazur’s Peer Teaching Concept Tests to the statics classroom. Students would ponder questions and the possible answers, argue those answers with one another, and reflect on the ultimately revealed correct answer. This heightened our confidence that many important aspects of problem solving in statics could be re-framed to allow real time, meaningful engagement of students and instructors. Together with the identification of central concepts and common misunderstandings, this paved the way for a web-based Statics course. The course seeks to meet the apparently opposing goals of permitting asynchronous, as-convenient learning, while making students’ thinking visible to themselves and to instructors. The centralized data gathering on student activities has dramatically increased our potential for assessment and monitoring.

From these various efforts, we have found that performance on conceptual questions is indeed a useful barometer: it correlates positively at most institutions with other class-relevant measures such as final exams. At many institutions, students on average perform very poorly on conceptual questions that faculty might think are reasonably straightforward. There are particular concepts that appear to be particularly challenging to students. Focused instructional efforts can produce improvements in concept scores, which happily can still correlate with class exam performance. We also find that interactive activities can be developed, which productively engage students and assess them on a range of aspects of statics. In some respects though, we still fall short in the extent to which we can draw students into meaningful assessment loops. There are some very important and difficult concepts of Statics for which we have yet to develop effective ways of probing students, and it is remains challenging to assess students engaged in the types of problem solving that involve integrating different aspects or conducting more detailed analysis. While computer-based assessment methods can play a dramatic role in helping to monitor and promote learning, they have still not fully displaced one-to-one verbal interactions and thoughtful diagnosis of handwritten work.