Re-Cycling

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A n old comedy routine on Saturday Night Live by Father Guido Sarducci introduced a “Five-Minute University” because five minutes is all that’s remembered after graduation anyway. In counterpoint, we discuss “cycling,” a teaching method for memory enhancement. Our principal implementation consists of offering a simple version of a given course in the first third of the semester, a deeper and more integrated version in the second third, and the final, targeted version in the last third. We describe the benefits and challenges in this tale from the trenches.

Introduction to cycles

For years we helped our students prepare for the physics Graduate Record Examination by addressing holes in their background. However, we were disappointed by how much the students had forgotten, even from classes taken the semester before. We spent most of our time revisiting standard stuff.

This “Teflon effect” prompted us to revisit how we teach. Fortunately, we were already immersed in a climate of innovation. The installation of a fiber optics network in 1989 at Case Western Reserve University led to electronic bulletin boards, emailed homework advice, video snippets, and more. The electronic learning environment and the novel employment of undergraduates had earned us a good deal of publicity.1,2

Thus, when the Teflon effect came to a tipping point, we were up for the challenge. Our premise was that students had only a single shot at certain subjects, so the associated knowledge tended to evaporate too quickly. Our solution was to take a 15-week semester and divide it up into two or three more or less equal time segments. For the three-part format, all main concepts with simple examples are presented in the first five weeks. During the next five weeks—the second cycle—we revisit everything but with more sophisticated mathematical modeling and more connections among the topics. The last five weeks, the third cycle, is at the desired level of interconnectedness, sophistication, and mastery of applications for all topics.

What about exams? There is typically an hour exam at the end of each cycle. However, there is no need for synchronization with the end of the cycle. An exam can and has been used in the middle of a cycle, testing the more advanced level of those subjects already revisited and retesting those subjects not yet revisited. The retesting portion may probe whether difficulties exhibited in homework, by students in the first cycle, say, have been overcome. We return in the third section to the exam content.

We have set up a website to showcase sample cycling material for the interested reader: http://www.phys.cwru.edu/sites/cycles/. Examples of semester schedules can be found there.

Benefits of cycling

By revisiting the material, we hoped students would better remember material, not only for the final exam but in subsequent semesters and years. After a decade with many different instructors, the encouraging news is that we believe more than just increased retention occurred. We list the benefits next, some of which were unanticipated, and come back to a discussion of challenges and assessment later.

1) Cycling helps students remember definitions, formulas, and applications. At the same time, students have the chance to reflect on difficulties and gain a deeper understanding of the concepts. The material is more deeply embedded and connected and therefore less likely to evaporate from memory.

2) Cycling provides an early picture of what the whole course is about. Students feel reassured because they know what is coming.

3) Cycling provides the necessary concepts and tools ahead of the weekly laboratory experiments. Conversely, more sophisticated math tools are not utilized until the second cycle, so students can get more help from their mathematics courses (e.g., calculus in university physics) they may be taking during the same semester.

4) We avoid the long hiatus between the time when the first subjects are presented at the beginning of the course and when they reappear for the final exam time. Students will have revisited that subject at least once.

5) With cycling, our students are not as overwhelmed by the hardest subjects, which are traditionally presented toward the end of the semester. Seeing the most difficult topics for the first time during a stressful period where the whole semester is coming to a head is avoided. We strengthen familiar concepts at the end of the semester instead of introducing new and intimidating topics at that time.

6) It offers a cure for the “post-exam syndrome,” where a student who does poorly on a midterm exam is downcast that we are going on to new material before she/ he has mastered the previous work.3

7) We have a natural mechanism for instructors to return to areas where the students may have exhibited difficulties.

