Many instructional strategies exist that address poor student success in the sciences. They often go untapped, however, due to the knowledge or time needed for implementation. This article presents a formula for success that has encouraged a significant proportion of faculty in a physics department to adopt teaching methods, involving the use of clickers in lecture, that support student-centered learning. Interview data from faculty new to the use of clickers and student survey data regarding attitudes toward clicker use are presented. The findings shed light on the potential of using clickers to ease faculty into implementing other proven instructional pedagogies.

As a physics education researcher, not only am I aware of these reforms, but also within my own courses, I have successfully implemented interactive engagement techniques in lecture (Hake 1998; Mazur 1996), *Tutorials in Introductory Physics* (McDermott and Shaffer 2002) in recitation, the use of peer instructors to support student problem-solving activities, and *RealTime Physics Active Learning Laboratories* (Sokoloff, Thornton, and Laws 2004). The impact of these reforms in my courses has been apparent in higher student attendance and success rates along with positive course evaluations.

Despite these encouraging outcomes, the reforms that I implemented have not transferred over to my colleagues’ courses. Teaching enhancement initiatives provided by the university and encouragement of reformed teaching by the department chair met with little enthusiasm. Some of my colleagues commented that the suggested reforms were no better than their own instructional methods, hence they could not justify additional preparation time or cost. Interestingly, the one reform that did capture the attention of my colleagues was the use of clickers in lecture.

**Clickers**

Clickers are part of a personal response system that changes lecture into a powerful interactive presentation that engages students in active learning. Multiple-choice questions are posed through a proprietary software application and students select responses via wireless keypads. Data is collected electronically, and a histogram of all responses is immediately displayed to both instructor and students. Proper use of clickers impacts student understanding not only by making the learning environment active, but also by making evident any knowledge gaps and misconceptions that the students
may have (Reay, Pengfei, and Bao 2008). Responses stored electronically can be later viewed to track student progress and attendance.

The financial investment of clickers can be substantial. Although clicker use was in the early stages of implementation at my university, the commitment had been made by the university to use clickers and supporting software from Turning Technologies, LLC. This commitment ensured students could purchase one clicker for use in multiple courses. When I started using clickers during the spring of 2007, the cost was $25 each if packaged with a textbook and $53 if purchased separately. Although the supporting software could be downloaded free from the supplier website, one receiver per classroom was needed at $100 each.

Regardless of the interest my colleagues had shown in using clickers, and despite the fact that the year before I started using clickers in my own courses several had attended a clicker demonstration set up by the department chair and conducted by a supplier representative, none had acted on this interest in part because of the financial investment for an instructional method for which they had no experience. Some expressed concern regarding the time it would take to (1) get the clicker hardware and software running, (2) develop effective clicker questions and create presentation slides, (3) learn the software for posing clicker questions and tracking students, and (4) rewrite current lectures to allow time for clicker use.

I also provided one-on-one training and presentation slides of all clicker questions I used in my courses.

Faculty response to clicker use
During the 2007–2008 academic year, 7 of the 14 physics faculty taught at least one course (or part of a course for those team teaching) using the clickers. Faculty were later interviewed to assess (1) how the clickers were used in their teaching, (2) their views about the advantages and disadvantages of using clickers, (3) the ease of implementing clickers into their teaching, and (4) whether they would use clickers again. Their responses are compiled in Table 1.

I was amazed at the overwhelmingly positive responses I received from the faculty regarding clicker use. All indicated that the advantages far outweighed the disadvantages and that they would continue to use clickers in future courses.

Student response to clicker use
Over 400 students used the clickers during this initiative in at least one course. Two sections, consisting of 142 students, were surveyed to assess student views regarding clickers. The survey, adapted from the work of Bao, Ding, Lee, and Reay (N. Reay, personal communication, April 19, 2007) used a 5-point Likert scale (−2 = strongly disagree, −1 = mildly disagree, 0 = neutral, +1 = mildly agree, and +2 = strongly agree). See Table 2 for survey results.

The survey also included two open-ended questions asking students to list the advantages and disadvantages of using clickers. Roughly 30% included in their list of advantages the instant feedback provided by the clicker questions. Twenty-five percent indicated that the conceptual clicker questions had a positive impact on their learning as opposed to their only doing numerical problem solving. Twenty percent indicated clicker questions were engaging and helped them stay focused. Less frequent comments included (1) clicker questions increased confidence, particularly when the displayed histogram of student responses indicated others also didn’t understand a concept; (2) questions helped assess what students didn’t know and provided direction for further study; (3) learning increased because of interactions with peers prior to answering questions; (4) attendance was recognized; and (5) anonymity of clickers enabled nonrisk takers to participate. Of the 142 students surveyed, 12 left the question blank and 2 wrote “none.”

