Interactive Engagement: How Much Is Enough?

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It is now widely known that interactive engagement (IE) teaching methods are the most effective methods of teaching physics. As physics instructors, we now have a variety of methods and models to choose from to make courses interactive. Included in these are methods that function as interactive adaptations to the traditional structure of physics classes, such as Peer Instruction (PI), and those that modify the entire structure of the course, such as the “studio” or “workshop” format. These possibilities raise the question: Is it worth the effort and expense to completely modify classrooms and instructional time by going to a studio model, or is a simpler IE method such as PI adequate by itself? What method will most easily help your students meet the course learning goals?

Over the past several years, the authors have taught in and compared the performance of students in three types of classes: a traditional lecture course, lecture with PI added, and the SCALE-UP model. These classes were all calculus-based physics, drawing from the same pool of science majors at Coastal Carolina University (CCU), with the same instructor.

Lecture modifications such as PI are easier to implement within the formal structure that is often found at larger institutions, or in departments with a high service course load. It is still possible, though, to implement studio-style instruction even when the class size is large. The SCALE-UP (Student-Centered Activities for Large Enrollment Undergraduate Programs) model, developed by the Physics Education Research Group at North Carolina State University, is an example of a studio-style class that has been shown effective in large classes. This method fuses the lecture and laboratory into a single entity where students learn physics in a technology-rich, interactive setting.

Most physics teaching at CCU is service for the majors of other natural science departments. Of the roughly 100 students enrolled in university physics (calculus-based) at CCU each year, 60% are women and 5% are minority. Two-thirds of the students are marine science majors (66% women and 2% minority) who have diverse interests and abilities. Most of our students belong to majors that require at least a C average in physics concepts for their upper-level courses. When the authors arrived at CCU, physics courses were taught in a traditional format, consisting of three hours of lecture each week and a separate three-hour lab. The physics classroom consisted of desks in rows, with a lecture-and-demonstration podium in the front of the room. The students met in smaller groups for a separate asynchronous lab.

It has been shown repeatedly that this traditional format has a woefully disappointing impact on student learning. When the authors began to perform pre- and post-testing on the students with the Force Concept Inventory (FCI), it confirmed the anecdotal evidence of a lack of student understanding of the material: the students’ average final score on the FCI was a 0.34 ± 0.13, with an average normalized <g> of 0.18 ± 0.17. This normalized gain factor is defined by Hake as

$$<g> = \frac{(Post-test - Pre-test)}{(100\% - Pre-test)}.$$  (1)

This tells us what percentage of the material the student learned that he/she did not already know. One of the advantages of using <g> is that it gives you the ability to compare the amount of student learning occurring in different classes where students may arrive with differing levels of prior physics knowledge. Hake defines three ranges of <g>: low (0 – 0.3), medium (0.3 – 0.7), and high (0.7 – 1.0). All traditional courses in Hake’s survey fell into the low-g category, while most IE courses fell in the medium-g category, and none obtained high-g results.

Our results were sobering when compared to Hake’s report of an average gain of 0.23 ± 0.04 for traditionally taught courses like ours, especially considering that a score of 60% on the FCI is considered the threshold of understanding of Newtonian physics needed for successful problem solving. Another point that these results suggested to us was that there was a huge variance in the effectiveness of the course among our students, with several students scoring worse on the post-test than the pre-test. It was obvious that changes were necessary; these physics students needed more support than the traditional lecture/lab environment could provide.

Over the next several semesters, the authors began to implement IE methods in the classroom. During this time, data were collected about student performance on the FCI and course averages and failure rates in calculus physics. The FCI test (a version with additional work and energy questions developed by Bob Beichner at NSCU) was administered to all students at the beginning and at the end of the course. Students received no credit or grade for the pre-test, but were given a quiz grade based on the post-test score that accounted for an extremely small part of their overall average. The primary instructor for these sections was Dr. Keiner.

We started our implementation of IE with the strategy of Peer Instruction. This has been successful in many settings in bringing IE into the classroom. It engages students by inter-
a close variant of this method, including a modified classroom and instructional time period design, cooperative group learning, active learning strategies, and the use of technology both in class and out of class. Among the major features of the SCALE-UP method are:

- **Instructional Time Structure:** The SCALE-UP model combines the lecture and laboratory into one two-hour block that meets three times each week. During this block time, there is a mixture of mini-lectures, laboratory experiments, computer activities, and group problem solving. Topics covered in the mini-lectures are immediately applied and reinforced by activities, problems, and laboratories (Fig. 1). The sequence of instructional techniques can therefore be more logical than with the traditional format. PI is still utilized in this model—it is just now part of a larger scheme of interactive engagement.

- **Classroom Space:** The classroom layout was completely changed to facilitate collaboration and interaction among the students. Rows of desks were replaced by seven-foot wide circular tables, which each sat nine students (Fig. 2). This format allows students to either listen to the instructor or work in groups as is appropriate. This format also removes any sense of a “front” of the room. The instructors use a mobile cart with a projector, which is placed in the middle of that classroom.

- **Cooperative Learning:** Students are arranged in groups of four, which remain throughout the semester. Each group sits together at the round tables and partakes in all the class activities together. These include think-pair-share exercises, in-depth real-world problem solving, running computer simulations, and traditional data-taking and analysis labs using PASCO and Vernier equipment for obtaining data with a computer. The members of each group are expected to help each other in class, on homework problems, and in studying for exams. To encourage this, groups are given bonus points on exams if the group’s exam average is above a certain threshold.

