Beating the Lecture-Textbook Trap with Active Learning and Rewards for All

David Pengelley

Note: The opinions expressed here are not necessarily those of Notices. *Responses on the* Notices *webpage are invited.*

My active-learning journey was sparked decades ago, when I realized I could best help students work on extensive calculus projects by doing so inside, not just outside, the classroom. Thus I needed to reduce lecturing. But with less lecturing, how would I cover the syllabus? And how would students first be exposed to new material? I faced what I call the "lecture-textbook trap." In this vicious circle, students don't seriously study text material in preparation for class because they know I will lecture on it. In turn, I must lecture on it because they don't study it first. Escaping this trap is the hardest thing I ever did in teaching. But liberation opened unimagined pedagogical doors, through which I discovered transformative rewards for both student and teacher.

Concomitantly, I began to question lecture's overall purpose, efficacy, and necessity. Countless times as a lecturer, students had tellingly told me "I understand perfectly when you lecture, but then I can't do problems at home." I slowly realized that while a lecture may feel extremely comfortable to teacher and student alike, and sometimes be inspirational, it accomplishes precious little to help students successfully do mathematics themselves.

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The many benefits of shifting from lecture toward active learning are now widely confirmed by scientific evidence, as amply elucidated and referenced in the February *Notices* [1], which also gives several examples of active learning paradigms (see too [2, 4, 5]). Here I will describe a different paradigm that integrates in and out of class active learning, and I will discuss its rewards for both teachers and students.

As I progressed from lecture toward in-class active learning built upon before-class preparatory work, I saw students increasingly gain confidence, satisfaction, and achievement in their own learning. The paradigm that evolved from this progression has three integrated parts.

Part A resolves the lecture-textbook trap by realizing this motto: Never lecture on something students can instead read and write about. I give students high quality reading on new material, and they write about it, to promote far deeper engagement than mere reading. I do not require much writing, but I expect all students to pose good questions about the mathematics, and describe what they did and did not understand. I also ask lower division students to respond to a couple of reading questions I pose. The overall goal is for students to think meaningfully about new material before class, and to leave no conceivable reason for me to lecture.

A critical feature is that I must receive their writing before I prepare for class. I can then prepare to lead a brief initial class discussion of a few questions I select from

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Students with the author at a faculty training workshop for "Transforming Instruction in Undergraduate Mathematics via Primary Historical Sources" (TRIUMPHS) tackle a project based on primary historical sources.[1]

their written responses, narrowly focused only on what their writing shows is really needed. This never occupies more than 15% of class time.

For Part B students prepare easy-to-medium-difficulty "warm-up problems" on the new material before class, and bring this work to compare, discuss, present, and perfect with others, with my help and guidance. When class begins, students usually do not even notice my arrival, since they are already engrossed comparing their prepared work. The goal of class time is for students to exhaustively resolve these warm-up problems. In class, I continually circulate to interact with groups of students. I often select solutions to go on the board, and choose which students will write them there. We then end with a whole class discussion of some of their solutions.

Thus the entire classroom experience starts on a higher plane than first engagement, ends with a satisfying resolution of problems, and students both feel and are well prepared for a few harder homework problems afterward. The experience incorporates what I consider the essence of active learning: Reduce or eliminate lecture, and devote substantial classroom time to student involvement in mathematical work that receives immediate feedback from other students and from the instructor.

Only once did I make the mistake of lecturing, on a hard topic, when my students were instead expecting to work together on their preparatory homework. Rather than appreciating my lecture, they became frustrated that I was stealing their collaborative work time! How delightful—they had taken ownership of their learning.

Part C is "final homework" to be completed after class, just two harder problems that build on the warm-ups completed in class. These I mark carefully for students, and I sometimes request reworking to attain top quality. They represent each student's highest degree of achievement on that day's mathematics. They are not normally discussed in class.

While the traditional lecture paradigm could be called "I-You" for "I lecture, then you do homework after class," what I describe can be labeled "You-You-We-You" for "You read and write, you prepare warm-up problems to bring to class, we master these together in class, and you do final homework after class." Observe the shift from "I" to "You," along with integration of before-, during-, and after-class student work. And the answer to the earlier question, "With less lecture, how will I cover the syllabus?" is that the syllabus is inherently covered by the learning community of students and teacher actively working together both in and out of the classroom, especially now that class time is devoted to actual work.

