

AC 2010-480: QUALITY ENHANCEMENT IN STATICS

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Quality Enhancement in Statics

Abstract

To satisfy accreditation requirements the University of Louisville recently developed a Quality Enhancement Plan (QEP) to improve undergraduate instruction across all disciplines. Central elements of the plan are: emphasis on critical thinking; integration of critical thinking throughout the curriculum; service learning for undergraduates; and a culminating experience. With the adoption of the QEP, instructors were asked to incorporate these concepts into their curriculum. One of the most interesting efforts in revamping course presentation has been to change the way a truly fundamental course, Statics, is taught.

In order to modify the existing Statics course to meet the QEP objectives, minor changes were necessary in areas of course design (course objective, culminating experience, flowchart of progress) and assessment procedures (pre-quiz, group problems, and optional final). The changes were not extensive, but rather only minor changes to presentation or organizational format. Statics is one of the core courses within the engineering curriculum and a significant amount of information must be conveyed and mastered. Thus, the changes presented do not disrupt the normal classroom flow, but rather shift the emphasis and language to incorporate critical thinking explicitly.

During the summer semester 2009, 115 students were enrolled in a single Statics session where the course modifications were enacted. Grade statistics from this class were then compared to data from previous classes taught between 2004 and 2008. Based on the recorded student performance data and comments received during the course evaluations, the minor modifications made in the class presentation had a positive effect on student attitude as well as performance.

Introduction

One of the requirements for accreditation according to the procedures of the Southern Association of Colleges and Schools (SACS) is development of a Quality Enhancement Plan (QEP) for improvement in undergraduate instruction. SACS is the recognized regional accrediting body in Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia for those institutions of higher education that award associate, baccalaureate, master's or doctoral degrees. "An effective QEP should be carefully designed and present a focused course of action that addresses a well-defined topic or issue(s) related to enhancing student learning." [1]

In January 2005, a QEP Team of faculty, staff and students were charged with developing such a plan for the University of Louisville. A university-wide survey was conducted to identify areas of instruction that needed improvement, and solicit suggestions on ways to remediate deficiencies. The range in response was quite wide, as expected, but generally fell into four broad categories 1) gaining the ability to solve problems and to apply theories in practice, through critical thinking; 2) integration of learning (no more outlier courses unrelated to any other course or practice area); 3) providing opportunities to apply classroom learning in practical

experiences through service learning; and 4) taking learning out to the community through a culminating experience to synthesize knowledge through practice that benefits the university and the community.

In October-December 2005, the QEP Team reviewed the four target areas in need of improvement and defined their mission as “Ideas to Action: Using Critical Thinking to Foster Student Learning and Community Engagement.”[2] The concept of critical thinking has been defined many times over the past forty years, but generally includes activities focused on key abilities: to question; to acknowledge and test previously held assumptions; to recognize ambiguity; to examine, interpret, evaluate, reason, and reflect; to make informed judgments and decisions; and to clarify, articulate, and justify positions [3, 4, 5, 6, 7, 8, 9, 11, 14, 15, 16]. It is evident that the approach developed by the QEP team reflects the determination that critical thinking is defined by mental activities and standards that are not specific to any profession or subject.

When incorporating critical thinking activities into the classroom, Paul and Elder [12] developed a learning paradigm that divided activities into three fundamental areas: 1) analysis of thinking by identification of the elements of thought as defined previously (e.g., questions, purposes, inferences, etc.); 2) critical evaluation of thinking by applying intellectual standards such as clarity, relevance, and accuracy; and 3) consequent development of intellectual traits desired in undergraduate students (intellectual humility; perseverance, autonomy, integrity, empathy and courage in a person who has confidence in reason and is fair-minded). Figure 1 below offers a simplified view of these components. When assessing this Paul-Elder paradigm with respect to engineering reasoning, it is apparent that the approach should be familiar to engineering educators and practitioners. [13].

I2A: What are the components?



Figure 1. Components of the implementation plan [13]

Application of the Implementation Plan

When faculty members in the J. B. Speed School of Engineering were asked for their reactions to the QEP and the subsequent implementation plan, their universal reaction was, “But I already do that.” All of the faculty members interviewed expressed the feeling that critical thinking is essential to engineering and routinely emphasized in classroom presentations, homework problems and design assignments. Additionally, for ABET accreditation, all departments within the engineering school already offered capstone design courses that epitomized the idea of a culminating experience. And finally, the Speed School curriculum requires students to complete three cooperative internships, a formal mode of service learning.

