AC 2008-1364: STUDENT PERFORMANCE AND FACULTY DEVELOPMENT IN SCALE-UP ENGINEERING MECHANICS AND MATH COURSES

Lisa Benson, Clemson University

Lisa C. Benson is an Assistant Professor in the Department of Engineering and Science Education, with a joint appointment in the Department of Bioengineering, at Clemson University. Her research areas include engineering education and musculoskeletal biomechanics. Education research includes the use of active learning in undergraduate engineering courses, undergraduate research experiences, and service learning in engineering and science education. Her education includes a B.S. in Bioengineering from the University of Vermont, and M.S. and Ph.D. degrees in Bioengineering from Clemson University.

William Moss, Clemson University

William F. Moss is an Alumni Distinguished Professor of Mathematical Sciences at Clemson University. He has a BS in Electrical Engineering from MIT and a Ph.D. in Mathematics from the University of Delaware. He has 37 years of teaching and research experience at Lockheed Aircraft, the Naval Nuclear Power School, Georgia Institute of Technology, Old Dominion University, and Clemson University. His research involves mathematical modeling and the use of active learning strategies and technology to improve learning outcomes in mathematics and engineering courses. He is current supported by an NSF Engineering CCLI grant: Adapting and Implementing the SCALE-UP Approach in Statics, Dynamics, and Multivariate Calculus. He is also supported by an NSF Mathematics Education CCLI grant: Adapting K-8 Mathematics Curricular Materials for Pre-Service Teacher Education.

Sherrill Biggers, Clemson University

Sherrill B. Biggers is a Professor of Mechanical Engineering at Clemson University. His research interests include computational solid mechanics, progressive failure and nonlinear response of composite structures, and optimum design. He has taught courses in structural and solid mechanics, and finite element methods. He received his PhD in Mechanical Engineering from Duke University, and has been on the faculty at Clemson since 1989, after 8 years on the faculty at the University of Kentucky and 11 years in the aerospace industry. He is a member of ASME, ASCE, ASEE, and an associate fellow of AIAA. He is a registered Professional Engineer (PE).

Scott Schiff, Clemson University

Scott D. Schiff is a Professor of Civil Engineering and the Director of the Wind and Structural Engineering Research Facility at Clemson University. He is involved in research activities related to wind and structural engineering and the teaching of structures and fundamental engineering mechanics courses. He received his Ph.D. in Civil Engineering from the University of Illinois in 1988 and has been on the Clemson faculty since 1989. He has participated in ASCE and ASEE conferences related to civil engineering education.

Marisa Orr, Clemson University

Marisa K. Orr is a Ph.D. student at Clemson University. She received her B.S. In Mechanical Engineering from Clemson in 2005. In her research, she is studying Engineering Mechanics Education.

Matthew Ohland, Purdue Engineering Education

Matthew W. Ohland is an Associate Professor in Purdue University's Department of Engineering Education and is the Past President of Tau Beta Pi, the engineering honor society. He received his Ph.D. in Civil Engineering with a minor in Education from the University of Florida in 1996. Previously, he served as Assistant Director of the NSF-sponsored SUCCEED Engineering Education Coalition. In addition to this work, he studies peer evaluation and longitudinal student records in engineering education.

Student Performance and Faculty Development in SCALE-UP Engineering Mechanics and Math Courses

Abstract

Our research team is in their second year of implementing active and cooperative learning in second-year engineering mechanics and math courses using the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) model. With this approach, large studio classes are taught with an emphasis on learning by guided inquiry instead of standard listening and note taking by students. The project focuses on the development and delivery of instructional material and documentation of student comprehension, performance and perceptions in Statics, Dynamics, and Multivariate Calculus courses at Clemson University. The project is also examining the benefit of integrating the content of the two traditional sequential engineering mechanics courses (Statics and Dynamics), and the parallel content in Multivariate Calculus. The research team is tracking student grades in these courses and follow-up courses, and performance on the Statics, Dynamics, and Force Concept Inventories for students in Statics taught in a traditional format, students in Statics taught in a SCALE-UP format, and students in multiple sections of integrated Statics and Dynamics taught in a SCALE-UP format. The team is also addressing the professional development needs of instructors and student learning assistants to effectively deliver student-centered course materials and in-class assessment of student understanding.

