PROJECT SUMMARY

The primary goal of the Student-Centered Activities for Large Enrollment University Physics (SCALE-UP) Project is to determine the best way to establish a highly collaborative, hands-on, computer-rich, interactive learning environment in large-enrollment physics courses. We know from extensive educational research that students should collaborate on interesting tasks and be actively involved with the material they are learning. The Physics Department at North Carolina State University has had considerable success with small classes taught this way and is now searching for the best way to "scale-up" the innovations so that students taking our large enrollment engineering physics courses can benefit. We are folding together lecture and lab with multiple instructors in a way that should provide an economical alternative to traditional lecture-oriented instruction. The project involves the development, evaluation, and dissemination of new curricular materials that will support this type of learning. The SCALE-UP Project has the potential to radically change the way physics is taught at large colleges and universities. The pedagogical techniques should be general enough to encourage similar reforms in other science, engineering, and mathematics classes.

PROJECT STATUS

This has been a very busy time for the SCALE-UP project. We finished renovation of our Phase 2 intermediate-size classroom and have completed a full year of instruction in that space. Building plans for the Phase 3 large classroom have been completed and construction funding has been secured. The 99 seat classroom should be available beginning in January 2000. Preliminary blueprints for a brand new Physical Sciences Instructional Lab Building also include a SCALE-UP classroom. PI Beichner is on the University's design team for that building.

Having the intermediate size (54 students) classroom space has permitted us to develop and test a multitude of new instructional approaches. In most cases these have been highly successful. We are finding ways to keep students actively engaged in the material through the application of a variety of research-based pedagogies. These will be more fully described below.

Project evaluation continues as a vital, on-going series of tasks. We have a researcher in the room during nearly every class, writing field notes and capturing the interactions between students and with the instructors. Videotapes of each class are recorded for further analysis. Interviews with individuals and focus groups have been conducted throughout the year. These are providing great insight into how this type of learning environment is affecting students. We are continuing our attitude surveys, along with additional standardized testing and comparisons with our Department's traditional classes.

The objectives outlined in the original proposal are listed below, along with our progress toward meeting them:

1. Design new modes of instruction for large enrollment sections

This objective concerns classroom management more than teaching materials. We are trying to develop techniques that will permit use of research-based pedagogies in large enrollment classes, even though many of these materials were originally created for small class settings. For example, we are trying different ways to utilize the Tutorials developed by the PER group at the University of Washington. We have found that they must be broken up into short segments, with discussion after each part. Before we tried this change in approach we found that it was difficult to keep so many students reasonably "synchronized" during a lengthy tutorial session. Interspersing brief, classwide discussions makes sure everyone is spending a reasonable length of time on each part of the activity and provides opportunities to address difficulties before any group gets too far behind. We are also seeing if we can have students conduct some of the grading of these materials, not only to reduce instructor effort, but also to encourage higher-order thinking skills.

Technology has been utilized as an organizer. Most course materials are available on the web, including the syllabus, a calendar, daily activities, and examples of notes and lab reports. *WebAssign*, NC State's web-based problem delivery system, is used both during and outside of classtime to present questions and problems for consideration. We have found that it works especially well to keep students on task since they know they will be graded. We are exploring the possibility of also using WebAssign to poll student answers, much like ClassTalk. To ensure that students read the textbook and are well prepared for class, we use the system to assign questions and problems that are due just as those topics come up for discussion in class. If this was not done it might be difficult to cover all the standard topics in the depth we feel is necessary. The students are responsible for independently learning simple definitions and straightforward concepts, so time in class can be spent grappling with the more difficult ideas. Java applets and simulations are a major part of our instructional methodology. These permit us to focus attention on areas where research has indicated common misconceptions. (More will be said about the use of technology in later sections of this report.) While students work on these carefully constructed activities, the instructor and assistant are able to move about the room, asking and answering questions.

One very nice aspect of this type of instruction is that teachers are physically near the students and can see what they are doing. Although this is a simple thing, its importance cannot be overstated. What it means is that students cannot be anonymous in the SCALE-UP classroom. For example, during the first two days of the fall semester, a particular student had not taken out paper and pencil during class and showed little interest in classroom discussions. During an activity, the lead instructor talked to the student and stressed the importance of taking good notes. Because the instructor knew him (nametags are in front of each student), he was able to repeatedly call on him by name during class. At first the student stumbled on responses, but he quickly realized that he needed to pay closer attention. With instructor encouragement for correct answers, this student soon became an active participant in the course, did quite well in learning the material, and went on to register for the second semester SCALE-UP class, where he displayed similar success.

We are finding that even slight variations in teaching methods can make a substantial change in how smoothly the class operates. For example, we found that it was taking an inordinate amount of time to collect and return papers, given the large number of students in the intermediate-size classroom. Simply alphabetizing the assignments for recording grades was quite time consuming. Now we normally only accept papers that have placed in the center of a table. At the end of class these are collected, keeping the table grouping intact. Instead of 54 papers to alphabetize, the assignments are now in groups of nine. Each smaller stack can be easily sorted into the three teams at each table. Further sorting is not needed. (And if the papers are from a group activity, there are only three papers per table.) After grading and recording scores, each small stack of papers is returned to the center of its table-a process that takes less than a minute. The students at that table can quickly locate their own work. This has proven to be much less disruptive to the class than trying to distribute a large pile of paper. An easy-to-do modification has made a substantial difference in the operation of the class. We are making a collection of large-class teaching tips for inclusion in the SCALE-UP teacher guide.

2. Create student "neighborhoods" within a large university

As noted in last year's report, the Phase I lecture hall setting was not particularly supportive of instructional student groups. Although long tables replaced the original "paddle-type" individual desks in the room, the fixed nature of the seating arrangement caused great difficulties. Students who wanted to avoid probing questions from the instructors simply had to sit in the center of the room, where they were mostly inaccessible.

This year's redesigned classroom was much more successful in establishing the kind of learning environment we were hoping for. Students readily worked in their own teams as well as in groups of nine. (The table arrangements supporting these groups are detailed under objective 3.) Each table of students seems to become its own little society and develops a unique personality. Students particularly enjoyed having each table work on a problem and then sharing their efforts with the rest of the class using the whiteboards that surround the room. Of course, each individual student was responsible for all the problems, ensuring good questioning when something was not clear in a table's presentation to the rest of the class.

In addition to the numerous pedagogic benefits, use of student groups cut many of the grading demands by 2/3. The use of contracts to outline group responsibilities helped alleviate difficulties as teams found ways to work together to accomplish complex tasks. However, our analysis indicates that we need to direct attention toward enforcing team roles (manager, recorder, skeptic). Table sized groups are very convenient for random collection of written homework (to ensure proper problem solving techniques even when electronically submitting answers) and classroom notes. During the first few days of class it is important to explain to the students why the group approach is being used. (In fact, we try to have the students evaluate why we do almost everything, right down to considering why a particular problem was assigned. Students are encouraged to do this type of critical thinking continuously in all their classes. It is also part of the problem solving protocol discussed later.) It is not hard to convince engineering students that they will be team-members in their jobs and that they will have to learn to cooperate with others in order to be successful. Detailed information from the teacher guide on setting up and managing student teams is included in the appendix.