When asked to list the disadvantages of using clickers, 71% either left the question blank or indicated “none.” Twelve percent cited a loss of class time that could have been devoted to numerical problem solving. Others listed disadvantages including (1) could not sleep in class, (2) could not skip class without being counted absent, (3) occasional software issues took up class time, and (4) questions interrupted flow of lecture.

Survey results indicate that students are highly favorable to the use of clickers and in general believe they positively impact their learning. Although only two courses using clickers were surveyed, faculty of the nonsurveyed courses reported similar responses on course evaluations and student comments in lecture itself. Survey results also provide guidance in writing clicker questions in that students indicated a preference for questions that extended their knowledge and made them think more deeply about the material rather than confirm what they already knew. In addition, students were okay with clicker questions taking away time from demonstrations and numerical problem solving. This is important because the lecture format must be restructured to allow time for posing clicker questions.

Impact of clickers
The clickers purchased under the grant were a huge success in regards to their wide-scale implementation.
and acceptance by a large portion of the physics faculty. One direct impact of clicker use was the dramatic increase in student attendance. Although only four of the seven faculty counted attendance toward students’ final grades, attendance rates were extremely high at 80%–95% for all classes that included clickers versus 50%–60% for classes without clickers. One faculty who used clickers for just the second quarter of a three-quarter course indicated attendance went up dramatically during this quarter but dropped to original levels in the third quarter. Her students commented how much they missed using clickers, which had made the lectures more engaging and fun.

Another important outcome was the impact clickers had on my colleagues’ thinking as they prepared for their teaching. All indicated a positive change in their instruction with increased focus on student-centered learning. The following faculty quotes demonstrate this:

“Because I have to write or choose appropriate clicker questions, I think about my teaching more now. I construct my lectures focusing on how best to present new material to students rather than just presenting it as the text does. I think my lectures are better designed now to support student learning as I have to think about the learning process.”

“The use of clickers made me think more about my teaching . . .

### TABLE 1

<table>
<thead>
<tr>
<th>Question</th>
<th>Summary of comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often were clickers used?</td>
<td>All used the clickers every lecture. Most posed 4–6 clicker questions in a 50-minute class.</td>
</tr>
<tr>
<td>Were clickers used in recording attendance?</td>
<td>All used the clickers for taking attendance. Four counted attendance as part of the course grade.</td>
</tr>
<tr>
<td>Did clickers impact the attendance rate of lectures in your course?</td>
<td>All indicated an increase in attendance (from 50%–60% attendance without clickers to 80%–95% with clickers).</td>
</tr>
<tr>
<td>Where did you get your clicker questions?</td>
<td>All collected clicker questions from a variety of sources including adapting questions from the textbook or test bank, writing their own, and from other colleagues. For most this was not overly time-consuming.</td>
</tr>
<tr>
<td>How were the questions used in class?</td>
<td>All scattered the clicker questions throughout lecture. Most used questions before introducing a concept to assess prior knowledge, throughout lecture to build conceptual knowledge, and after coverage to assess learning. Most indicated they altered their lecture according to student responses.</td>
</tr>
<tr>
<td>What were some of the advantages of using the clickers in class?</td>
<td>Similar responses included an increase in attendance, creation of an active learning environment, and instant feedback to both instructor and student.</td>
</tr>
<tr>
<td>What were some of the disadvantages of using the clickers in class?</td>
<td>All cited the biggest disadvantage was a decrease in class time for lecture notes and quantitative problem solving. Minor disadvantages (cited by a few) included equipment problems and additional preparation time.</td>
</tr>
<tr>
<td>What type of difficulties developed as you implemented the clickers into your course?</td>
<td>Although all experienced some minor technology issues, there wasn't any issue cited by more than two. Some difficulties included software that could have been more user-friendly, software that froze when large simulations were running in the background, difficulty in cutting and pasting clicker questions from one application to another, receiver not installed in time, and learning how to run data reports.</td>
</tr>
<tr>
<td>Would you use the clickers again?</td>
<td>All indicated they would use clickers again. Several have made plans for students to purchase their own clickers for courses in which the department is not able to provide them.</td>
</tr>
</tbody>
</table>
that is, reduce lecture and do more example problems.”