Introduction

Teaching in a student-centered environment alters the instructor's role in the classroom from orator to more of a facilitator and coach. This new approach to teaching, Student Centered Active Learning Environment for Undergraduate Programs (SCALE-UP), was developed to teach Physics at North Carolina State University[1], and the researchers at our institution are among the first to promote the use of this method in engineering mechanics and math courses.

Background and Methods

The primary goal of this project is to deliver more effective Statics and Dynamics instruction to students at Clemson University. We have developed and delivered cooperative learning activities that are delivered using the SCALE-UP model, teaching large studio classes of up to 70 students. We have revised the present lecture approach to these topics and the integration of the content of the two sequential courses according to the needs of students in our mechanical engineering program.

All sections of SCALE-UP Statics and Integrated Statics/Dynamics were offered in a 1700 square foot SCALE-UP classroom space created and equipped for instruction and learning in the SCALE-UP mode. The space includes eight 7-foot round tables that can seat up to 9 students each (two or three teams per table). The tables have power and wired-internet to facilitate laptop use. Instructor space includes a Sympodium linked to dual projectors. White boards for instructor and student use occupy two opposing walls.

Instruction was accomplished as a team of one professor, one graduate student, and from one to two undergraduate student teaching assistants, depending on enrollment. Teaching assistants also provided supplemental peer instruction in the evenings, which students could attend on an as-needed basis.

Typical class periods consist of mini-lectures covering the theory of the topic, followed by working one

or two simple example problems. In-class activities of similar difficultly to the worked examples are then

assigned, which students work through in teams of two to four. These small problems focus on the basic and direct application of the material covered in the lecture, providing an opportunity to apply the lecture material under supervision of the instructor and the opportunity for peer instruction.

Gains in conceptual understanding of the material over the course of a semester were assessed through the use of concept inventories given on the first day of class, and again at the end of the semester. These include the Statics Concept Inventory[2], Force Concept Inventory[2] and Dynamics Concept Inventory[3]. Student grades during the semester prior to enrollment in these courses, course grades, common exam question scores, and grades in follow-on courses were tracked to assess student performance. These were compared to similar data for traditionally taught (lecture only) classes.

Student Performance Indicators

Based on normalized gains in the Statics Concept Inventory, students in SCALE-UP classes showed somewhat greater improvements in conceptual understanding compared to those taught in traditional classes. There were no significant differences in Dynamics Concept Inventory scores between the two methods. Preliminary results for student grades in follow-on courses indicate that for similar cohorts of students (i.e. those who took the course for the first time and passed), grades in follow-on courses were improved for students who took prerequisite courses taught in SCALE-UP mode. For example, 95% of students who passed the integrated Statics and Dynamics SCALE-UP course also passed their follow-on Mechanical Systems course, compared to an 82% passing rate for students taught in traditional statics and dynamics courses. These data need to be studied methodically to better understand the effects of confounding factors, and to the extent possible, control for them. These include differences from semester to semester in students' incoming grade point averages, the number of students repeating the course, and pre-course SCI scores, indicating differences in pre-existing knowledge of the concepts.