We tried to arrange scheduling so that students would be in the same groups for a co-requisite math class and the SCALE-UP physics class. Because of a mismatch of course enrollment, this was not possible. (Plans are now in place between the Physics and Math Departments to permit this cross-registration next spring when we start working with class sizes of 99.) Nonetheless, we have observed many of the benefits found in other studies of collaborative learning. We will definitely keep the group nature of the SCALE-UP learning environment and strive to make it even more successful.

3. Experiment with classroom layout

Teaching in the Phase 2 classroom (supporting 54 students) has enabled us to further test classroom layout and management concerns. As noted above, we have been very pleased with the performance of the room in promoting active and collaborative learning. Figure 1 shows the room before renovation. It was a crowded, traditional classroom with 55 desks. Figure 2 illustrates the dramatic change in the appearance of the room, which now holds 54 chairs. Each 6' round table supports interactions between and within three teams of three students each, with each team sharing a laptop computer. The flexible seating allows students to arrange themselves

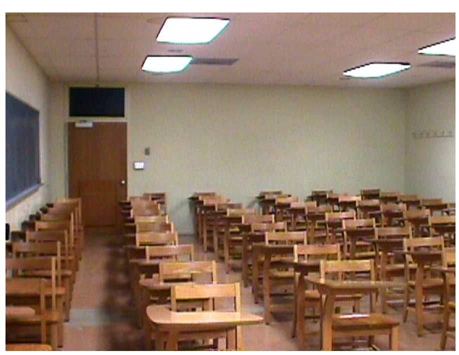

Figure 1. The Phase 2 SCALE-UP classroom before renovation, seating 55.

for the most convenient working space. This is important because of the wide variety of activities they work on during class. Figure 3 shows students measuring the coefficient of friction between their books and the table surface. Note how they have placed themselves in different locations and have (rather precariously!) moved the laptop out of their way.

Figure 2. The Phase 2 SCALE-UP classroom after renovation, seating 54.

Figure 3. Students in a tangible activity, estimating the coefficient of friction between a book and the table top.

Figure 4. There is no "front" to the SCALE-UP classroom, as you can see by noting the students looking toward both ends of the room.

We are now considering a test of 7 foot diameter tables. (We have already tried 6, 9, and 10 foot round tables, in addition to the more traditional rectangular lab benches.) Our current room is too small (21' by 34'), necessitating 10 foot centers between 6 foot diameter tables. This appears to be the minimum dimensions that will support this type of instruction. It can be difficult for students to get to the whiteboards and some student groups are not visited as often as they should be because of difficulty in moving through the tight spaces between tables, especially when backpacks are on the floor. We will be reviewing videotapes to ascertain how the instructors traveled about the room.

The technological components of the classroom have worked very well. We have had surprisingly few computer or networking problems. The projection system for the instructor's computer and the Elmo Visual Presenter has worked flawlessly. Students have no difficulty picking one of the two screens for convenient viewing (see Figure 4). All syllabus material and daily schedules are kept on the class website. The majority of the activities are there also. We have found that the laptop computers are an absolute requirement. In the pilot project which utilized desktop computers, the monitors essentially eliminated within-table discussions by blocking lines of sight. Keeping the computers themselves below the tables reduced, but did not eliminate this problem. In addition, this stopgap measure meant that plugging in the computer interfacing equipment required crawling under the table to make the necessary connections. Switching to laptops has completely alleviated these difficulties. When the laptops are not needed or are causing a distraction, asking students to "close the lids" instantly removes the computers from the scene. We are strongly recommending to visitors that the extra cost of using laptops instead of desk computers is worth it. In comparisons with the Phase 1 classroom, we have also seen that continuous student access to computers is a vital part of the classroom environment. Basically, the technology provides a focus for the students, bringing their attention to bear on the physical phenomenon being examined, whether that study is conducted through data collection and analysis, constructing mathematical models, running a simulation, or gathering other relevant information. This frees the instructor, who doesn't have to always be in front of the classroom but instead can move about and talk with the students.

We have successfully completed Phase 1 of our design testing—situated in a regular lecture hall setting. (Although the first portion of the project accomplished what we had hoped, we plan to introduce some additional innovative techniques into traditional settings during the coming school year.) We are currently 2/3 of the way through Phase 2 in our specially remodeled classroom. The last semester of the project will take place in a Phase 3 setting where we will be working in a custom-built classroom with seats for 99 students at round tables. Equipment is being ordered to outfit the new classroom and construction will begin this summer. We have been discussing our needs with the University's facilities planning group and several commercial architects. This will continue throughout the project. We want to see what classroom arrangements not only facilitate, but actually encourage the types of student-student and student-instructor interactions we are trying to establish. As noted earlier, we are also providing input to the designers of a new Physical Sciences Instructional Building that is being planned for the campus. There has been interest from other Universities and so we have given colloquia and invited conference talks about effective layouts and other aspects of managing a large, highly interactive classroom.

4. Write instructional materials

Tangibles (short hands-on activities) and ponderables (interesting questions to consider) continue to work very well. Most of these tasks are based on known areas of student difficulty. In addition to developing our own activities, we are also modifying existing materials, such as the University of Washington Tutorials and Mazur's Peer Instruction Questions. As an effort to move these ideas into the "mainstream," some original materials have been incorporated into Serway and Beichner's *Physics for Scientists and Engineers, 5th ed.*, as seen in Figure 5.

This textbook and the accompanying *Instructor's Manual* and *Student Guide* also incorporate the GOAL problem solving protocol that was utilized throughout the mechanics course. Figure 6 is from the text and describes the protocol. A variation of this procedure involving a template on paper was developed for the electricity and magnetism class. These enforced solution structures made homework and exam grading much easier. Of course, while reducing instructor time on administrative duties is important, the critical question is whether or not student learning is improved. We have seen increased performance in problem solving compared to the traditional classes here at NCSU. These results are discussed below.

QuickLab

Determine the thickness of a page from this book. (Note that numbers that have no measurement errors—like the count of a number of pages—do not affect the significant figures in a calculation.) In terms of significant figures, why is it better to measure the thickness of as many pages as possible and then divide by the number of sheets?

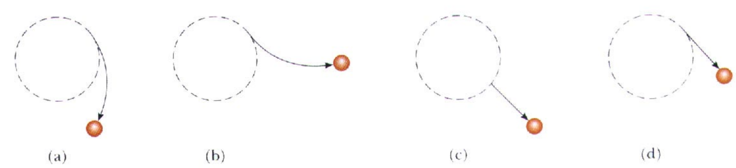

Figure 6.3 A ball that had been moving in a circular path is acted on by various external forces that change its path.

Quick Quiz 6.2

A ball is following the dotted circular path shown in Figure 6.3 under the influence of a force. At a certain instant of time, the force on the ball changes abruptly to a new force, and the ball follows the paths indicated by the solid line with an arrowhead in each of the four parts of the figure. For each part of the figure, describe the magnitude and direction of the force required to make the ball move in the solid path. If the dotted line represents the path of a ball being whirled on the end of a string, which path does the ball follow if the string breaks?

Figure 5. Examples of tangible and ponderable activities incorporated into Serway & Beichner, *Physics for Scientists and Engineers,* 5th ed. (2000) Philadelphia: Saunders.