        Table I. Data on student performance in traditional, Peer Instruction (only), and SCALE-UP classes.

<table>
<thead>
<tr>
<th># Sections</th>
<th>Lecture 1</th>
<th>Lecture + PI 4</th>
<th>SCALE-UP 7</th>
</tr>
</thead>
<tbody>
<tr>
<td># Students</td>
<td>20</td>
<td>145</td>
<td>192</td>
</tr>
<tr>
<td>Mean Pre-FCI</td>
<td>19.1%</td>
<td>26.6%</td>
<td>30.1%</td>
</tr>
<tr>
<td>Mean Post-FCI</td>
<td>34.1%</td>
<td>43.8%</td>
<td>54.7%</td>
</tr>
<tr>
<td>at or above 60%</td>
<td>5%</td>
<td>22%</td>
<td>46%</td>
</tr>
<tr>
<td>&lt;g&gt;</td>
<td>.18</td>
<td>.24</td>
<td>.36</td>
</tr>
<tr>
<td>Low &lt;g&gt;</td>
<td>65%</td>
<td>57%</td>
<td>32%</td>
</tr>
<tr>
<td>Medium &lt;g&gt;</td>
<td>35%</td>
<td>39%</td>
<td>61%</td>
</tr>
<tr>
<td>High &lt;g&gt;</td>
<td>0%</td>
<td>4%</td>
<td>7%</td>
</tr>
<tr>
<td>D/F rate</td>
<td>20%</td>
<td>18.2%</td>
<td>13.5%</td>
</tr>
</tbody>
</table>

spersing short conceptual questions (ConceptTests) throughout the lecture to increase student understanding and reveal to the instructor (and the students) where misconceptions are present. It is easy to implement within the existing structure of a lecture, and there exists much material ready to be used in class. We used the ConceptTests from Mazur’s book,\(^2\) as well as developing ones of our own.

Our results with this implementation were positive (Table I). We saw the mean student FCI score go to a 43.8%, with 22% of our students over 60%. Our observed \(<g>\) increased to 0.24. This was a welcome change from the dismal results that we had seen before, but it was definitely not yet where we wanted our students to be. Of note is that 7% of students were still scoring worse on the post-test than the pre-test. Our goal has always been for all of our students to come to at least a basic understanding of physics, and we were not there yet.

We then decided to increase the amount of IE in the course by implementing the SCALE-UP model at CCU. The SCALE-UP model consists of a blend of IE strategies that have been proven successful at teaching physics.\(^12\) We have implemented

Fig. 1. Students involved in group activities: A video-analysis laboratory.

Fig. 2. (a) Original configuration of the classroom.

Fig. 2. (b) Remodeled classroom – round tables and whiteboards on the walls.
With the implementation of the full SCALE-UP model, our classes crossed into the medium-\(g\) range for the first time (Table I). Our students’ mean post-FCI score increased to 54.7%, with a mean <\(g\)> of 0.36. Perhaps most importantly, the number of students crossing the 60% threshold increased to 46%. There were, of course, variations in student learning gains by semester (Fig. 3). However, student performance in the “worst” SCALE-UP semesters was better than that in the best of the previous semesters.

It is important to note that the IE methods were successful in raising the performance of both our lowest performing and highest performing students. The percentage of students scoring in the low-\(g\) range drops with each step, and the percentage of students scoring in the medium- and high-\(g\) ranges increases. In the SCALE-UP classes, 68% of students’ gains are at least in the medium-\(g\) range, with 7% in the high-\(g\) range. Figure 4 illustrates the shift in the numbers of students making large learning gains in the SCALE-UP class. The D/F rate also fell with each implementation of IE strategies.

These data confirm to us that the greater the amount of IE techniques used in the classroom, the greater the amount of student learning. While in our context, introducing PI made major improvements in the amount of student learning, that technique by itself was not sufficient for most of our students to get to the level of understanding necessary for really understanding Newtonian physics. This experience stands in contrast to that of some PI adopters,\(^{15}\) who report student learning gains in the medium-\(g\) region. Here, it was only when we completely redesigned the course structure and setting in the SCALE-UP model that we began to see large numbers of students reaching minimally satisfactory levels of understanding.

Our use of the SCALE-UP model has also had positive effects beyond our physics courses. This instructional model has been applied in other subjects, such as physical oceanography, and the SCALE-UP classroom has become popular with other science departments. As other disciplines see the benefits of such collaborative learning environments, they are moving to set up their own versions of this classroom environment.

This is not to say that everything went smoothly with our transition to the SCALE-UP model. We found that there was initially a great deal of resistance from students to participating in class activities. Some resented the fact that when they came to class, they were expected to be actively involved in applying the material that they were learning. When we talked to these students about this, we found that this was the first college class in which they were expected to actively participate during the “lecture” portion of the course. What we learned from this was that it was very necessary to inform the students about why we were running the class in a certain way, and to show them the gains that previous students had experienced in understanding along with the increase in the average grade in the class. In doing so—making the students feel a part of the process—we were able to increase their understanding and satisfaction with the course.

In conclusion, we have found that our students need a highly interactive learning environment in order for them to succeed in introductory physics. For us, this came with the addition of the full SCALE-UP model to the PI methods that we were using. Our suggestion to instructors interested in applying IE methods is to start, as we did, with techniques that are easy to implement, and then to add more until your students are learning as much as they should. We are still looking for ways to improve. Our goal, once again, is for all of our students to have a good understanding of physics and the ability to apply it to their majors and in their everyday lives.

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References


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