SIGACT News Complexity Theory Column 106: Teaching Models, Computability, and Complexity in Time of COVID-19

Lane A. Hemaspaandra
Dept. of Computer Science, University of Rochester, Rochester, NY 14627, USA

As I write this in July 2020, I have no idea what the COVID-19 situation will be like when this September 2020 issue reaches your mailbox or your previewer. My typical advice is to prove exciting theorems. But in these times, all I can share are my hopes: that you'll each be safe and well (and that the medical profession will create an effective vaccine quickly enough that early in 2021 schools can return to fully in-person teaching); that you'll find ways to, if a faculty member, help your students thrive even in the hybrid-mode-learning settings they'll probably find themselves in for the fall semester; and that you'll (while staying careful and safe) find time to (yes, here it comes) prove exciting theorems.

This column's slot became open at the last moment. Since this is such an unusual time, with in-person teaching having been abruptly changed to online learning as a pandemic sweeps through the world, I have for this issue written this very short note on some of my impressions of what it was like to teach models/computability/complexity in that setting.

Of course, if you too were teaching during the pandemic, you'll have your own impressions of and experiences with of the ups and downs of online teaching, and those might or might not

be similar to mine. Also, by mentioning my impressions on teaching, I don't at all mean to be insensitive to the horror and enormous human cost of the pandemic. As I write this, there have been more than 674,000 deaths worldwide, a truly terrifying toll.

Nonetheless, we have had to teach online, and that might continue for a term or more still. At my school, most large classes will have to be purely online during the fall term, due to social distancing rules, though many other classes will be taught in a one of a variety of "hybrid" modes, offering online access to those who cannot attend in person, and often having about half the class attend in person while most of the other half is viewing the session synchronously via Zoom, and swapping halves based on the parity of lecture number, so to speak.

But before some brief comments on teaching models/computability/complexity online, let me mention to you what the complexity columns in the upcoming issues will be, namely, we will have articles by:

- *Mark Bun and Justin Thaler* (tentative topic: Approximate Degree in Classical and Quantum Computation),
- *Muthu Venkitasubramaniam* (topic TBD),
- *Alexander Knop, Shachar Lovett, Sam McGuire, and Weiqiang Yuan* (tentative topic: Intermediate Models Between Query Complexity and Communication Complexity),
- *Carlo Mereghetti and Beatrice Palano* (tentative topic: Quantum Finite Automata), and
- *Ben Lee Volk* (topic TBD).

I'm much looking forward to their articles, and am very thankful to each of the guest articles' authors for generously making the time to contribute a column during a pandemic.

Although I can't predict the future, the past is in at least somewhat clearer view. Myself, in fall 2019 I taught our graduate-level complexity course to a very bright, enthusiastic mix of Ph.D. students and upper-level undergraduates. That was months before the COVID-19 pandemic reached New York State, and so it was an typical-mode-of-delivery term, which I much enjoyed. I had no idea that being able to teach in person might not hold in following term.

But then in spring 2020, as I was teaching our required-for-the-B.S. "Sipser" Models of Computation course to 80 undergraduates, during Spring Break our administration, reasonably enough since it was trying to keep everyone safe, basically told the students, "Don't come back from Spring Break!" And, like so many schools, every course switched to online delivery, via Zoom, after just a short gap to allow some frantic preparation for online teaching. Myself, I did my best to quickly guess what my course delivery would look like, and then in a rush bought via Amazon the needed toys: an iPad, an Apple Pencil, noise-canceling headphones, and a really lovely, retro, brushed aluminum Blue Snowball USB condenser microphone (pictured).

I wish I could say everything went perfectly. It turned out that that would be too much to hope for. For example, having a major exam

online is potentially quite problematic.[1] Zoom a first takes some getting
used to. And I found that even for those lectures I gave "live" (though online), the attendance was not at all what it had been when we were all live in the same classroom. (I much hope that the attendance drop was simply because—due to the fact that not all students could attend online talks synchronously—all my lectures were being recorded and made available inside my school's learning management system.) In class, I often break up the in-person class into twenty-something groups of three with all the groups trying try to solve the same challenging question. As the groups work on the question, the graduate TA and I circulate among the groups to answer any questions the groups have on the models in or meaning of the problem, and we see how the groups are doing, and we encourage them (or even give hints, while trying not to take away from the students the fun of seeking and finding insights). Unfortunately, this type of experience is a more than a bit hard to duplicate in Zoom. However, on some days with not many students attending, the Zoom "breakout room" feature really was pretty good at doing precisely this. And the TA and I could indeed circulate between the groups, but now in the online world of their Zoom breakout rooms.

Like many of my colleagues, while teaching online I discovered that online teaching takes substantially more time than classroom teaching. Part of that might have been my learning curve for all the new tools and toys, as well as things such as video editing (which is a rabbit hole I quickly decided to stop going down, after a very computer-savvy colleague let my department know that even he had mostly decided to bail on doing video editing to patch recorded versions). And part of the time cost of online teaching was doing the out-of-nowhere initial, and then ongoing, planning of how to structure the course's suffix to be in the online-learning model. But also, in online teaching and exams, a lot of special cases and technological problems can come up, and the time adds up.

Despite the limitations mentioned above, overall the online teaching went far better than I had expected. And I think the single most central reason for that is this: The material we get to teach as complexity theorists is simply very beautiful and very fun. It can withstand a lot—even online teaching—and still shine through. While still in-person I had gone relatively quickly through the regular-set coverage, the CFL coverage, and a prefix of the undecidability coverage of the course. So most of the online part of the course was (finishing the undecidability unit, and then) an introduction to P, NP, and complexity theory. And that material is so robustly nice that it is a pleasure to teach even online... and I hope and believe that it was fun too for the students (who were Zooming in, some from near and some from far). Even remotely, students did a great job tackling challenges such as working in groups to show that if there is an NP-hard tally set, then P = NP (Berman's Theorem), and then extending that to show that if there is an coNP-hard sparse set, then P = NP (Fortune's Theorem), and so on.

So even amidst all the disruption and tragedy of the pandemic, I think there is an upbeat tidbit. We're all very lucky to be in an area where there is such beauty and structure: to be able to explore it ourselves as best we can, and to help students not just learn the material but also appreciate the material's the beauty. Donald Knuth, in the now-famous quotation:

> ... pleasure has probably been the main goal all along. But I hesitate to admit it, because computer scientists want to maintain their image as hard-working individuals who deserve high salaries. Sooner or later society will realize that certain kinds of

[1] There were issues of access to the testing platform that the school advised us to use, there were amazingly time-consuming issues regarding having the math parts of exam questions render correctly within that platform, and due to students being located all over the world the students had a 24-hour window during which to take the 75-minute exam, which could lead to cheating though as far as I know it did not.

> hard work are in fact admirable even though they are more fun than just about anything else – Donald E. Knuth, *The Stanford GraphBase: A Platform for Combinatorial Computing*, ACM Press, 1994

used the phrase "more fun than just about anything else." The quotation itself as you can see is using that to speak of "certain kinds of hard work" (by implication, done by computer scientists). But please forgive me if I imagine that Professor Knuth was really thinking about complexity theory research and teaching when he used the phrase "more fun than just about anything else"!

So coming back to where we started, except not quite: Wishing you, insofar as you can find them in this disrupted, fragile time, safety and fun.