# STEM Teaching Practices: Before, During, and After Pandemic Response Teaching

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*Spring 2020 marked the start of a national pandemic response teaching (PRT) period as colleges and universities responded to the public health emergency and associated upheavals and restrictions. Instructional practices and delivery modalities changed during this period, but there have been lingering questions about any lasting impact on pedagogy. In 2025, we conducted a national survey, following up with instructors of undergraduate chemistry, mathematics, and physics courses who had reported on their teaching in 2019, to explore this question. This paper focuses on questions about modality of instruction, distribution of class time between lecture and more active practices, and a set of other common instructional practices. In general, we find an aggregate return to pre-PRT practices, although there has been uptake of certain auxiliary digital practices (e.g., online office hours).*

*Keywords:* introductory courses; teaching practices; pandemic; instructional change

Instructional practices in introductory STEM courses vary across disciplines, campuses, courses, and individual instructors. Over the last several decades in the US, there has been a push to incorporate research-based instructional strategies (RBIS) in these courses, with a particular emphasis on "active learning," an umbrella term used to describe pedagogical approaches that incorporate doing and discussing mathematics during regular class meetings. Despite some shifts, the majority of introductory STEM students still spend the majority of time in class listening to an instructor lecture or solve problems, something which has been repeatedly documented in large studies across the USA (Apkarian et al., 2021; Dancy et al., 2024; Johnson et al., 2022; Wang et al., 2024; Smith et al., 2021; Stains et al., 2018; Yik et al. 2022b).

Since then, higher education experienced a massive disruption. In particular, the global COVID-19 pandemic caused many institutions to move online in Spring 2020, and to incorporate modified practices due to public health concerns and local policies (Johnson et al., 2020). Across states and institutions, these modifications varied both in their nature and duration, though most colleges and universities returned to "normal" by the end of the 2021-22 academic year. Questions have persisted about any lasting effects of instructors' pandemic response teaching (PRT), particularly in the aggregate (Engelbrecht et al., 2020; 2023). These questions affect both our understanding of the current STEM instructional landscape and our ability to leverage research conducted prior to the pandemic.

This paper is part of an ongoing study aiming to answer those questions with particular attention to practices used in introductory general chemistry, single-variable calculus, and physics at undergraduate institutions. We re-surveyed instructors of these courses who had previously reported on their practices in 2019, giving us a unique ability to report on shifts (or lack thereof) in pedagogy. This paper specifically focuses on two research questions:

1. Has the time distribution of in-class practices, across lecture, individual work, group work, and whole class discussion, changed since 2019?
2. What common practices did instructors use before, during, and after PRT? Which, if any, were more likely to be abandoned, paused, or adopted throughout this period?

## Background & Theory

### Pandemic Response

On March 11, 2020, after months of monitoring the spread of disease, the World Health Organization officially declared COVID-19 a pandemic (World Health Organization, 2025), sparking international public health policies which included school closures around the world, including most higher education institutions in the United States – at least temporarily (Nurunnabi & Almusharraf, 2020). This generally meant a rapid shift to online remote instruction without significant prior preparation, previous experience, or professional development (Johnson et al., 2020; Kirkman et al., 2021; Skliarova, 2022).

Pedagogy in Spring 2020 is sometimes referred to as *emergency remote teaching* or *emergency response teaching*; we refer to the entire period of Spring 2020 through the end of the 2021-22 academic year as *pandemic response teaching* (PRT), including both the immediate response and more planned instruction as policies shifted and restrictions eased. We note that, while instructors had more time to prepare for teaching under extenuating circumstances for the 2020-21 and 2021-22 academic years, it was broadly understood that the policies in place to ensure public health would be in place for an unknown, but finite, period – as opposed to a permanent adjustment.

Since the shift to PRT, there have been questions about the extent to which those practices will have some lasting impact on college instruction (e.g., Engelbrecht et al., 2020; 2023). Optimists noted many examples of instructors around the world taking the pandemic as an opportunity to examine and reflect upon their teaching practices and experiment with new ideas as alternatives to standard practice became a necessity (e.g., Albano et al., 2020; Gosztonyi, 2021; Maciejewski, 2021; Rapanta et al., 2020) and hoped that change would be widespread, and positive (Engelbrecht et al., 2023). Others urged caution, in particular noting that the emergency-response online teaching enacted in Spring 2020 was distinct in design and implementation from purposefully developed online learning programs (Hodges et al., 2020). There can be no doubt that human experiences through the pandemic impacted individual instructors, but the question of how those experiences impacted teaching practices at scale remains open.