Besides what you might expect to learn about physics concepts, a very valuable skill you should hope to take away from your physics course is the ability to solve complicated problems. The way physicists approach complex situations and break them down into manageable pieces is extremely useful. We have developed a memory aid to help you easily recall the steps required for successful problem solving. When working on problems, the secret is to keep your GOAL in mind!

GOAL Problem-Solving Steps

Gather information

The first thing to do when approaching a problem is to understand the situation. Carefully read the problem statement, looking for key phrases like "at rest" or "freely falls." What information is given? Exactly what is the question asking? Don't forget to gather information from your own experiences and common sense. What should a reasonable answer look like? You wouldn't expect to calculate the speed of an automobile to be 5×10^6 m/s. Do you know what units to expect? Are there any limiting cases you can consider? What happens when an angle approaches 0° or 90° or when a mass becomes huge or goes to zero? Also make sure you carefully study any drawings that accompany the problem.

Organize your approach

Once you have a really good idea of what the problem is about, you need to think about what to do next. Have you seen this type of question before? Being able to classify a problem can make it much easier to lay out a plan to solve it. You should almost always make a quick drawing of the situation. Label important events with circled letters. Indicate any known values, perhaps in a table or directly on your sketch.

Analyze the problem

Because you have already categorized the problem, it should not be too difficult to select relevant equations that apply to this type of situation. Use algebra (and calculus, if necessary) to solve for the unknown variable in terms of what is given. Substitute in the appropriate numbers, calculate the result, and round it to the proper number of significant figures.

Learn from your efforts

This is the most important part. Examine your numerical answer. Does it meet your expectations from the first step? What about the algebraic form of the result—before you plugged in numbers? Does it make sense? (Try looking at the variables in it to see whether the answer would change in a physically meaningful way if they were drastically increased or decreased or even became zero.) Think about how this problem compares with others you have done. How was it similar? In what critical ways did it differ? Why was this problem assigned? You should have learned something by doing it. Can you figure out what?

When solving complex problems, you may need to identify a series of subproblems and apply the GOAL process to each. For very simple problems, you probably don't need GOAL at all. But when you are looking at a problem and you don't know what to do next, remember what the letters in GOAL stand for and use that as a guide.

Figure 6. The GOAL Problem-Solving protocol utilized in the SCALE-UP mechanics class and incorporated into Serway & Beichner, *Physics for Scientists and Engineers.*

In addition to the short "tangible" activities, we also have more extensive, group-based laboratory work that requires a formal report. For certain topics we have developed labs consisting of three independent but interrelated activities that can be performed simultaneously. For example, one group at a table might be using microcomputer-based lab equipment to collect data on the motion of a cart rolling to the top of a ramp and then back down. Another group at the same table would be performing a video analysis of a movie of a basketball foul shot. While this is going on, the last group might be creating a simulation of the famous Monkey & Hunter demonstration. The groups rotate through the three portions of the lab and attempt to find the physics that is common in all of them. This type of setup was originally conceived because of interference between different sonic rangers operating simultaneously. Not only was this problem solved, but there are additional benefits of this approach. For one thing, students learn to help each other with portions of the lab that they have already completed. We also believe that approaching the same concepts from different directions will benefit students with different learning styles. Whereas sensory thinkers might learn best from the hands-on manipulation and observation of the cart reversing itself on the ramp, intuitive thinkers might appreciate the more theoretical demands of producing an accurate simulation. Visual learners certainly benefit from being able to replay a movie and see graphs synchronized to the frames depicting motion. From an economics standpoint, some lab equipment needs are cut by 2/3. To facilitate apparatus distribution and collection, each table's equipment is placed in a plastic bin. Laptop cables and cords are kept in "zip-top" plastic bags to minimize tangling and loss. We currently have to bring the laptops and equipment into the room for class. Next spring, this will be eliminated because of storage space included in the design of the classroom itself. This will also allow students to make their own determination of what equipment would be best suited for a particular task.

Following suggestions from the collaborative learning literature, as part of their lab work each individual examines the teamsmanship of themselves and their group mates. The quality of their evaluation is worth 10% of the lab grade. We also have created practical lab exams where each student must demonstrate every skill required for a lab. This has worked well to insure that everyone gets an opportunity to use all the equipment and thoroughly understand all parts of the lab. Thus individual accountability and group responsibility are built into each lab activity.

Students have also requested help in writing thorough class notes. Techniques are discussed in class and good and bad exemplars are posted on the web. Students put substantial effort into creating useful notes and so they often ask to have their work collected for grading. This is done at random intervals. Early in the semester, notes from all the students are collected. Later on, notes from just one or two tables can be quickly reviewed and returned the next day. This is done using a ✓–, ✓, ✓+ system to facilitate fast grading. From time to time, examples of high quality student work are projected for a discussion of the merits of taking good notes.

As time goes on, we are more fully utilizing *WebAssign*, our system for posing questions and problems over the web for homework or to promote classroom discussion. Java applets appear to be especially promising in this regard. We are using many of the "Physlets" developed by Wolfgang Christian at Davidson College. We hope to create our own video analysis applet and perhaps a web-based simulation engine as well. The main advantage of this type of software is that it is readily available outside of class for student homework or review. Non-web-based applications require multiple user licenses or else students must go to a special computer lab where the software is available. Web-based applications are available on any computer (including those in dorm rooms) that has an Internet connection.

This summer we are taking the materials developed during the past year and fitting them into a template that incorporates several important features, including objectives, known student difficulties, tasks to assign, reasons for assigning them, and pitfalls to avoid. We will continue to develop and modify these as we complete additional classroom trials. We have hired a post-doctoral student to help us work on this. We have had 24 visitors so far this year, including people from South Africa, the United Kingdom, and one person who has made two trips from Egypt.

5. Create teachers' guides

Our meetings with the advisory board have underscored the importance of these guides. It will be especially important to include information about setting up and managing groups. We will include references to the education research literature for those teachers who want to learn more. The references will provide backup to their internal proposals for support to incorporate SCALE-UP methods and materials in their own schools. An example of a lesson plan was given in last year's report. This year the appendix includes a portion of the guide that discusses the creation and management of student groups.

6. Improve student learning

We have been looking at several different aspects of "learning," including problem-solving, conceptual understanding, and even attitude development. We measured problem-solving skills by taking problems from the Department's common examinations and giving them to the students in the SCALE-UP mechanics classes as part of their exams. We included both multiple choice and "show solution" types of questions. (The second semester Electricity & Magnetism SCALE-UP classes had specially prepared exams that were more in-depth and provided a better fit to what we were teaching.) We have had positive results. In the fall semester, the SCALE-UP students outperformed their peers 88% of the time. In the spring we looked a bit more closely at specific types of problems. We found that the SCALE-UP students had higher scores on 20 of the 29 common problems selected for comparison. When the traditional students did better, the problems tended to be one-step problems like simple unit conversion.

Conceptual understanding in the mechanics course is also greatly enhanced. Results on the Force Concept Inventory (FCI) and the Force and Motion Conceptual Evaluation (FMCE) have been very encouraging. According to a study by Richard Hake, normalized gains on the FCI from pre-test to post-test for traditional mechanics classes average 23%. Our fall and spring semester mechanics classes averaged normalized gains of 43% and 50%, respectively. The latter class's post score compares vary favorably with results from the most successful classes in a previous study conducted by our post-doc. Only 5 of the 34 innovative classes in the study had a higher post score. The spring semester class also posted fractional gains on the FMCE, an alternative mechanics-concept test, that were more than three times higher than their peers in our traditional classes. We have not seen such successful outcomes in our electricity and magnetism course and are working to see if this is a problem with our measuring instruments or our instruction. Nationally normed assessment tools are not nearly as well developed for second semester topics and this may be influencing our results. We are participating in the "beta testing" of an E & M concepts evaluation that may provide additional insight.