With all of the primary goals of the QEP mission already addressed, most faculty members in the Speed School felt that they already were in compliance with the improvement plan, and needed to do nothing but wait patiently for their ensuing university accolades. They were not ready for more pointed questions such as, “When do you define critical thinking for your students?” and “Do you explain to your students how they are thinking critically when they do the homework problems or design assignments you give them?” Only in a few senior-level or capstone courses were the concepts of critical thinking described overtly and emphasized clearly. No comprehensive effort had been made to introduce critical thinking overtly to engineering students, and the inclusion of critical thinking in most courses was not intentional; i.e., instructors seemed to think that students would absorb critical thinking skills by some sort of osmosis. For critical thinkers, the engineering educators had been remiss in applying intellectual standards to their course content and presentation.

Implications for Engineering

To remedy these deficiencies, far-reaching changes were made to the introduction to engineering course, the service learning program, and introductory engineering mathematics courses. Other changes were enacted by individual faculty members to include explicit mention of critical thinking, and exercises in their courses based on application of the Paul-Elder paradigm. The alterations in these courses have not focused on changes in content, but have been modifications in mode of presentation. In no course has this change in approach been more interesting than in a truly basic course, statics.

Changing Statics

In 1687 Newton published his laws of motion in the *Philosophiae Naturalis Principia Mathematica*. This work ultimately became the source material that has been passed on from teacher to engineering student through Engineering Mechanics: Statics and many other derivative courses. Unfortunately the teaching methods used to convey the information also have been relatively fixed. A quick review of available textbooks indicates the same rote presentation sequence (some books are on their 12th edition). In contrast, the QEP mandated overt, intentional presentation of critical thinking. Could critical thinking be included overtly in a well established, fundamental, almost archaic engineering course? Yes many ways of requiring critical analysis and evaluation can be adapted to statics with only minor tweaking of the course presentations.

That tweaking was done with guidance from a number of sources on how to improve student learning with

- teaching strategies that require students to be active learners through involvement in groups
- practicing skills in multiple settings (in class, in groups and through homework)
- using examples that are similar to situations the student will encounter in practice
- monitoring of student understanding and progress toward an identifiable goal
- incorporating a rationale for learning the skills emphasized in the course
- using motivational techniques (4, 13, 14).

Statics is one of the core courses within the engineering curriculum and a significant amount of information must be conveyed and mastered. Changes to incorporate critical thinking could not disrupt the normal classroom flow, but altered course design and grading procedures to emphasize critical thinking concepts...

Course Design

Course objective - Often the first exposure many students have to statics is the course description read during class registration. The course description currently used at our university for statics is as follows:

Apply fundamental concepts of statics to examine forces, equilibrium, friction, centroids and moments of inertia, to analyze and solve engineering problems. Both vector and scalar methodologies are used.

Is a new student likely to understand these terms or be even minimally excited by these two sentences? Please reconsider the sentences after removing the jargon phrases of “fundamental concepts of statics”, “centroids”, “moments of inertia”, and “equilibrium” and removing previously undefined words of “forces,” “vectors,” “scalars,” and “friction”. The only words left for a new student to understand are “The purpose of this course is to analyze and solve engineering problems using methodologies.” Thinking about course objectives from the students’ perspective and concentrating on learning objectives and action items produced the following description:

Complex engineering problems can be disassembled into small components that can be solved with basic science and math skills. By asking simple questions that focus on what information we have and what information we need, we can develop simple strategies to solve many problems. Through this process the fundamental concepts of vectors, forces, equilibrium, friction, centroids and moments of inertia, may be used to analyze and solve engineering problems.

Focus on tasks to be done and the means to accomplish those tasks clearly indicated the fundamental concepts to be presented. Furthermore, emphasizing simple questions to be answered goes to the heart of critical thinking as applied in engineering. Halpern [5] emphasizes that all critical thinking skills are involved in problem solving, including generating and selecting

alternatives and evaluating those alternatives. Those activities require hard work—thinking. A change in disposition is required in student attitudes toward coursework. As Halpern [5] points out, “There are large differences among cognitive tasks in the effort that is required in learning and thinking. For example, most people effortlessly learn the plot of a television sitcom they are watching, but they need to expend concerted mental effort and cognitive monitoring to learn how to analyze complex arguments or *how to convert a word problem into a spatial display*” (italics added). Visualization is a key skill in solving statics problems.

Culminating experience – Student responses to the QEP poll were similar to ABET accreditation requirements for a “culminating experience” to synthesize what has been learned in prior courses. Many schools meet ABET accreditation standards by requiring students to take a single capstone design course. Will that psychological and pedagogical demand for a goal to synthesize what was learned be incorporated into a basic course? Yes!

One of the main advantages of a culminating experience is the clear understanding of the final product or skill set as an achievement signifying success in a course. Many instructors march through the requisite chapters in a selected textbook in chronological order. Skills are developed in a systematic fashion, one building upon the other, until the semester ends. Where is the culminating experience, the feeling of achievement? In our view, the typical statics course can be seen as steps in building the skill set necessary to analyze the internal and external forces in any member of a truss. To set a worthy goal in statics, early in the semester the instructor must declare that the test of mastery of the skills taught in this course is success in truss analysis, and show the students that every step, every chapter, every homework problem contributes to that objective in some fashion.

