AC 2009-1358: ADAPTING AND IMPLEMENTING THE SCALE-UP APPROACH IN STATICS, DYNAMICS, AND MULTIVARIABLE CALCULUS

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Adapting and Implementing the SCALE-UP Approach in Statics, Dynamics, and Multivariable Calculus

Abstract

Our team seeks to deliver more effective statics, dynamics, and multivariable calculus instruction through active, student-centered courses and integrated course curricula. These courses were transformed to an inquiry, collaborative learning approach, and were assessed using a mixed method approach. Student performance in the courses and in follow-on courses have been used to measure improvements in concept retention. Conceptual tests (Statics and Dynamics Concept Inventories) were administered before and after each semester of the project, and normalized gains were compared with those for traditional learning environments wherever possible.

Improvements in statics concept comprehension and course performance indicators demonstrate the project's success. Learning activities for the statics-dynamics courses integrated material from multivariable calculus, and vice-versa, which is unique and beneficial. Students are selecting courses taught in our student-centered environment over traditional formats, as they gain a reputation as being more challenging yet rewarding courses. Classroom renovations to accommodate active and cooperative learning through studio environments have been completed in seven classrooms at our institution (Clemson University), indicating administrative support for these pedagogical innovations, and faculty willingness to practice active learning in studio environments.

Introduction

We are in the third year of implementing active and collaborative learning in second-year engineering mechanics and mathematics courses at Clemson University as part of a CCLI Phase 1 grant. This approach is modeled after Beichner and colleagues' Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) method[1]. An integrated statics and dynamics course for Mechanical Engineers, one section of statics for other engineering disciplines, and a simultaneous multivariable calculus course were taught using the adapted SCALE-UP method. Although the approach has been studied in physics courses, it has not been validated in engineering courses, until this study. We have examined the effectiveness of this pedagogical approach through student performance indicators, and through feedback from students and faculty. We also addressed the professional development needs of instructors to deliver student-centered course materials effectively, through workshops and course support materials.

Methods

Student performance in the SCALE-UP multivariate calculus, statics, and integrated statics and dynamics courses and in follow-on courses have been used to measure improvements in concept retention. Course grades were also tracked for a statics course taught in a traditional lecture format for comparison. Conceptual tests (Statics and Dynamics Concept Inventories) and Improvements in conceptual understanding of topics were assessed through student scores on the Statics Concept Inventory[2] for students in SCALE-UP statics versus a comparable statics course taught in a traditional lecture format. The SCI was administered before and after each semester of the project, and normalized gains were compared with those for traditional courses where possible. SCI and Dynamics Concept Inventories[3] (DCI) were compared for those taught in SCALE-UP integrated statics and dynamics, and normalized gains were tracked. The average time for students to successfully complete the integrated statics and dynamics course was compared to the time to complete separate traditionally taught statics and dynamics courses. Student interviews were conducted to assess study habits and the impact of different course resources and approaches.

Results

The SCALE-UP method is showing positive effects in the multivariate calculus and statics courses in terms of improvement in grades (Figure 1). Also, a reduction in DFW rate (percentage of students receiving a grade of D or F or withdrawing from the course) was observed for SCALE-UP statics when compared with traditional lecture format courses taught during the same semesters (Figure 2). The DFW rate for Fall 2006 for SCALE-UP and traditional methods were 34% and 39%, respectively. During subsequent semesters (Spring 2007 - Spring 2008), these DFW rates fell significantly.

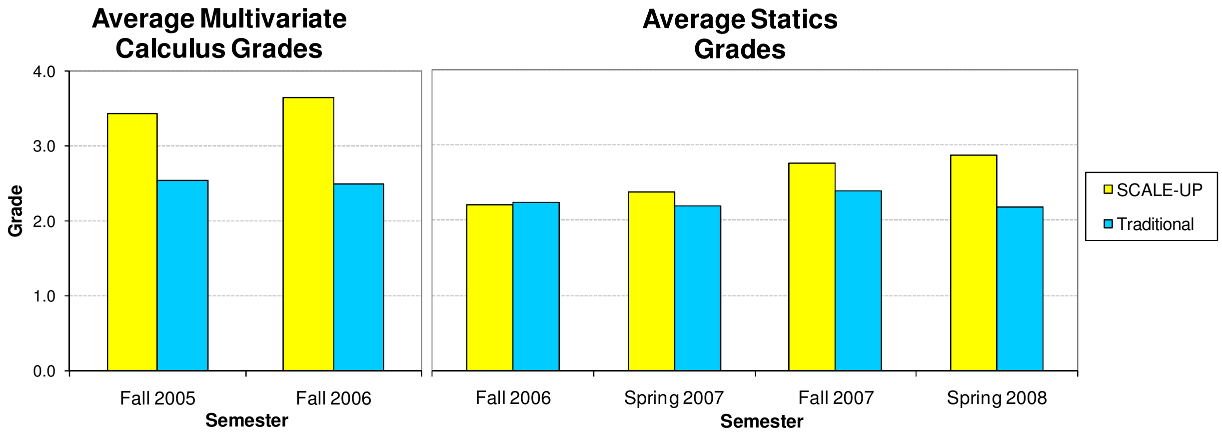

Figure 1. Course grades for courses taught in SCALE-UP and traditional formats over four semesters.