7. Improve student attitudes

Results from focus groups and individual interviews have been quite encouraging. Students seem to genuinely enjoy the course and how they were taught, as illustrated in these quotes from transcribed audio tapes:

On the classroom design:

"I can deal with the lecture class, it is just that I enjoy more...getting more into the interactive projects. It is more hands on. If you don't understand something you just ask the guy next to you, nobody yells at you for talking."

" …you have your professor right in the middle and you have a couple of guys spread out and you can flag them down –'Hey, can you answer this question for me?' In the lecture, you are sitting 100 rows back, 25 rows back, you really don't have anyone but the two people next to you and they don't know. You really don't have anyone with some knowledge to help you out."

On what is learned in SCALE-UP:

"We are probably more equipped to go out and take on a job. Whether it is in the world or in a project and be able to complete it. A lot of the students that are in the lecture class–you might know what the book tells you, but other than that, you know nothing more than what the book tells you, what the teacher has told you. In the class, we know what the book tells us, we know what the teacher has told us, and we know what trial and error has also told us or taught us. "

" I actually know how I learn through the SCALE-UP physics…through the way that it is set up, through the way they taught us by solving problems. It helped me to learn not so much to get an answer but to actually understand concepts. I also apply that to the rest of my classes. I think from now on, I will do a lot better in my classes just by taking this class–through all the teaching we learned how to solve problems and think through problems."

"I have studied for a test with some of the traditional 205 students and like they always point to the book for everything, like looking for a formula for everything. Dr. Beichner makes sure that we understand the concept, we can almost derive the formula for whatever we need. And we seem to understand more of the aspects of physics. I definitely feel that, compared to traditional, we have a more in depth understanding and knowledge of what is going on."

What do you think about WebAssign?

"Web assign lets you know what you should know or need to know for class..."

"If you get something wrong, that forces you to go back and redo it–I know I did something wrong. Doing something more than once allows you to learn the material instead of just doing it and getting it done and going on to the next thing."

"Most people after they had gotten the homework back, half the people read the comments, half the people just flip through the grades and say "Ok, it's done and over with." You don't tend to really go back and look at your old homeworks until test time. I guess [with] WebAssign, you are not given comments. You are forced right there at the moment to learn that material in order to go on to the next assignment. If you are forced to learn each homework assignment, once you get to the test, you are not forced to go back a month ago to try to learn something you should have learned."

In addition to these individual and focus group interviews, we have been measuring student attitudes with the MPEX attitude survey that our post-doc helped develop. This test not only examines attitudes about the content of the course, but also students' ideas about science and learning in general. The MPEX is evaluated in terms of an overall score and six subscales: Independence, Coherence, Concepts, Reality Link, Math Link, and Effort. Previous MPEX studies found that even classes that show improvements in other areas show deterioration of their MPEX scores over time, particularly in the Effort subscale. Hence, little or no change is a good result. The MPEX scores for the spring semester mechanics class showed no significant change in four of the six subscales, resulting in no overall change. The exceptions were the Reality Link and Effort subscales. Both shifts are comparable to those observed for innovative curricula implemented at other schools. There was an impressive 1.5 standard deviation increase in the coherence subscale that looks at student belief in the coherence of physics knowledge.

8. Promote instructional reform

As noted above, co-PI Beichner has been involved in rewriting a leading physics textbook. Some of the project's hands-on activities have found their way into the revision as "QuickLabs." Many ponderables will appear as a series of "Quick Quiz" questions embedded in the chapters. Beichner is also on the steering committee of a national group working to promote the reform on undergraduate physics instruction. The group held a well-attended conference in early October. He also has given keynote presentations at the American Association of Physics Teacher's New Faculty Workshops. (We feel the work with new faculty is especially important because we can have the greatest impact on teachers who are still forming their own instructional styles.) We also continue giving talks and searching out schools interested in trying our instructional methods. Several of the graduate students involved in the project worked at nearby Duke University, helping them implement the University of Washington's Tutorials and even teaching several sections of their classes. Co-PI Risley and post-doc Saul provided Teaching Assistant training at Duke. We continue to welcome visitors from both large and small institutions around the country (as well as several international visitors). Colloquia and talks at national conferences appear to be working well to stimulate interest in reforming instruction. A list of outreach efforts is available in the Appendix.

We have begun to raise awareness and interest on campus with talks to different faculty and administrators. Project staff led two short workshops on the use of technology to improve pedagogy and a $2\frac{1}{2}$day workshop on effective teaching. Another technology workshop will be offered this summer. Response has been enthusiastic.

During the spring semester an external review team examined the Department very thoroughly. They recommended expansion of the Physics Education R & D group's efforts. Based on their recommendation, the Department is asking the University to support the establishment of a *National Center for the Reform of Undergraduate Education*. Because this is a very recent development, it is too soon to judge whether it is feasible or not. If it can be successfully carried out, this could greatly expand the impact of the SCALE-UP project and might even have the most significant consequences of any project FIPSE has ever supported. A brief description of this effort can be found in the appendices.

CONCLUSIONS

In summary, the second phase of the project is accomplishing our objectives. We are finding ways to maintain an active learning environment, even with large numbers of students. Collaboration is possible (and desirable) in these large classes and has many of the benefits seen in smaller classes. We have learned a great deal about the importance of careful design of classroom settings. Because we need to compare to the control group of our traditional students, we are constrained as to how much we can change the overall list of topics covered. Nonetheless, we have been able to add skills like note-taking, group work, project planning, evaluation, presentation, and practical lab skills to the more typical objectives of an introductory physics course. We have continued to develop "tangibles" and "ponderables" and students seem to be learning substantially more than in traditional settings, both in terms of conceptual understanding and problem solving ability. During the coming year we plan to develop materials that are especially aimed at helping students with varying learning styles. Other universities continue to be interested in our materials and we are organizing them for paper and web distribution.

BUDGET INFORMATION

For further information, contact beichner@ncsu.edu

CHANGES

We are making excellent progress toward our goal and at this time we see no need to change this original direction or our plans for future work.