8) Cycling synchronizes nicely with a three- or two-midterm exam schedule, with each midterm at the end of a cycle. Each exam is a preliminary, simpler, and shorter version of the final exam. The period between the
last midterm and the final is in effect another cycle where the student has by then a good picture of how well he/she is prepared and can study accordingly. We have been giving three tests, one every five weeks over the 15-week semester through the years. But, for example, one colleague favored two cycles, and two exams, for electromagnetism (one may use two cycles in EM, which allows the preview of the fundamental relationship of electric and magnetic fields through their time dependence, and in quantum mechanics, which allows a conceptual preview followed by more detailed quantitative work).

9) Cycling partners naturally with the new reform methods of learning, like “peer instruction,” “active inquiry,” and group study. Since we can go at a comfortable pace (see below), we use clickers and demonstrations in all cycles like any other class.

10) We are supported by cognitive research such as the proposal that students can learn better by “layering” or “interleaving,” rather than by “continuous” or “blocking” approaches. In particular, recent research does support the relevance of modern educational theories of student knowledge building, highlighted by David Kolb’s “learning cycle” description for “experiential learning.” Indeed, from where we sit, our method takes the students completely around the “learning cycle” with a pattern of lecture/homework/study/exam every five weeks. Moreover, the idea that “long-term memory” needs systematic feeding from “working memory,” which is limited in how much it can provide, is at the basis of “cognitive load theory.” The limitations mean we should think of optimal “chunks” to remember.

Challenges to Cycling

What price do we pay for the benefits? We analyze the challenges next:

1) Are standard textbooks inappropriate for cycling?
We find the beginnings of standard chapters serve the first cycle fairly well, and the rest of the chapters reasonably correlate with subsequent cycles. Roughly, one can take the first third of a traditional chapter for the first cycle, the second third for the second cycle, and so forth. The challenge includes choosing the proper level of homework, which can be difficult if problems are chosen indiscriminately. (A modest but complete textbook for mechanics designed for three cycles can be found at our webpage.)

2) Does an hour midterm exam at the end of each cycle have to cover all the subjects of the entire course?
No, tests (even with multiple-choice questions) never cover all the material in any approach. We do maintain in cycles the “free response” form of questions requiring detailed solutions. For broader coverage, we write compos-ite questions with parts connected to different subjects, and we use (sparingly) multiple-choice problems. Longer problems are still viable. As always, students do not know which subjects will be tested and need to be generally prepared.

3) Are homework and tests getting harder in later cycles?
Homework and tests are presented at increasingly higher levels of mathematics and sophistication, but this is our objective. As the students continue to revisit and reflect on the material, their abilities grow along with this increase in difficulty.

4) Are we jumping around too much?
By definition cycling does move through a larger number of subjects per week. But in our experience, with well-integrated general subjects such as mechanics, electromagnetism, or quantum mechanics, and covering fractions of chapters, we keep a reasonably natural flow to the cycles, as we have implemented them, that is coherent, not “jumpy.”

5) Will students dislike it, when they perhaps have become accustomed to going through a subject just one time?
The key to making students comfortable is making sure the homework and examination levels are appropriate for a given cycle. A serious error that a teacher can easily make is to put a problem on an exam that is more suitable for a following cycle. If we explain the what and why about cycling, students are more willing to embrace change when the process is perceived as transparent and directed to their benefit.

6) Is it boring to have nothing new to look forward to after the first cycle?
The richness of any of the areas of physics makes it easy to maintain student interest. There is always a new and surprising demo to go along with the revisiting of an area. Our students seem to appreciate that cycling shortens connections between apparently disparate topics.

7) Does this mean a lot more work for the instructor?
We feel that the level of preparation is not significantly different from the workload required to first-time teach a course in the standard linear format. Even the lack of textbooks written for cycling is not so daunting; see our previous suggestions about adapting standard physics texts.