Flowchart of progress – Usually, students in a statics course are exposed to a variety of concepts [equilibrium, position vectors, moments, etc.] necessarily presented in a linear fashion (Figure 2). However, the information does not fit together as simply as the textbook would imply. In our experience, students have difficulty fitting the lecture de jour into an overarching context, or they lose their perspective on the course objective. To provide a better intellectual perspective, a revised visual perspective on course components was developed, as shown in Figure 3.

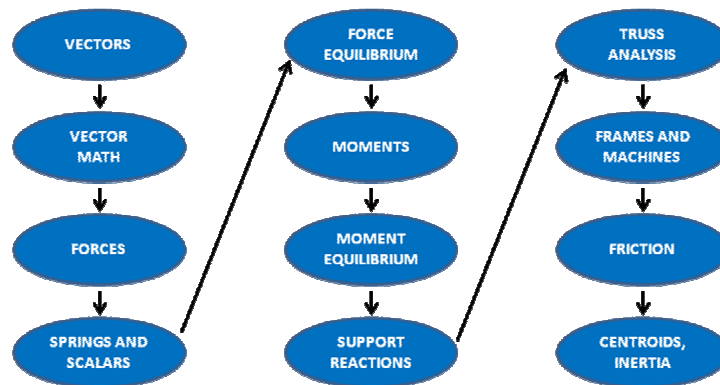


Figure 2. Traditional flow chart of information presentation within Statics.

Figure 3 clearly indicates the importance of fundamental vector operations. The diagram highlights the linkages among forces, moments, and equilibrium, and clearly shows equilibrium as a concept central to all statics problems. Because of the way information is stored and then used in human mental processes, defining and illustrating linkages among topics is a powerful aid to memory [5]. Showing connections from one concept to many others, according to cognitive psychologists, defines *meaning*

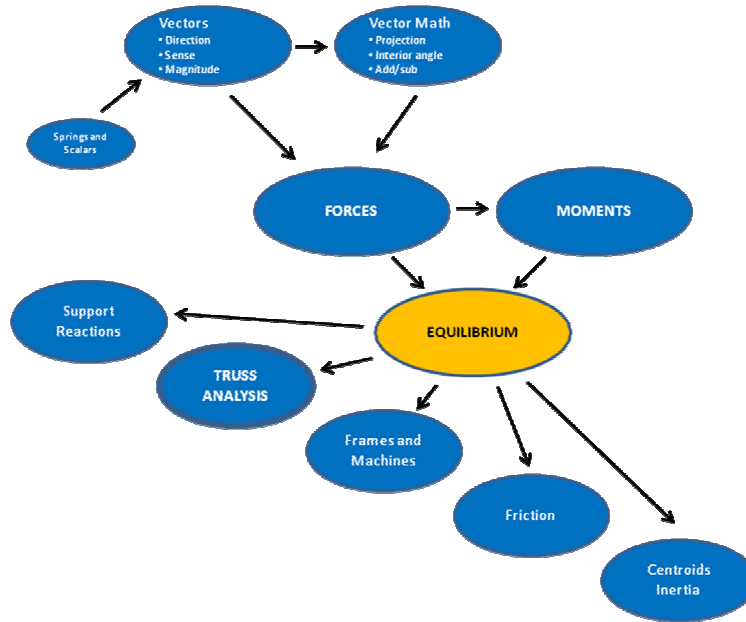


Figure 3. Modified flow chart displaying concept relationship for Statics.

Grading Procedures

There is no universal acceptance of a uniquely appropriate grading procedure that will work for all courses or all instructors. The grading procedures described subsequently seem to produce reasonable diagnostics for statics, and are presented for the reader's critical review and possible adoption.

Pre-quiz – Many students, particularly younger students, do not come to class prepared. Only a minority, if left to their own devices, would read the lecture material before class and be prepared to comment on the problems. To show students that preparation is important, and in accord with the mantra that “if something is important, measure it,” a pre-lecture quiz is given at the beginning of every class [except for test days] on the preparatory materials. It is designed to take no more than five minutes. Students who prepare are rewarded, and the reward [or punishment] indicates the importance of being ready. Students can monitor the success of their own preparation. Time lost during the quiz is made up easily because students who prepare have a preliminary understanding of the material to be covered. Also, thoughtful questions on the quiz require the student to consider a concept in connection with a situation reflective of actual practice so that the relevant concepts allow solution of real problems.