APPENDICES

Talks and workshops dealing with SCALE-UP
Publications referring to SCALE-UP
Teacher Guide section on collaborative learning
National Center for the Reform of Undergraduate Education description
Implementation support for SCALE-UP adopters

1. Contributed and Invited Talks at Conferences

(Note: Only presentations and posters related to the SCALE-UP project have been listed.)

a. "Evaluation of PER-based group activities in large lecture classes: Lessons from the SCALE-UP Project," J. M. Saul, D. W. Abbott, R. J. Allain, M. H. Dancy, D. L. Deardorff, S. W. Bonham, R. J. Beichner, J. S. Risley, and M. Gjertsen (contributed talk to be presented at the AAPT Summer Conference, San Antonio, TX, August 1999).
b. "How WebAssign and Physlets affect the teaching and learning of physics: A case study with SCALE-UP," J.S. Risley (contributed talk, AAPT Winter Conference, Anaheim CA., January 1999).
c. "Progress report on the Student Centered Activities for Large Enrollment University Physics (SCALE-UP) project at North Carolina State," D. Abbott, R. Beichner, J. Risley, J. Saul, S. Bonham, M. Dancy, D. Deardorff and R. Allain (contributed talk, AAPT Winter Conference, Anaheim CA., January 1999).
d. "Group problem solving using multimedia-focused problems," S. Bonham, D. Abbott, J. Risley, R. Beichner, and W. Christian (contributed talk, AAPT Winter Conference, Anaheim CA., January 1999).
e. "Group problem solving using multimedia-focused problems," S. Bonham, D. Abbott, J. Risley, R. Beichner, and W. Christian (contributed talk, North Carolina Section AAPT Conference, Asheville NC, November 1998).
f. "WebAssign and grants to high school teachers in North Carolina," J. Risley and L. Martin (contributed talk, North Carolina Section AAPT Conference, Asheville NC, November 1998).
g. "WebAssign," J. Risley (keynote address, International Conference on Multimedia in Physics Teaching and Learning, University of Sciences and Technology of Lille, Lille, France, September 1998).
h. "New teaching environments at NC State," R. Beichner (invited talk, AAPT Summer Meeting, Lincoln NE, August 1998).
i. "Do multimedia-focused problems meet the needs of learners or are they just another way to torture students?," A. Titus, & R. Beichner (invited talk, AAPT Summer Meeting, Lincoln, NE, August 1998).
j. "Physics education research using web-based assessment systems," S. Bonham, A. Titus, R. J. Beichner, and L. Martin (contributed talk, AAPT Summer Meeting, Lincoln NE, August 1998).
k. "Motivating and evaluating students using web-based technology," A. P. Titus and L.W. Martin (contributed talk, AAPT Summer Meeting, Lincoln NE, August 1998).
l. "Introduction to the Physics Education Research and Development Group at NC State," J. Saul, R. Beichner, S. Bonham, A. Titus, M. Dancy, R. Allain, D. Abbott, and J. Risley (contributed poster, Physics Education Research Conference, Lincoln NE, August 1998).
m. "Physics education research with web-based assessment and testing systems," S. Bonham (contributed poster, Physics Education Research Conference, Lincoln NE, August 1998).

n. "Integrating video and animation with physics problems," A. Titus (contributed poster, Physics Education Research Conference, Lincoln NE, August 1998).

2. Workshops and Exhibits

a. "Effective Use of a Web-Based Assessment System: Case Study from SCALE-UP," ," J. Risley and P. Gjertsen (workshop, AAPT Summer Meeting, San Antonio, TX, August 1999).
b. "WebAssign," J. Risley and P. Gjertsen (exhibit, AAPT Winter Meeting, Anaheim CA, November 1998).
c. "WebAssign," J. Risley, L. Martin, A. Titus, and P. Gjertsen (exhibit, North Carolina Section of the AAPT, Asheville NC, November 1998).
d. "WebAssign," J. Risley, L. Martin, P. Gjertsen (exhibit and workshop, NC Science Teachers Association, where Greensboro, NC, November 1998).
e. "WebAssign," J. Risley and P. Gjertsen (exhibit, National School Board Meeting Association, where Nashville, TN, October 1998).
f. "WebAssign," J. Risley, L. Martin, and P. Gjertsen (exhibit, Educom meeting, Orlando Fl, October 1998).
g. "SCALE-UP," J.M. Saul and D. Deardorff (exhibit, North Carolina State University Educational Technology Exposition, Raleigh NC, September 1998).
h. "WebAssign," J. Risley, L. Martin, and P. Gjertsen (exhibit, North Carolina State University Educational Technology Exposition, Raleigh NC, September 1998).
i. "Video capture and analysis in physics courses," P.W. Laws, P.J. Cooney, R. Beichner, and R. Teese (workshop, AAPT Summer Meeting, Lincoln NE, August 1998).
j. "WebAssign," J. Risley and P. Gjertsen (exhibit, J. Risley, A. Titus, and P. Gjertsen, AAPT Summer Meeting, Lincoln NE, August 1998).
k. "WebAssign for high schools," J. Risley, L. Martin, and P. Gjertsen, (workshop, North Carolina High School Teachers, Raleigh, NC, June/July 1998).
l. "WebAssign," J. Risley and P. Gjertsen (exhibit, NSTA Meeting, Las Vegas NV, April 1998).

3. Seminars and Colloquia

Faculty:

John Risley:

a. "WebAssign," seminar presented at Renssellaer Polytechnic Institute, Troy, New York in May 1998.
b. "Teaching physics with computers," colloquium presented at University of Tennessee in Feb 1998.

Robert Beichner

a. "SCALE-UP," a colloquium at Drexel University, Philadelphia, PA in March 1999.

b. “SCALE-UP Project,” a panel presentation at the FIPSE Annual Project Director’s Meeting, Washington, D.C. in October 1998.
c. “NC State's Physics Program: A Case Study,” a seminar at the Revitalizing Undergraduate Physics Conference, Alexandria, VA. in October 1998.
d. “SCALE-UP,” a colloquium at University of North Carolina, Charlotte, NC in September 1998.
e. “Using Technology to Establish Learning Environments,” Presentation for the Preparing the Professorate Program, North Carolina State University, Raleigh, NC, in January 1999.
f. “Linking Technology to Pedagogy,” Presentations for the Faculty Center for Teaching and Learning, North Carolina State University, Raleigh, NC, in June & July 1998, June 1999.
g. “Using Technology to Help Students Learn,” Hewlett Fellows Presentation, North Carolina State University,” Raleigh, NC in March 1998.

Postdoctoral Research Associates:

Scott Bonham

a. “Enabling physics education reform, computers and world wide web,” Colloquium presented at University of Northern Iowa, Cedar Falls, IA in March 1999.
b. “Enabling physics education reform, computers and world wide web,” Colloquium presented at Texas Tech University, Lubbock, TX in February 1999.

Jeff Saul

“The role of the hidden curriculum or what physics education research can teach us about the introductory physics course.” Colloquium presented at Duke University, Durham, NC in August 1998.

Journal Publications

a. "Case study of the physics component of an integrated curriculum," R. Beichner, L. Bernold, E. Burniston, P. Dail, R. Felder, J. Gastineau, M. Gjertsen, and J. Risley, *Phys. Ed. Res. Supplement to Am. J. Phys*., in press.
b. "Writing web-based prediction-observation questions," S. Bonham and L. Martin, submitted to *Computers in Education* (1999).
c. "GOAL-Oriented problem solving," R. Beichner, D. Deardorff, and B. Zhang, submitted to *Phys. Teach*., (1998).
d. "Using Physlets to teach electrostatics," S. W. Bonham, J.S. Risley, and W. Christian, *Phys. Teach., 37, 276-280.* (1999).
e. "Education research using web-based assessment systems," S. W. Bonham, A. Titus, R. J. Beichner, and L. Martin, submitted to *J. Res. Comp. Ed*. (1998).
f. "What physics education research can teach us about the introductory physics course: A response to 'Innovations in physics teaching, a cautionary tale,'" J.M. Saul, E.F. Redish, and R. Beichner, in preparation for submission to *Phys. Teach*. (1999).
g. "The role of the hidden curriculum: An evaluation of research-based approaches to the introductory physics course," J.M. Saul and E.F. Redish, in preparation for submission to *Phys. Ed. Res. Supplement to Am. J. Phys*. (1999).