Cycling assessment

Over the 10 years we have had at least 10 different faculty try cycling for more than 25 course-semesters at two universities and on the subjects of introductory mechanics and electromagnetism and advanced quantum mechanics. But are the students learning better? To look for evidence, we examined exam scores, attempting to make them similar from year to year (and even very similar—we generally do not
release the final exams back to the students and there are controls to see that students of subsequent years have no access to previous final exams). For example, in one of our courses we saw a final exam average of 85 for each of the first two cycled years, while for five previous uncycled years, the average final exam score was 81±2 (with average class size 60-70 students, the same instructor, and the grading done by a team of graduate students). While this is less than a 3σ difference, it is some support for our subjective view that cycled students were indeed handling difficult problems with more facility. Nonetheless, we have not done the kind of research we would like: we cannot offer two simultaneous courses, for instance, in order to compare two equivalent populations, one cycled and one traditional.

In anonymous questionnaires, we have consistently received positive responses during this decade. In the early years we had many spontaneous and explicit comments favoring the new cycling system; far fewer were negative about the method. (In one questionnaire, out of 47 responses there were 23 positive comments versus two negative ones.) In more recent years, it is interesting that there are sparse spontaneous comments about cycling, pro or con. The students express great enthusiasm for our cycled courses, but it is almost as if the idea of revisiting is second nature. We do hear anecdotes about more and more high school classes systemically revisiting material in their curricula, perhaps accounting for an increased comfort with cycling.

Despite its role as an early motivation, we could not easily follow up to see any effect of cycling on the GRE Teflon effect. The reason is we have developed a set of flashcards for the physics GRE over the same decade, culminating in a professionally printed version, a web app, and now a smartphone app. This was addressed directly to the memory problem and has had a greater influence than cycling on student GRE performance.

We have made reports to the physics community on cycling through the years. There have been two AAPT national presentations, four regional AAPT and APS papers, and a Reinvention Center Workshop session devoted to cycling. Five of our undergraduate seniors have carried out capstone projects on cycling, including one leading to an AAPT presentation.

Cycling outlook
To make this teaching method better known and more available, we likely need a series of heavily vetted, polished textbooks and workbooks for all the introductory physics courses. Right or wrong, a “law” of teaching is that “courses and teachers follow their textbooks.” Wider usage of cycling may have to wait for electronic publishing advances. Still, we feel the time and effort necessary for the adoption of cycling are not as great as for just-in-time learning and “flipped” classrooms. A clear obstacle for these options is the large initial investment needed, particularly troublesome for junior faculty doing research. In our experience, many faculty are interested in these innovations, but do not view their own teaching, especially of upper-class courses, as “broken” and have been slow to embrace any new direction, including cycling.

Circa 2015 we are comfortably ensconced in cycling the introductory courses we teach. Although assessment has not been comprehensive, there is some evidence-based motivation from the past. The dominant factor is our observations on how helpful it has been for our students to revisit and reflect on concepts and techniques once or twice. No longer do we have the plaintive cry of a student at final exam time with just one week left in the course to master the hardest material, asking us, “What is torque, anyway?”

References
5. See, for example, N. J. Cepeda, E. Vul, D. Rohrer, J. T. Wixted, and H. Pashler, “Spacing effects in learning a temporal ridge-line of optimal retention,” Psychol. Sci. 19 (11), 1095–1102 (2008). Some reference in the education reform world is made to “spiraling” as a description of revisiting, such as in mathematics. But to avoid the imagery of converging or diverging as we go, and to connect well with “layering,” we have continued to be more comfortable with our original “cycling” connotation.
8. We can also report steady improvement beyond the 85 averages, but the average SAT scores in our classes have been increasing, too.
9. More than 2000 sets were mailed out over the past two years, and 800 sets were given as prizes at CU/WIP (Conferences for University Women in Physics) by APS. See http://great.cwru.edu.

Bob Brown is Institute and Distinguished University Professor in the CWRU physics department. His teaching and research are intimately connected to basic (e.g., particle) and applied (e.g., MRI) physics, entrepreneurship, a manufacturing company, and outreaching through, for example, “Doc Brown’s GRE Flashcards.”

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