### Choosing Practices

One consistent result found across many studies of instructors' practice is that their personal experiences influence their instructional approach (Andrews & Lemon, 2015; Apkarian et al., 2021; Emery et al., 2021; Oleson & Hora, 2014; Yik et al., 2022ab). Thus, we assume that how instructors thought and taught prior to PRT influenced the decisions they made during PRT, and that their experiences during PRT now also influence their current decisions and practices. Figure 1 shows a toy model of this theorized influence: prior practices and beliefs contribute to current practices and beliefs, mediated by PRT experiences. We cannot say, *a priori*, however, in what direction(s) these changes might have occurred.

In higher education contexts, most theories of change focus on guided change (with identifiable change agents and premeditated, though flexible goals) or long-term unguided evolution. The unique conditions of the COVID-19 pandemic with regards to higher education mean that many change theories are not entirely satisfactory in terms of predicting outcomes across the country - hence the need for empirical work such as that presented in this paper.

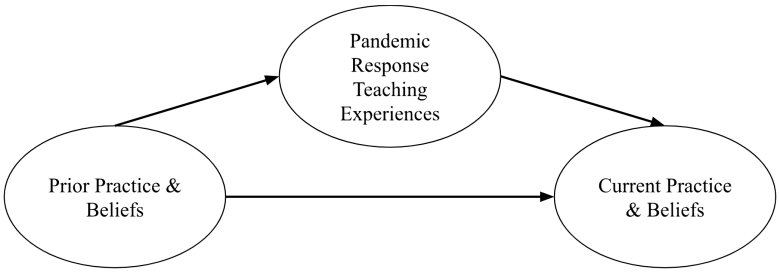


*Figure 1. Toy model of theorized influence of prior practice and beliefs, mediated by PRT experiences, on instructors' current practices and beliefs.*

The CACAO model (Dormant, 2011; Viskupic et al., 2022) draws on many change theories and is intended to help people plan changes, drawing focus to four elements: the *change* itself, the *change agents* who support the intended *adopters* through the change process, and the *organization* in which they reside. This model outlines five stages of the adoption process for new practices: awareness, curiosity, mental tryout, hands-on tryout, and adoption. Viewed through this lens, we can say that the pandemic forced many instructors to skip directly to the "hands-on tryout" stage, without prior preparation or the support that might be provided by deliberate agents of change. We note that there was not a unitary "change" being tried out, but rather a constellation of strategies, techniques, and technologies being engaged across different and evolving contexts. As such, we explore which aspects (if any) of instructors' PRT were adopted after the crisis had passed and mandates were lifted.

## Research Methods

### Participants & Data Collection

We leveraged the roster from a previous research study, conducted in 2019, to recruit participants to the study. The initial roster consisted of roughly 17,000 names gathered from publicly available information on university websites and targeted those who had taught introductory chemistry, physics, or single-variable calculus at colleges and universities across the country in the 2017-18 or 2018-19 academic year; 3,679 of these met the desired criteria and participated in the original study.

The entire original roster was contacted again to capture those who taught before *and* after the pandemic-induced disruption c. 2020-2023. To be eligible, instructors must have taught one of the target introductory courses in the 2023-24 and/or 2024-25 academic year. In total, 933 participants provided usable responses to our survey: 339 chemistry, 279 mathematics, and 315 physics; roughly two-thirds of responses in each discipline came from individuals who completed the 2019 survey, allowing for direct comparison. Instructors who participated in both surveys can be linked via an anonymous identifier, allowing for direct comparison.

Data was collected via web-based survey using the Qualtrics platform. The majority of the survey questions were copied from the survey used in 2019 (Apkarian et al., 2021; Yik et al., 2022ab), and asked instructors about their course structure (e.g., class size, classroom setup), department context (e.g., coordination of course content), instructional practices, experiences with research-based instructional strategies, professional context, and personal identity questions. New items were developed to capture instructors' experience during the pandemic response teaching period, including questions about how many terms they taught online, which (if any) RBIS they tried, and the resources and support they had access to in that period.