Books or other non-periodical, one-time publications

a. *Physics for Scientists and Engineers, 5th ed.,* R. Serway & R. Beichner, in progress (Saunders, Philadelphia PA, 2000).
b. *Instructor's Manual to Accompany Physics for Scientists and Engineers, 5th ed.,* (see Ref. a.) R. McGrew, C. Teague, and J.M. Saul, in progress (Saunders, Philadelphia PA, 2000).
c. *Study Guide Student Solutions Manual to Physics for Scientists and Engineers, 5th ed.,* (see Ref. a.) by J. R. Gordon, R. McGrew, and R. Serway, in progress (Saunders, Philadelphia PA, 2000). D. Deardorff, an NSCU PER-D Ph.D. student, is contributing the GOAL solutions for all 44 chapters.

Cooperative Learning

"The best answer to the question, 'What is the most effective method of teaching?' is that it depends on the goal, the student, the content, and the teacher. But the next best answer is, 'Students teaching other students." McKeachie, W. (1994) *Teaching Tips*, 9th ed. Lexington, MA, Heath & Co.

As you might guess from the name, cooperative learning (CL) involves students working in groups on structured tasks. However, CL is *not* students sitting around a table studying together or assigning group projects where one student ends up doing most of the work. According to countless studies, there are five absolutely critical aspects of successful cooperative learning. Omit one or more of the items on the following list and group work will almost certainly fail in your classroom. The five defining aspects of CL are:

1. *Positive interdependence*. Team members have to rely upon one another.
2. *Individual accountability*. Each member is responsible for doing their own fair share of the work and for mastering all the material.
3. *Face-to-face interaction*. Some or all of the group effort must be spent with members working together.
4. *Appropriate use of interpersonal skills*. Members must receive instruction and then practice leadership, decision-making, communication, and conflict management.
5. *Regular self-assessment of group functioning*. Groups need to evaluate how well their team is functioning, where they could improve, and what they should do differently in the future.

These criteria can be found throughout the literature. If you are interested in more details visit Richard Felder's website www2.ncsu.edu/effective_teaching/ or read D.W. Johnson, R.T. Johnson, and K.A. Smith, *Active Learning: Cooperation in the College Classroom*, 2nd Ed. Edina, MN, Interaction Book Co., 1998. Many of the ideas listed here come from these two sources.

The benefits of CL include improved student-faculty and student-student interaction, information retention, academic achievement, higher-level thinking skills, attitudes, motivation to learn, teamwork and interpersonal skills, communication skills, self-esteem, attendance, race/gender relations and reduced levels of anxiety. Although this seems like a huge list, there are numerous studies where these results have been carefully documented. Of course, for the teacher there are fewer and better papers to grade. There is quite a bit of educational psychology behind why CL techniques work so well (if all 5 aspects are present). These include the fact that the learning is done in an active manner, groups keep going when individuals might give up, students see alternative problem-solving approaches, more and higher quality questions are produced, there is less fear in class, and as noted in the quotation above, people learn best when they teach.

There are basically two different strategies for implementing cooperative learning: informal and formal. The informal methods can be put into practice "on the fly" during class.

Informal CL Structures

For all of these techniques, be sure you clearly explain the task, randomly call on students to report, circulate around the room and listen, and don't get into a pattern of always alternating short lectures with CL. Variety is the spice of life!

- In-class teams: Divide students into groups of 2 to 4 students and choose a recorder ("Who has the longest last name in your group?", "Who got up earliest this morning ?" or similar questions are icebreakers and automatically select a variety of recorders.) Give the teams a couple of minutes to recall prior material, answer a question, start a problem solution, work out the next step in a derivation, think of an example or application, figure out why a given result may be wrong, identify underlying assumptions in a solution, brainstorm possible answers to a question, generate an exam problem, summarize material, etc. Collect some or all the answers.

- Think-Pair-Share: Ask a question that requires careful consideration (perhaps from Eric Mazur's *Peer Instruction: A User's Manual*, 1997, Upper Saddle River, NJ, Prentice-Hall). Give students a minute or two to think about the problem individually. Have them pair up to discuss and produce an answer agreeable to both, and then select teams to share their answers with the class. Be sure to elicit comments on answers that changed and why the pair decided a particular answer was right or wrong. Students don't need to say which member of the pair had the original, incorrect answer so you will be more likely to hear reports of the kinds of misconceptions that are commonly seen. If students don't mention a particular misunderstanding that you know is widespread, bring it up for discussion. You can be sure that someone in the room was thinking along those lines and could benefit from a re-examination of their understanding.

- Cooperative Note-Taking Pairs: At the beginning of class, pair up the students. Every once in a while during class, pause and have one partner summarize their notes to the other. The other person can add information, ask for clarification, or make corrections. The goal is for everyone to improve his or her note taking ability.

- Guided Reciprocal Peer Questioning: Have students work in teams of three or four give them a collection of "generic question" stems like these:

How does … relate to what I've learned before?	What if …?
What conclusions can I draw about …?	Explain why …
What is the difference between … and …?	Explain how …

What are the strengths and weaknesses of …?
What is the main idea of …?
What is a new example of…?
What is the best … and why?
What is … important?
How are … and … similar?
What is the meaning of …?
How would I use … to …?
How does … affect …?

Have each student prepare several thought-provoking questions. Form groups of two or three and have members answer the individually-created questions. Bring the whole class together to discuss particularly interesting or problematic questions. For additional ideas, see King, A. (1993). "From sage on the stage to guide on the side," *College Teaching, 41* (1), 30-35.

- TAPPS (Thinking Aloud Pair Problem-Solving): Have students do this with key problems or an important derivation. This activity takes a lot of time, but it is very powerful. It works well in conjunction with the different steps of the GOAL problem-solving protocol. Start by forming pairs, with one student being the problem-solver and the other the listener. Present the problem to the teams and assign a specific portion to be the focus of effort. The solver talks through the first part of the solution while the listener questions, prompts the solver to keep talking (that's the thinking aloud part), and gives a few clues, if needed. After a few minutes, collect partial solutions from several listeners (not solvers) and reach a classwide consensus. Reverse the roles and have the teams continue. More detailed instructions can be found in Lockhead, J. & Whimbey, A. (1987). "Teaching analytical reasoning through thinking aloud pair problem solving. In J. E. Stice (Ed.), *Developing critical thinking and problem-solving abilities: New directions for teaching and learning, No. 30,* San Francisco: Jossey-Bass.

Formal CL Structures

One thing you don't want to do when getting ready to implement formal CL approaches is to let students select their own groups. In order for everyone to be treated fairly, the groups must be heterogeneous in ability. This can be done by reviewing GPA or other background information provided by your university. Another method that is useful is to give students a diagnostic test at the beginning of the semester. Not only will this help you form groups, but it gives you a "before snapshot" so that you (and your students) can see how far they've come by the end of the semester. Once you have a ranked list of students in a class, simply divide them into top, middle, and bottom thirds. (Don't tell the students how the groups were selected or they'll spend the rest of the semester worrying about whether they are the "slow kid on the team.") Select a student from each ability level to form groups of three. There are additional constraints on these selections: (1) Don't pick people you know are already friends to be teammates. The other person in the group may not fit in well. (2) If you can collect schedule information, try to make sure there are common times the teams can get together outside of class. (3) Don't let underrepresented populations (usually women or minorities) be outnumbered in a group. Studies have shown that this precaution reduces the tendency for contributions from these students to be minimized.