You may be wondering whether students will really do what I expect, and whether I spend my whole life reading student papers; the answers are yes and no, respectively.

Students do the three-part daily work because I confidently and repeatedly emphasize what to do and the benefits it will bring them, because there is considerable peer pressure from group members and the board presentations I demand, and because they quickly experience success and confidence. Crucially, too, this daily homework is the majority (at least 60%) of the course grade, with exams minimized, reinforcing the message that the daily work is the fundament of learning.

Regarding grading, the reading/writing is marked in literally 5–10 seconds with a +,✓,- only for effort and diligence, and an occasional quick note for them or for my own class preparation. The warm-up problems are also assigned a single overall +,✓,- solely for diligence at preparing before class, since they were fully worked through in class and need no appraisal; this takes even less time, perhaps 3 seconds. The final daily homework of just two problems is all that I mark closely, and it receives a single unified letter grade, using no time-consuming, distracting numerical points. The course grade is a holistic evaluation, with the letter grades on final homework generally predominant, so that evaluation and learning are in harmony. Overall the amount of time I spend teaching, including grading and otherwise, is no greater than when I used to lecture.

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The benefits for me as a teacher include rich and satisfying interactions with students. There are fewer exams to grade, an elevated intellectual level of homework evaluation, and a far steadier schedule of time demands for all. A big difference in the classroom is that its direction now involves continual unknowns, depending on what arises from student work, thoughts, and questions, unlike lecture, which is entirely predictable and controlled. This may be unsettling to some faculty, but I have come to embrace it. All these features keep me fresh and avoid burnout.

Here are three illuminating student responses: Often, if students are working in groups until the end of class, no one even notices that class has ended, and I have to point

[1] webpages.ursinus.edu/nscoville/TRIUMPHS.html

it out (Has this ever happened in a lecture?). Students often ask why all mathematics classes aren't taught this way. And students will comment that this approach provides lower stress with more learning, reducing both uneven time demands and the cram-exam-forget phenomenon.

In what courses and of what sizes can this be carried out? I have implemented this, with minor variation, over twenty years of multiple incarnations of sixteen different courses at all university levels from mathematics appreciation and calculus through PhD qualifying exam courses. Some courses have had up to 45 students, taught without any form of assistance. If I were faced with larger courses, I would not hesitate to train graduate or undergraduate assistants to serve both in and out of class, and adapt the paradigm (see [3]). The challenges would be institutional commitment and constraints for supporting an active learning course structure. I would never retreat from melding active learning both in and out of the classroom, since I have experienced its transformative rewards for all.[2]

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References

[1] B. Braun, P. Bremser, A. Duval, E. Lockwood, D. White, What Does Active Learning Mean for Mathematicians? *Notices Amer. Math. Soc.* **64** (2017), 124–129, www.ams.org/publications/journals/notices/201702/rnoti-p124.pdf.

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[3] SCALE-UP: Student-Centered Active Learning Environment with Upside-Down Pedagogies, scaleup.ncsu.edu .

[4] C. Wieman, Large-scale comparison of science teaching methods sends clear message, *P. Natl. Acad. Sci. USA* **111** (2014), 8319–20, pnas.org/content/111/23/8319.extract.

[5] C. Wieman, A Better Way to Evaluate Undergraduate Teaching, *Change*, January/February 2015, 6–15, www.changemag.org, or www.cwsei.ubc.ca/SEI_research/index.html.

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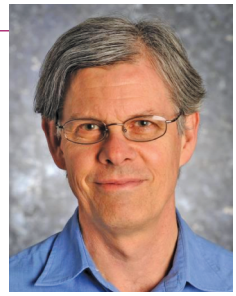
Photo of David Pengelley with students courtesy of University of Colorado—Denver.

Headshot of David Pengelley courtesy of New Mexico State University

[2] *A longer version of this article, with more detail, references, and provocation, as well as guidelines for students, grading, logistics, sample assignments, etc. is at* https://www.math.nmsu.edu/~davidp/.



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David Pengelley's research is in algebraic topology and the history of mathematics. He teaches with primary historical sources, has received the Mathematical Association of America's Haimo Teaching Award, loves backpacking and the wilderness, is active on environmental issues, and is a fanatical badminton player.