## Data Analysis

This paper reports on three sets of survey items. The first captured instructors' experience teaching undergraduate courses in four different modalities (face-to-face; online synchronous; online asynchronous; hybrid) before, during, and after PRT. The second set asked instructors to estimate the percentage of class time, in a typical week, that students spend (a) listening to the instructor lecture or solve problems; (b) work on tasks individually; (c) work on tasks in small groups; and (d) engage in whole class discussion (these were required to total 100). The third set of questions presented instructors with a list of eight teaching-related practices and asked instructors to indicate if they had used the practice before, during, and/or after the pandemic response period; "never" was also an option, to distinguish between those who skipped the item and those who had never used a practice.

Analyses were conducted on complete cases (by focal item) and so the *N* size varies. We present descriptive statistics leveraging both the earlier data set (collected in fall 2019) and the new data set (collected in spring 2025). We leverage *t*-testing to compare data from 2019 and 2025, both in the aggregate using the entire sample and paired t-tests to directly compare repeat participants and applied a Bonferroni-corrected threshold to account for the increased rate of Type I errors when engaged in multiple hypothesis testing.

# Results

## Instructional Modality

As expected, instructors in our study were predominantly teaching face-to-face courses until partway through the spring of 2020, when public health led to widespread social distancing policies. In the later part of the spring, online synchronous and online asynchronous were the most common modality in the emergency situation. In the first full academic year of pandemic response teaching (2020-21), with some additional time for preparation but before vaccines were widely available, these four modalities were almost equally in use. The following year (2021-22) saw an increasing return to face-to-face teaching, and by 2025 when the more recent data was collected, the pattern of instruction was back to pre-PRT levels, closely matching reports about teaching modalities early in the Spring of 2020 (see Figure 2).

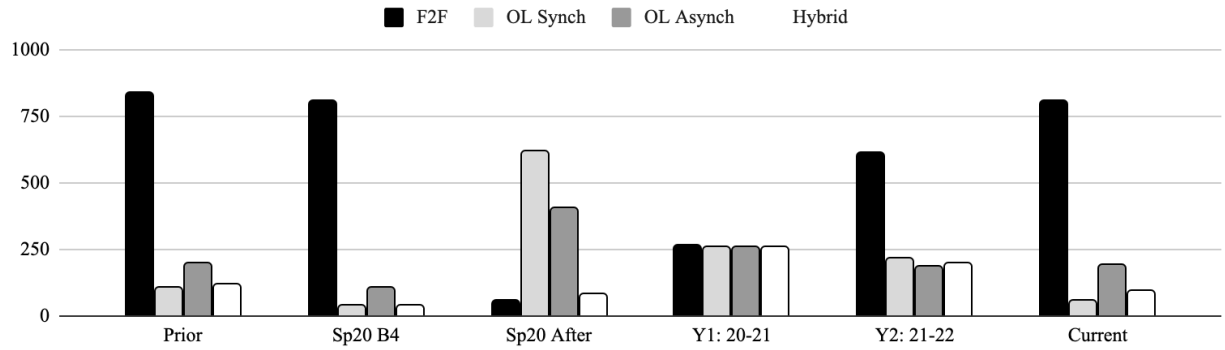


*Figure 2. Chart showing number of respondents reporting using each of four modalities, for any course, from before Spring 2020 through Spring 2025 (current).*

## Distribution of Class Time

One outcome measure used in the first study was the reported percentage of class time, in a typical week, that students spend listening to the instructor lecture or solve problems, as opposed

to working individually, working in small groups, or engaged in whole class discussion. Instructors' averages, disaggregated by discipline, are presented in Table 1.

*Table 1. Average reports of the percent of class time students spend in different learning activities.*

| | Chemistry | | Mathematics | | Physics | |
|---|---|---|---|---|---|---|
| | 2019 *N*=1207 | 2025 *N*=339 | 2019 *N*=1293 | 2025 *N*=279 | 2019 *N*=1141 | 2025 *N*=315 |
| Listening | 59.01 (24.70) | 54.66 (25.98) | 56.48 (25.15) | 54.36 (25.53) | 53.94 (25.59) | 53.16 (26.63) |
| Individual Work | 11.69 (11.61) | 14.20 (15.37) | 11.31 (11.80) | 13.04 (13.95) | 10.60 (11.68) | 11.21 (14.31) |
| Small Group Work | 18.40 (19.43) | 20.79 (21.38) | 17.14 (17.90) | 19.27 (19.10) | 22.45 (20.53) | 23.99 (21.43) |
| Discussion | 10.89 (11.76) | 10.35 (11.37) | 15.07 (14.56) | 13.33 (14.18) | 13.01 (11.64) | 11.64 (10.84) |

*Note: table entries give cell mean (standard deviation). For 2025 data, N=933; for 2019, N=3641.*

In general, we see very small changes in the direction of slightly less lecturing and discussion being reported, and slightly more individual and small group work on mathematical tasks. We consider these slight differences to be of no practical significance, well within what we might accept as rounding error on the part of participants. We additionally conducted paired *t*-tests with the 2019 and 2025 data for the 588 individuals who responded to both surveys and filled out this item completely. With an adjusted *p*-value to account for multiple testing, none of the differences were statistically significant.