You will need to explain to your students why you are having them work in groups. This may be a new idea to them. If they are engineering students, simply remind them that they must work with other people before they can get their professional license. This is certainly the way the workplace operates now. There are numerous employee surveys illustrating that team skills are a top hiring criterion. If nothing else, explain how it will help them learn!

Once groups are formed, keep them intact for at least a month while students work out the any difficulties that arise. Again, remind them that they generally won't get to pick who they work with on the job. With guidance from you, have each team write a contract listing goals and expectations. Have each member sign their contract, make copies for the team, and submit the original for your files. It helps to have samples available. Brainstorming characteristics of a successful group is also a useful exercise. You will almost certainly need to provide teamwork instruction. Visit the excellent Collaborative Learning Website at www.wcer.wisc.edu/nise/cl1 or download the *Team Training Workbook* from www.eas.asu.edu/~asufc/teaminginfo/teams.html.

Make a concerted effort to support the five criteria mentioned earlier. To help promote positive interdependence, assign different roles (manager, recorder, skeptic) to group members. Give critical information only to the manager. Rotate roles periodically or for each assignment. Provide one set of resources and require a single product. Don't forget to require individual accountability—use primarily individual testing. Have someone in the group routinely checking everyone's understanding. Call on individuals to present and explain results (while groups are working and after work is complete). Make groups responsible for seeing that non-contributors don't get credit. Get each member to rate everyone's contribution, including their own. Make sure they explain their ratings. Provide last resort options of firing a group member or quitting. Although this seems silly, if a substantial portion of the grade comes from group work, there is considerable motivation to be part of a group if that is the only way those assignments can be submitted.

It is especially important that you do not curve course grades. It should be possible for everyone in the class to earn an "A" (or an "F"). If students know that their grade depends on them doing better than others in the class, there isn't much motivation for cooperation. Establish a set of objectives for each topic and provide students with a syllabus that clearly delineates cutoff points. Students are much more motivated to perform if they know exactly what is required of them and the consequences of not performing.

Several formal structures to facilitate collaborative learning are listed below. More can be found in the references noted throughout this section and on the web. Forms to support team self-assessment along with instructor checklists for each of the techniques below are available on the SCALE-UP website.

- Team homework: Assignments are completed and handed in by teams. (Only active participants' names are included on materials submitted for grading.) One grade is given for the entire team, although it is possible to adjust the academic score by incorporating members' "teamsmanship" scores. For problems sets, it is a good idea to have each individual outline a solution to each problem before getting together to complete the solutions. You can enforce this by occasionally collecting everyone's outlines. Beware of the tendency of groups to "divide and conquer" an assignment by having individuals finish entire problems on their own and simply collecting the results. They don't get the benefit of group thinking and it's hard to make sure that everyone understands all aspects of the assignment.
- Team projects: You can illustrate the value of groups by giving assignments that would be too difficult or too much work for an individual to complete in a reasonable amount of time. These can include designing something, creating web pages discussing the physics of familiar devices or situations, giving presentations to the class, etc. See the Jigsaw technique for a way to facilitate this type of effort. Each team gets a single grade that may be adjusted for individual contributions.
- Jigsaw: Individual group members have access to resources that the others don't have. These could be something as simple as a handout describing a specific portion of their task or even specialized instruction that only one member of a team receives. This fosters interdependence within the group and encourages learning as each individual shares what they know with the others. To set up the "expert areas" within each group, give each team member a number: 1, 2, or 3. Gather all the #1 people together and give them their particular set of information. Do the same with the #2 and #3 people. Then they can get together (either in class or out of class) to complete the task. This approach also works nicely when students study for a test. Each member becomes an expert on a particular topic and makes sure his or her teammates thoroughly understand it.
- Group bonus: If the average exam score for a group is above 80 or some other value you decide upon in advance, each member of the group gets an additional 5 points added to their score. (Do *not* require that each individual score be above the cutoff. This puts tremendous pressure on the lower performing student.) This technique has been very successful in promoting learning. It is a wonderful way to motivate the more advanced student to participate in group work rather than feel "pulled down" by the others in the team. Of course, if you recall from when you first taught a course, it is in teaching others that we really gain understanding. So the brighter student benefits at least as much as the others in the group.
- Individual Test followed by Group Test: Hand out exams as you normally do. After a specified time, collect the tests but then allow teams to work together on the same problems. Incorporate performance on the group test into the individual scores, perhaps by giving a bonus if the group test is above 90% or add some fraction of the points earned on the group test.

A National Center for the Reform of Undergraduate Education

We propose the establishment of a Center to rigorously study and model the reform of undergraduate education, primarily in science, mathematics, and engineering. We have an excellent opportunity to make a national impact on college-level teaching. A particularly fortuitous combination of people and events means that if a systemic restructuring of undergraduate education is ever going to happen, it would happen at NCSU first!

Why here?

The University's Mission Statement stresses the importance of establishing an innovative learning environment that emphasizes mastering fundamentals, building intellectual discipline, promoting creativity, enhancing problem solving, and increasing students' responsibility for their learning. The Strategic Plan notes that the technological expertise found at NCSU makes it easier to prompt substantial "changes in our classroom paradigm: from group lecture to individual exploration, from passive absorption to active apprenticeship, from omniscient teacher to educational guides, from homogeneous to diverse learning experiences, and from stable to fast-changing content." Thus the University has already recognized its strengths and responsibilities in regards to teaching and learning and is acting on them. Since we are already involved in reforming our own instruction, it makes sense to expand these efforts and become a national model for others to emulate.

We currently have experts in most of the areas that need to be represented in the Center. Our own Physics Education R & D Group is highly regarded. Besides creating WebAssign and publishing instructional software, we also have been involved in several textbook and CD authoring projects, including writing books for K-6 teachers and developing nationally normed achievement tests. The Science House provides some of the best teacher training to be found anywhere. The Chemistry Department has just hired a faculty member in Chemistry Education Research and Engineering's Rich Felder, probably the most widely respected engineering educator in the country, has expressed great interest in the possibilities raised by the Center. The entire College of Engineering has been extremely supportive of educational innovation and could take a major role in the work of the Center. We have also benefited from many collaborative projects with John Park from Science Education. The Education School should be able to provide a great deal of expertise to the Center. There should be a substantial synergistic benefit to having all these groups working cooperatively to conduct rigorous studies of college-level instruction.

There are several other groups on campus that would also be important components of the National Center, including the new Faculty Center for Teaching and Learning, the Center for Learning Technologies, and the Center for Research in Mathematics and Science Education. The Computer Science Department also has several studies of instructional technologies in progress. The Preparing the Professorate program and the Hewlett Initiative illustrate University-wide efforts to improve teaching and learning.

Why now?

