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A perturbed system: how tenured faculty responded to the COVID-19 shift to remote instruction

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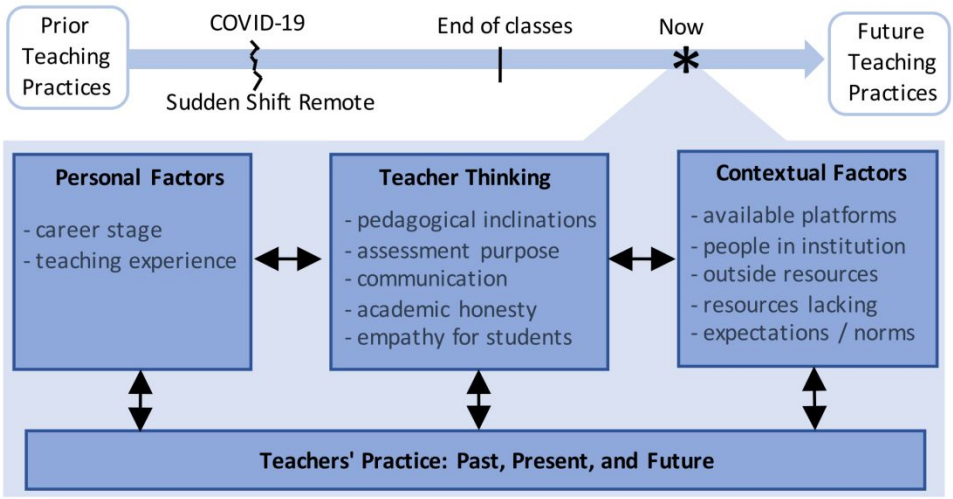
ABSTRACT

This study investigates university professors' reflections on the shift to remote instruction during the Spring 2020 semester in response to the COVID-19 global pandemic. The rapid shift in instructional platform presents an opportunity to learn from unresolved challenges that persisted through the semester. Here we present a qualitative study of how experienced (e.g., associate or full) chemistry professors report their teaching practices, in light of the COVID-19 disruptions. We observed four major themes: personal factors, contextual factors of the structure and culture, teacher thinking, and teachers' practice. These themes revealed that the professors in this study adapted quickly using institutionally offered platforms, modified their courses as minimally as possible, struggled with assessment, and held diverging beliefs about teaching and students. The outcomes of this study have implications for ongoing efforts to reform instructional practices at the institutional and departmental level. Specifically, we recommend similar studies to ascertain current faculty beliefs and instructional practices in other departments in order to identify shared visions for change and effective supports for enacting that change.

GRAPHICAL ABSTRACT



KEYWORDS

Audience: first-year undergraduate / general, second-year undergraduate

Domain: Chemical education research

Pedagogy: computer-based learning

Topic: professional development

The rapid shift to remote instruction in early March 2020 was an unprecedented moment for college and university chemistry instruction. In the middle of the Spring 2020 semester, faculty at every career stage suddenly had to learn new instructional practices. This historic moment required significant instructional changes and presented an opportunity to gather university professors' candid perspectives on their instructional practices generally, and online learning specifically, in the context of this disruptive time.

Meta-analyses have evaluated the learning gains between online and face-to-face instruction, finding no significant difference in effect size of achievement, attitude, and retention but wide variability on which format outperforms the other.[1] Within the chemistry education literature, there are a variety of efforts to engage students in learning in an online environment,[2] but fully online chemistry degree programs did not exist until 2017.[3] Therefore, chemistry professors may be unlikely to have experience with online teaching tools, and the rapid move to remote instruction within the context of chemistry may have required more significant change in instructional practice than other

non-science disciplines. Furthermore, quality online teaching requires choosing pedagogical practices that overcome inherent challenges (e.g., interaction with students).[4]

We refer to *remote instruction* as what faculty were asked to do during this pandemic, because they had to switch from face-to-face instruction to a web-based environment in a short amount of time; in the context of this study, the faculty had one week to make this transition. We use the term *online learning* to refer to faculty beliefs about the online environment, where students were engaged in learning. We make this distinction to acknowledge that faculty lacked time to plan for teaching online, and thus their remote instructional practices are likely different than they may have been in other circumstances. Nonetheless, characterizing professors' perceptions of their teaching practices during this time, and how they anticipate their future teaching practices will be influenced by this, has value.

Prior work has shown that chemistry instructors enact practices based on their beliefs about students and learning.[5] However, due to many factors—such as institutional or curricular barriers—practices often lag behind beliefs.[6,7] Efforts to examine or change chemistry instructors' practices have largely focused on early career individuals such as graduate teaching assistants,[8–13] post-doctoral scholars,[14–16] and assistant-level professors,[6,17–21] possibly because their beliefs and instructional practices are thought to be more malleable. The global pandemic has changed instructional practices as courses move online. To what extent the structural changes induced by the COVID-19 pandemic affected faculty beliefs about learning remains unclear. If faculty beliefs were affected, it is also unclear how these changing beliefs influenced immediate instructional practices or how these beliefs might influence future instructional practices.

RESEARCH QUESTION

Here we examine how chemistry professors describe their teaching practices related to teaching during the Spring 2020 COVID-19 move to remote instruction, and how these practices reflect their beliefs about teaching and students. Specifically, our research question is: How did the professors describe changes in their instructional practices due to the shift to remote instruction?

CONCEPTUAL FRAMEWORK

We use the Teacher-Centered Systemic Reform (TCSR) Model of Educational Reform[22] to structure this work. This model highlights how teachers' practices are mutually influenced by several contextual factors: personal factors, structure and culture, and teachers' thinking (Figure 1).