Note that this is not equivalent to saying that *no* instructors changed their practices over the previous six years. However, those changes average out to zero. As shown in Figure 3, across all three disciplines instructors reported balanced changes toward and away from lecture - both in number of instructors and the magnitude of the reported shifts.

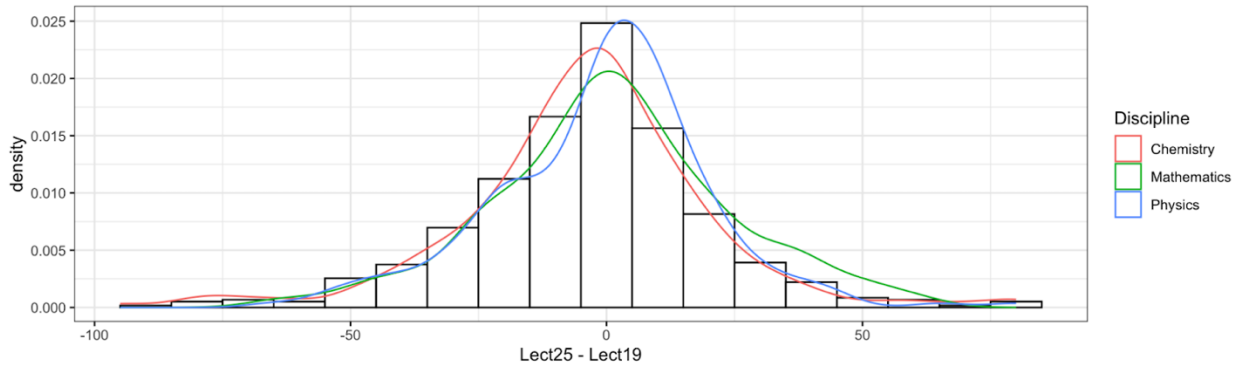


*Figure 3. Chart showing density of reported changes in the percentage of class time spent in lecture from 2019 to 2025. Histogram shows aggregate responses, while colored lines show density distribution by discipline.*

## Usage of Instructional Practices Pre/Post

Looking across all instructors (chemistry, mathematics, and physics) certain patterns emerge from instructors' usage of certain practices before, during, and after the pandemic response teaching period (PRT). Table 2 shows the proportion of respondents who indicated that they had never used a particular practice, and the proportions (of the rest) who indicated each *pattern* of usage for that practice. That is, "only before" refers to those who used a practice before PRT, but not during or after; "during and after" refers to people who did not use the practice before PRT but used it during and after that time. For example, 40% of respondents indicated that they had

never used live polling in their class; of the 60% who *have* used polling, 20% did so only before PRT while 42% used it consistently before, during, and after PRT.

In terms of the CACAO change model, we are particularly interested in practices which instructors started or stopped using during PRT. With regards to the former, the "only during" pattern is indicative of trying out a new practice during PRT and discontinuing usage afterward; the "during and after" pattern is indicative of trying out a new practice and then adopting it. With regards to the latter, the "only before" pattern can be interpreted as trying out *not* doing something (e.g., trying teaching without live polling) and adopting that non-practice afterward; "before and after" discontinues that absence, returning to previously adopted practices. These patterns are the focus of our queries regarding changes to instructional practice which might have been catalyzed by the pandemic response, despite the unplanned nature of these changes.