“I was already using multiple-choice questions in class, but with clickers all students participate rather than just one or two students answering verbally. I also now alter my instruction based on the feedback I get with clickers.”

In addition, the following faculty quotes indicate reflective teaching practices as some comment on the instructional changes they will make the next time they use clickers:

“In the future I will use the clickers to track students and those scoring poorly on questions will be asked to come in for extra help.”

“I don’t think I spent enough time on why some clicker question choices were incorrect. I will have to do that better next time.”

“I can’t spend as much time doing problems in class but I think over time I will learn to better balance conceptual clicker questions with quantitative problem solving.”

“Not many students talked before answering the clicker question. I think if their answers counted for credit they might talk more. I will do this next time I use the clickers to further increase student engagement.”

With a dramatic increase in student attendance and more faculty attention drawn to effective teaching practices, an increase in student success is naturally expected; that is, more students earning a grade of C or higher. Because only a handful of courses have now incorporated the use of clickers, this data is somewhat limited. In addition, other pedagogical course reforms were implemented at the same time as clickers, including RealTime Physics Active Learning Laboratories in all lab sections, Tutorials in Introductory Physics in some recitations, and other interactive engagement techniques in some lectures. Although we are beginning to see increases of as much as 28% in student success rates when compared with baseline levels of student success rates for nonreformed courses, the data is still limited and any increases cannot be solely attributed to clicker use. These findings, however, are consistent with those reported in the research literature, which indicates courses with higher levels of interactive engagement yield higher rates of student success (Crouch and Mazur 2001; Hake 1998).

**Lessons learned**

Multiple lessons were learned, including the best way to distribute clickers to students. Each clicker contains a unique code, and because we wanted to track student performance and attendance, each clicker purchased under the grant was assigned to a student who brought it to each lecture. Although students were not given their final exam until the clicker was returned, students who dropped the course often did not return it, and within two quarters 40 clickers were missing. A new procedure in which clickers were individually labeled with students’ names and kept in the classroom was implemented to reduce further loss. Students picked up their clicker on the way into class from one of four alphabetically marked bins and dropped it into the same bin upon leaving. This new strategy was highly successful and the loss of clickers decreased dramatically. In addition, to extend our supply of clickers, we have successfully used the same set of clickers for two courses that meet on different days of the week. In this case each clicker contains two student names on different colored labels, with each student from a different course.

Some suggestions to improve the effectiveness of clicker use include (1) track student attendance so students who miss class often can be contacted, (2) give additional credit to those getting the questions correct to promote discussion and reduce guessing, (3) encourage students who consistently perform poorly on clicker questions to seek additional help, (4) ask several students to explain their reasoning behind various answers before revealing the correct answer to solicit information about student thinking, (5) design questions at an appropriate level with minimal words to encourage students to think through answer choices rather than give up and guess, and (6) consult existing resources. Many ancillary textbook materials include clicker questions, and multiple articles and websites include tips for clicker use (Milner-Bolotin 2004; Reay et al. 2005).

**Conclusion**

This is the first pedagogical reform that has been truly embraced by a large portion of my department. I was certainly surprised by the number who adopted this technology once it was made directly available. Others not given the opportunity to use clickers have expressed interest. The demand within the department is so high that students in some of our multiquarter courses now purchase their own clickers as we do not have enough to loan out.

One possible reason faculty latched onto this pedagogical reform is its immediate impact. Faculty suddenly witnessed an increase in student attendance and one commented, “The glazed-over eyes of the students disappeared when I used clickers.” The clickers make the teaching of large lecture courses more personable and enjoyable for faculty because they receive feedback from their students. Interaction is now possible with the entire class and not just those in the first row. For those of us who spend hours preparing lectures, suddenly seeing a large proportion of our students not only present but also
engaged and excited is certainly gratifying. It is also pleasing that students’ response to clicker use is highly favorable and that they believe it positively impacts their learning.

An important outcome of the wide-scale implementation of clickers within our department courses is that it has opened the channels of communication regarding student learning. In talking with the faculty about their clicker implementation experiences, it became clear that all want to improve student success but many lack the knowledge or time. Previous attempts at course reform had been unsuccessful, but it appears a formula for success includes (1) a faculty member who pioneers the reform, (2) provided resources (i.e., clickers), (3) easily accesssible faculty support and training, and (4) the backing of the department chair and university. All parts of this formula were apparently needed, and it is enlightening that during just one quarter of using clickers all have been sold on the pedagogy. With the channels of communication opening, I have high hopes that more and more of my colleagues will become receptive to other reformed teaching methods as well. ■

References

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