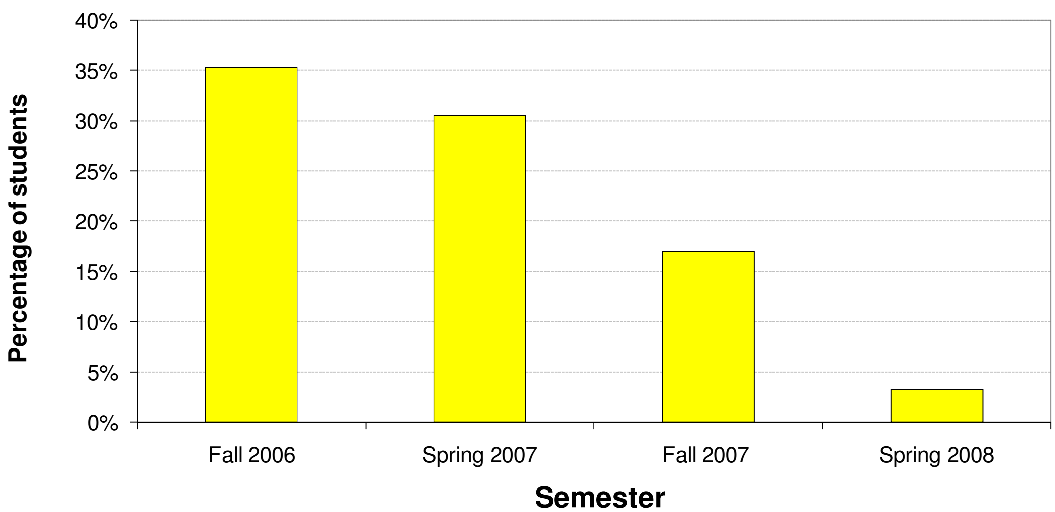

Figure 2. Percentage of students earning a D or F, or withdrawing from SCALE-UP Statics (DWF rate) over four semesters.

We have also documented reductions in the DFW rate (students earning a D or F, or withdrawing from a course) over the four semesters after the introduction of the SCALE-UP integrated statics/dynamics course (36% for SCALE-UP vs. 54% for separate, traditionally taught statics and dynamics courses). In terms of completion rate and time to completion, we found that 86% of Mechanical Engineering students complete the SCALE-UP statics/dynamics class in an average of 1.30 semesters while 72% of Mechanical Engineering students completed the traditionally taught separate statics and dynamics courses at Clemson in an average of 2.49

semesters. Preliminary student performance data in follow-on courses in ME show a significant increase in the number of students passing the course for those completing integrated statics/dynamics in SCALE-UP versus those taught statics and dynamics separately in a traditional lecture format. Students who completed integrated statics/dynamics are more likely to pass the follow-on course, “Strength of Materials” than students who took traditional statics and dynamics. The majority (63%) of students earning an A in integrated statics/dynamics earned an A in the follow on course; 100% of them passed it. Half of the students who got a B in integrated statics/dynamics also got a B in the follow on course.

Based on comparisons of SCI scores for students in taught in a traditional statics classroom environment (Fall 2005) and in SCALE-UP integrated statics and dynamics (Fall 2007), we have observed increases in statics concept comprehension in the SCALE-UP classes. Non-ME majors showed gains in SCI scores from pre- to post-test of 25% in traditional mode, versus 27% gains in scores for students in SCALE-UP classes. These gains were more pronounced for students who were attempting the course for the first time (i.e. not including those who failed previously and were repeating): 16% gains in traditional mode vs. 22% in SCALE-UP mode. The normalized gains on the SCI for the integrated course were higher than observed at the completion of separate statics course (31% vs. 22%), and the DCI gains were slightly higher than those observed at the completion of the separate dynamics course (17% vs. 14%). These results are encouraging for several reasons including: (1) gains were observed even when the instructors were teaching in SCALE-UP format for the first time, (2) the students were learning dynamics a semester earlier than with the sequential approach, and (3) some students were predisposed to the opinion that the 5-credit course was an experiment doomed to fail, and likely withdrew in anticipation of a return to separate courses. No significant differences were observed between normalized gains on the SCI in statics courses taught with the two instructional methods (22% in both SCALE-UP and traditional formats).

Feedback from participating students and faculty at Clemson indicate a positive attitude towards the SCALE-UP environment. An example of from a student evaluation: “[My group] held me accountable to my work, and we worked well together. We could explain things to each other when one of us didn't understand it.” Other faculty members have reported that students are continuing to work in “SCALE-UP” mode even in traditional lecture-style classes. One instructor in Civil Engineering gave an account of how, when students turned and talked to each other during his lecture, he was at first disturbed by their behavior, until he realized that they were working out details of what he was teaching. He ended up adapting his lecture format to allow time for students to discuss the material with each other during class. One instructor in Mechanical Engineering stated that students in a 4^{th} semester fluid systems class, having taken SCALE-UP statics/dynamics, seemed unusually mature and ready to work on in-class activities on the first day of class. Another instructor of the same class confirmed that the quality of questions and comments coming from his students seemed much more mature than in the past.

Significance

Reduced lecture time makes this approach attractive for developing cross-disciplinary courses or courses combining topics that are traditionally taught separately (such as statics and dynamics). The time to develop course materials and innovations is considerable, and may inhibit broader application of this valuable approach to instruction. We have incorporated our materials into a workshop, engaging participants in an authentic SCALE-UP learning activity and identifying strategies for implementing it in specific courses. Our goal in disseminating the findings of our study is to streamline the process of adapting the method to new and existing courses, thus improving undergraduate STEM education.

Acknowledgments

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