*Table 2. Proportion of instructors who used practices by pattern of usage.*

| | $N_1$ | Never | $N_2$ | Only Before | Before & During | Only During | During & After | Only After | Before & After | Always |
|---|---|---|---|---|---|---|---|---|---|---|
| Online office hours | 838 | - | 808 | - | - | 0.39 | **0.42** | - | - | 0.15 |
| Recorded lectures | 831 | 0.14 | 711 | - | - | 0.30 | 0.37 | - | - | 0.26 |
| Supplemental videos | 824 | 0.16 | 691 | - | - | 0.15 | 0.25 | - | - | **0.50** |
| Group work | 829 | 0.14 | 715 | 0.08 | - | - | - | - | 0.29 | **0.52** |
| Think pair share | 807 | **0.41** | 477 | 0.13 | - | - | - | - | 0.31 | **0.46** |
| Live polling/clickers | 816 | **0.40** | 489 | 0.20 | 0.06 | 0.12 | - | - | 0.11 | **0.42** |
| Online exam proctoring | 821 | 0.31 | 568 | - | - | **0.69** | 0.14 | - | - | 0.11 |
| Online HW system | 834 | 0.11 | 746 | - | - | - | 0.07 | - | - | **0.78** |

*Note: Values ≤ 0.05 are omitted for clarity; no cell is truly zero (minimum 2); values ≥ 0.4 are **bold**. Individuals who skipped all possible answers for a particular practice are not included. $N_1$ refers to the total number of people who responded to the item at all; $N_2$ refers to the number of people who answered the question and at some point used the practice.*

Fewer than 5% of respondents indicated using any of these practices after PRT without prior usage. Online homework systems were the most consistently used, with 78% of people who ever used such a system reporting that they *always* used such a system. Online exam proctoring, on the other hand, was primarily a PRT-exclusive practice: of the 489 instructors who ever used online exam proctoring, 69% report only using it during PRT, with another 14% reporting that they adopted the practice during PRT and continued to use it afterward.

Practices which were "picked up" during PRT and maintained afterward include online office hours (42% of users), recorded lectures (37%), and supplemental videos (25%). Instructors not in this category were most likely to report using online office hours and recorded lectures exclusively during PRT (39% and 30%, respectively), and to report using supplemental videos throughout (50%).

To summarize the highlights: online/digital resources (office hours, recorded lectures, supplemental videos) were broadly adopted during PRT and maintained afterward; practices related to student-student interaction (group work, think pair share) were consistently used by many instructors, though a sizable group paused their use during PRT; live polling was also used fairly consistently, with a few instructors using it only during PRT and a few pausing their usage in that period; for those who used online exam proctoring, it was primarily consigned to PRT; online homework systems were already broadly in use and were used consistently throughout.

## Discussion

We did not identify significant changes in reports of how class time is spent across any of the three disciplines with regards to the four major categories reported: listening to the instructor lecture or solve problems, working individually, working in small groups, engaged in whole class discussion. However, we did identify several changes between 2019 and 2025 in calculus instructors' usage of RBIS. While some change is expected due to an additional five years of teaching experience, we conjecture that some of these changes may have been accelerated by instructors' experiences during the pandemic response period. Note that this discussion is heavily conjectural, and further analysis of the quantitative and qualitative data is needed to support these conjectures.

Increased usage of online office hours, supplemental videos, and recorded lectures starting during PRT and continuing afterward suggests that once instructors had "figured out" these strategies, they maintained their usage. That is, PRT prompted instructors to take certain actions which were relatively straightforward to maintain, and they saw enough value in those practices to continue using them. In comparison, the interactive practices of think-pair-share and group work were used less frequently during PRT than before/after, although some maintained usage throughout. This is perhaps unsurprising, given the logistic difficulties of having students talk in small groups on web-based platforms that were widely in use. That think-pair-share saw a greater drop than group work may again be due to logistical considerations: putting students into breakout rooms to work on a task for 5-10 minutes may have been more manageable than quickly separating students into pairs for just a minute or two.

Online exam proctoring was fraught with considerations of integrity, logistics, privacy, and so on; upon the return to in-person teaching, it is therefore not surprising that it went back to being sparsely used, though it does appear that it had some uptake - perhaps allowing instructors to move examinations out of regular class meetings and save that time for additional instruction. Perhaps more surprising is that there was not an uptick in usage of live polling, since this is a built-in feature of many web-conferencing platforms and might have been easily employed by instructors. Overall, we see no major shifts to in-class instructional practices, although some auxiliary resources were adopted during PRT and remain in usage. This suggests two main conclusions: (1) there has been little lasting pedagogical change since the pandemic response teaching period; and (2) large-scale studies conducted prior to 2020 are likely still valid descriptions of undergraduate STEM instruction.

## Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. 2416741 and 2534608 (2025-27) and 1726126, 2028134, 1726328, 1726042, and 1726281 (2017-2022). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

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