With the recent arrival of Chancellor Marye Anne Fox, we have gained a nationally recognized proponent of educational reform. As chair of the NRC's Committee on Undergraduate Science Education that produced *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*, Dr. Fox has demonstrated that she should be a strong supporter of the Center and its work. According to the report, "The time has come for the institutionalization and sharing" of instructional reform and improvements to courses, programs, and curricula. Her implementation of the Compact Planning approach provides us with an avenue to increased University support for our efforts. Coincidentally, new Deans coming on board simultaneously in PAMS and the College of Education and Psychology may facilitate a restructuring to further facilitate cooperation between these two Colleges.

New accreditation standards from ABET require that engineering students be exposed to inquiry-based learning throughout their studies. Given that we cannot economically provide reduced class sizes for the large number of engineers that we serve, NCSU (and, of course, all other engineering schools) will be searching for creative ways to revise their programs. Our Center would not only develop new approaches to instruction and conduct thorough studies of educational effectiveness, but it could act as a national clearinghouse of information as schools respond to the ABET recommendations.

Another driver for undertaking the large-scale examination of reform at this time is the rapid advance of technology. Although many faculty are utilizing computers and the internet in their teaching, relatively little research has been done to study educational technology's impact or to explore the most effective ways of incorporating it into existing curricula. Technology may provide the means of serving large numbers of students while still maintaining active instructional environments. As distance learning becomes more popular, we must find ways to incorporate it into our offerings or risk being put out of business. Virtual universities are gaining accreditation and students are now graduating from their programs. Since it is already reforming our ideas about education, we must examine distance learning and determine when it is most effective and when it is not. A recommendation of the University's Board of Visitors states that "as instructional technologies are developed, special care be taken to ensure that the human dimension of the educational experience is enhanced and not lost. To the extent that resources allow, NC State should strive to utilize technology that enhances human interaction by promoting collaboration, collegiality, and increased one-on-one exchanges between faculty and students." This should serve as a guide to our efforts to change the way the University teaches. The UNC system's current emphasis on technology means that this is the time to expand upon our strength in technology and find brand new ways to improve learning at the university level.

What would the center do?

Given the technology orientation of the University, it is clear that we should continue the development and study of instructional technology. The Department is already highly regarded in this area and faculty at the Center should be able to extend these efforts into other disciplines. WebAssign usage is expanding rapidly. It can be a vehicle for promoting educational change and is itself an interesting area of research. The SCALE-UP project has been working to find effective teaching strategies and new materials to engage students in physics. These techniques can be adapted to courses taught by other departments. And pedagogy that is shown to work well in the large SCALE-UP classes should translate to improvements in small classes as well, including upper division courses.

Because a substantial fraction of the University's instruction is aimed at generating new teachers (through the entire K-16 range), teacher education should be an important effort of the Center. We could develop programs where teachers get a strong content knowledge along with new ways of teaching that content. Obviously the College of Education ought to play a leading role in these efforts. But our own Science House has tremendous experience in showing K-12 teachers how to improve their instruction. The

Center would support these efforts as well as implement workshops for K-16 teachers on a national level through discipline-oriented teaching societies like AAPT and the NSTA and by extensions of the popular Felder/Brent workshops. Of course, these would be taught using the latest pedagogy, a critical point since "teachers teach as they were taught." Through cooperative efforts with teachers from K-12 schools, experts in teaching techniques could share their expertise with college faculty, who in return would provide content knowledge. These workshops could use the classroom facilities and materials we develop during our efforts at reforming our own classes.

It may also be possible to support web-based sharing of teaching materials along with educational research information, as is found in the NCSU-based *Electronic Journal of Statistics*. We might be able to provide similar publications in physics education and perhaps other areas as well.

What does the Physics Department get out of it?

A successful National Center would bring substantial recognition to the University. We have already had many visitors to the SCALE-UP project. A University-wide effort to carefully study and revise the way we teach should result in a continuous stream of inquirers. Of more direct benefit to the Department would be the additional Center faculty who would strengthen an existing research group and also reduce the service teaching load on the rest of us. Of course, with continuing systematic efforts to improve learning, NC State also becomes known as the place to go for a high quality education. That is where the real benefit lies.

Implementation Support for SCALE-UP

Introduction:

The implementation support for SCALE-UP has four components. These are:

1. SCALE-UP evaluation visit to NCSU
2. Implementation Planning Workshop
3. Two site support visits by SCALE-UP advisors
4. SCALE-UP website

Each component has a specific goal, and partial financial support is offered by SCALE-UP. Below each component is described in more detail.

1. SCALE-UP evaluation visit to NCSU

The goal of the SCALE-UP evaluation visit to NCSU is to allow a 2-3 person team from a potential partner institution evaluate the SCALE-UP model through direct observation of SCALE-UP in action.

The visit is expected to be one day long. During that time, the team will meet with students and faculty, observe SCALE-UP in a classroom setting, and receive information about the costs, and the impact on student learning. **SCALE-UP will provide up to $200 travel support to the team, the remaining costs to be borne by the home institution.** Following this visit, if the partner institution wishes to proceed with an implementation, they will be invited to send a team to the Implementation Planning Workshop.

2. Implementation Planning Workshop (IPW)

The goal of the IPW is to develop implementation expertise around SCALE-UP model and to develop a draft implementation timeline to take back to the home institution. The expertise comprises experience with the pedagogical techniques of SCALE-UP, as well as familiarity with the nuts and bolts operating issues. This expertise is critical for the development of a draft implementation timeline that takes into account the material needs of a SCALE-UP approach, professional development needs for faculty and TAs, adequate assessment and evaluation, and the institutional support for the program.

The IPW will be a 2-day workshop that begins on a Saturday and ends Monday. The topics to be covered are:

- The structure of SCALE-UP and the pedagogical underpinnings
- Implementing SCALE-UP - the nuts and bolts
- Practice in using the SCALE-UP approach - sample lessons given by participants
- Planning an implementation timeline
- Quantitative assessments of implementation costs and faculty time commitment

Participation is by invitation after discussions about the match between the needs of the institution and the SCALE-UP approach. Usually there will have been a site visit as described above. Participating institutions will send a team of 3-4 members to the IPW after. **Each team accepted to the IPW will receive $800 in travel support, with the remainder to be provided by the home institution.** The department chair is to be a member of the team; exceptions will be made sparingly.

3. Site support visits by SCALE-UP advisors

The goal of the site support visits is to provide sites implementing the SCALE-UP model with additional support and consultation, and to provide the NCSU SCALE-UP team with direct information about implementation issues that my benefit future SCALE-UP sites. Each partner institution will be able to request two site visits by SCALE-UP advisors. **The first visit will require that the partner institution cover local expenses for the advisor, while the costs for the second visit will be borne by SCALE-UP.**

4. SCALE-UP website

The goal of the SCALE-UP website will be to provide a means for partner institutions to exchange information about SCALE-UP. Portions of this website will be public, with basic information about SCALE-UP and the support for implementation. Other portions will be private and reserved (IP-protected) for those institutions that are implementing SCALE-UP. The reserved portions will include threaded discussion groups and a listserve for the exclusive use of SCALE-UP partners.

Conclusion:

The proposed support structure will provide partner institutions with considerable assistance in implementing the SCALE-UP program. Additional support in the form of a SCALE-UP implementation conference, or satellite meeting at AAPT may also be considered depending on the needs of the community.