Group problems – In engineering school, we learn in much the same way that we practice after graduation, in groups. In study groups and laboratory work, students don't learn in isolation. Group learning exposes students to a variety of individuals and viewpoints, and enables them to ask questions in a relatively safe environment. A small group in the classroom is one form of a "circle of trust." [10] In the revised statics course, students usually are asked to complete one homework problem prior to the end of class, and they are encouraged to work in small teams. However, each student must submit an individual handwritten solution for evaluation. Such assignments force an immediate application of the presented material. Students that do not readily grasp the lecture materials are then mentored by those that do, further solidifying understanding of course materials.

Optional final – Gaining mastery of basic science and math skills required to solve simple engineering problems is a basic goal in statics. Some students may struggle initially with primary concepts, but through repeated solution of example problems most students master the subject matter. However, a sequential grading format in which each test is cumulative on grade, works to punish students unduly if they have one low test score. It is so difficult to recover from one poor test score, that they drop the course. One way to maintain student commitment is to have an optional final that will replace the lowest test score. High achievers like this option because they can choose not to take the final. Students with one poor test grade remain hopeful because they can significantly improve their class grade with the last chapter exam and a good score on the final. To make the final exam meaningful, students are cautioned that if they choose to take the final, their score will be included in their average, whether it helps or hurts their performance.

Results

To assess the effect of the modified course curriculum, student performance during the summer 2009 semester of Statics (115 students) was compared to performance in seven prior courses taught by the author between 2005 and 2008. At the University of Louisville, student co-op experiences are required and thus three full semesters are conducted each year. As such, when students are in sequence, Statics is normally scheduled for the summer semester of their sophomore year.

Figure 4 displays a comparison of the grades for the previous courses and for the Summer 2009 session. As shown in the figure, it appears that there was a significant shift of students to higher grades. Many of the "B-C" students appear to be in the "A-B" range. Unfortunately, the "F" students appear to have benefited little from the course changes.

To account for possible difference between in phase and out of phase student groups, the data were subdivided into semesters and then compared to the Summer 2009 modified course curriculum. The grade distribution trends between in phase and out of phase students were essentially similar and thus could be effectively lumped together as only pre 2009 data for the analysis.

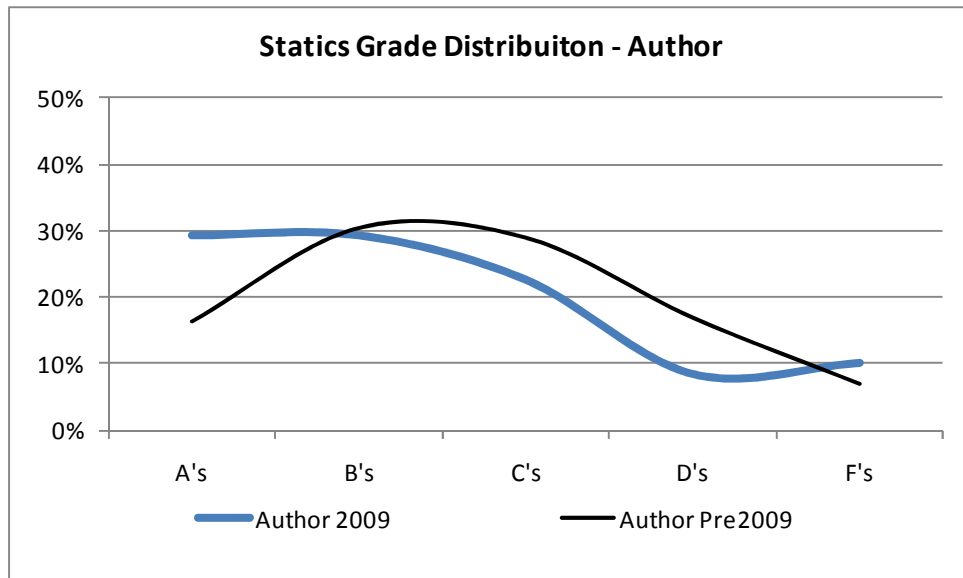


Figure 4: Course grade comparisons between modified curriculum and previous statics classes

Conclusions

Maintaining course content but presenting it in a different format and using explicit language to emphasize critical thinking enhanced student learning. This experience showed that broad sweeping changes are not required in order to improve learning; a number of incremental changes in presentation geared to clear identification of goals and the means to achieve goals, however, did make a difference. No epiphany in education occurred but the course modifications produced a modest change in student performance.

While the changes observed are relatively modest, is it reasonable to expect dramatic changes in performance in a course that already was well-designed, but was only modified to improve critical thinking abilities? Halpern [5] has put this type of effort into perspective: “Courses that are designed to enhance the thinking abilities of students will usually identify a subset of skills...and design instruction to develop the selected skills...Given our knowledge of cognitive development, it would be unrealistic to expect a huge gain in the thinking abilities of college students that can be attributable to one course that is a quarter or semester in length...Cognitive growth is a gradual and cumulative process; there are no quick fixes. It is more realistic to expect modest improvement in thinking abilities...”

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