There were also some changes in how material was delivered in response to student comments and preliminary data over the course of this project, which must be considered when evaluating the method. For example, in the integrated Statics and Dynamics SCALE-UP course, reading was required during all semesters included in the study, but it was enforced in different ways. During one semester, the students were required to answer "journal" questions based on the reading and turn them in at test time. Grading for these assignments was time-consuming, leading to delays in providing feedback to students. The following semester, similar questions were posted online, but responses were not required; instead reading was checked at the beginning of class periods through short reflective questions answered through MessageGrid[4], a web-based response system. While this eliminated paperwork, it added set-up time, and some level of distraction for the students, as they did not otherwise use their laptops in class. Student survey results indicated that this approach did not do much to increase the students' emphasis on reading, perhaps due to an overly generous grading policy for the in-class questions. In the spring of 2007, MessageGrid was replaced by the iclicker system which requires students to purchase a iclicker as part of their course materials. We are finding this much less disruptive, more timely, and students seem to like it very much. MessageGrid has been found to be effective, however, in other SCALE-UP courses where laptops are required for learning activities, such as in our first year engineering courses.

Faculty Development Activities

Considering both the theoretical and practical aspects of adapting SCALE-UP in engineering courses, we have developed a list of essential components, and best practices that are critical to its successful implementation.

- Mini-lectures, which replace full period lectures
- High engagement learning activities: discovery learning, guided inquiry-based learning, and cooperative learning
- Student tables that provide power and network capability for student laptops or tablets (typically seven foot round tables seating three teams of three)
- Formative assessment by the instructor and one or more learning assistants during the learning activities, and/or through the use of technology such as "MessageGrid" or "clickers".
- Rich social interactions that develop a community of learners
- Effective, ongoing training for faculty to develop SCALE-UP material and confidence with teaching in this mode

This last element is critical in order for instructors to convey a positive attitude to students and teaching assistants with regard to the teaching method. In a student-centered course, students take responsibility for mastery of the learning objectives, which, according to the SCALE-UP model, is better supported in the classroom by activities other than lecture. This involves a concerted effort in the classroom on the part of the students, and on the part of the instructor to ensure that this mastery is taking hold. Instructors must develop materials that guide inquiry and learning; students are still responsible for mastery of the concepts, even if the supporting material for a learning objective is not explicitly stated during class (i.e. problems written out on the board, detailed steps itemized on hand-outs, etc.). This fundamental shift from traditional classroom techniques takes a level of adaptability and "buy-in" on the part of the faculty.

In the traditional mode of instruction, each class period is devoted to lecture with questions occasionally asked by students and answered by the instructor or questions asked by instructor and intended to be answered by students. Research shows that the attention span for lectures is on the order of 12 minutes[5] so it is not surprising that after class, students struggle to interpret their class notes and to solve the assigned problems.

In an active learning mode of instruction, the lecture is interspersed with activities which can be quite varied. For example, in think-pair-share students are given a minute or two to think about a problem, then turn to their neighbor and share. Electronic student response systems can be used to collect and display student thinking. A one minute essay can be used at any time within a class period.

The key difference between these approaches and SCALE-UP, and a key to its success, is the collective interaction among students, instructor, and teaching assistants. This facilitates several aspects of deep learning. One is formative assessments by the instructor and learning assistants through listening to student conversations and watching students work. They serve as facilitators of guided inquiry by asking students leading questions when they get stuck. The instructor no longer has to wait until the first exam to determine "who is getting it." Formative assessment informs instruction. Another is that rather than having students solve sets of problems for homework, often independently, SCALE-UP brings collaborative problem-solving into the classroom as a routine activity, and as a critical part of instruction. The formation of teams is done with careful attention given to evenly distributing student abilities, as we desire peer-to-peer instruction especially among teams where the team members have different levels of understanding.

Conclusions and Recommendations:

While SCALE-UP was designed to address issues related to large sections, the teaching approach is effective regardless of class size. Its effectiveness increases as class size increases, as it facilitates more varied opportunities for student interactions, richer "lessons learned" from peers, and makes efficient use of resources. Future directions for this study include the evaluation of student and faculty viewpoints on SCALE-UP and the practical aspects of its implementation. Our team will also be continuing rigorous data collection and analysis on student performance and conceptual understanding to inform our growing body of knowledge of best practices and methods for implementing SCALE-UP in engineering classes.

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