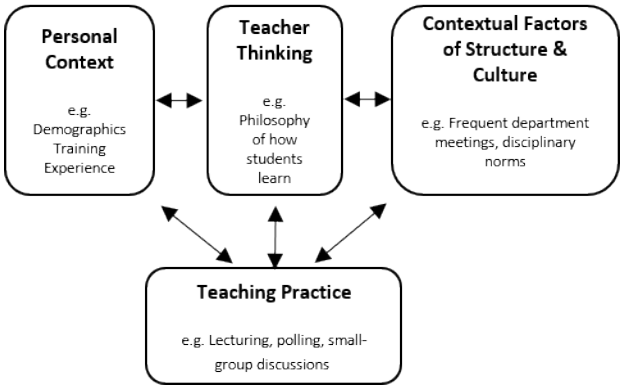


Figure 1: Teacher-Centered Systemic Reform (TCSR) Model[22], highlighting the mutual interaction between teaching practices and contextual factors. Examples of each factor are included but are not a comprehensive description of each category.

Personal contextual factors address teachers' background experiences and aspects of identity, such as demographic profile, how long a teacher has been teaching, and exposure to professional development. Structure and culture address various levels (national, institutional, departmental, and classroom) of teaching contexts and consider the evaluation standards, norms of interaction, and resources available. A departmental culture of regular interaction via frequent meetings or of limited interaction that only happens when colleagues pass in the halls would be examples of departmental contextual factors of the structure and culture. Teachers' thinking addresses knowledge and beliefs about teaching, content, and students; one example is a belief that lecturing is the best way to teach. Teachers' practices include specific forms of instruction and assessment, such as use of polling in class or assessment via timed multiple-choice exam.

The TCSR model was originally designed to assist in developing and evaluating K-12 reform initiatives,[22] and has been used to analyze chemistry education reforms.[23] This framework is relevant because, while professors did not initially intend to change their instruction to an online setting, changes were imposed on them by the pandemic. Thus, one might say the pandemic perturbed the

system of instruction, potentially precipitating some types of reform. This framework helps consider the types of changes that occurred due to the shift in instruction (e.g. teaching practices) and how they interact with professors' contexts and beliefs about teaching and students (e.g., personal context, structural context, or teacher thinking). We use *teacher* when referring to the TCSR model and *professor* when referring to the participants in this study.

METHODS

Context and Participants

This study was conducted at a high research activity (R2) university in the Midwestern United States with a diverse undergraduate student body: 52% White Non-Hispanic, 19% Hispanic, 18% Black Non-Hispanic, 6% Asian, 2% Non-Resident Alien, and 4% Two or More Races. Furthermore, 51% of students are first-generation to college, and 41% are Pell eligible. The institution recently identified severe racial equity gaps in introductory chemistry courses. The institution extended spring break for in-person classes by one week as faculty prepared to shift to remote instruction. The faculty development center provided workshops and a website with resources for teaching using Blackboard, the institutional content management system, though use of one particular tool was not a mandated. The institution and the department did not prescribe a singular approach to providing instruction for various types of courses (e.g., laboratories). In contrast to institutions with coordinated, grant-funded investments in teaching reform, this study is in a pre-reform context as there are no documented past efforts to coordinate, examine, or change teaching practices in the department.

All chemistry department faculty were invited to participate in this study. Participants were tenured associate (n=3) or full professors (n=3), which provides a contrast from recent literature that has focused on early-career individuals.[6,8,17–21,9–16] Although the interview protocol did not include a question about the individual participants' years of teaching experience, all of the professors taught classes at the institution for at least 10 years and more commonly for 20 years or more. Participants taught either one or two courses in Spring 2020; faculty in the department typically teach 3 courses per year, depending on grant activity. Two of the professors also had administrative roles on campus.

Data Collection

This work received approval from our institutional review board (#HS20-0346). To build transferability,[24] professors were purposefully recruited from the chemistry department through email. Gender-neutral pseudonyms and pronouns (they/their/theirs) are employed to maintain confidentiality.

The professors engaged in 45-60 minute remote semi-structured interviews[25] via phone or Zoom and did not receive compensation. The same researcher conducted all interviews roughly one month after the Spring 2020 semester. Interview questions (see Supporting Information) focused on spring instructional choices, impacts to participants' views of students and teaching, and future instruction. The interview did not specifically probe laboratory practices, which are primarily taught by graduate teaching assistants. Therefore, professors focused their comments on course lecture components. Interviews were audio-recorded and transcribed before analysis.

Data Analysis and Trustworthiness

The interviews were coded in accordance with the phases of thematic analysis.[26] This included multiple iterations of coding.[24] First, two transcripts were open-coded by one researcher using descriptive coding, in which topics highlighted by participants were noted.[27] Next, two other researchers examined the same two transcripts to ensure all data relevant to spring, fall, and future teaching had been captured. Then, two researchers discussed the open codes and produced a first round of focused codes, which were codes made to gather the initial open-codes into categories.[27] Next, three researchers coded the six transcripts using the focused codes, ensuring each transcript was coded by two people. These researchers wrote analytical memos and discussed coding, which aided in the creation of axial codes (which link and relate codes at the theoretical level). These axial codes led to the adoption of the TCSR framework.[22] Finally, focused codes and axial codes were revised and used to recode the transcripts in accordance with a code/recode strategy.[24] That is, knowledge gained by generating themes allowed codes to be revised and split in accordance with axial themes and the transcripts were coded again (recoded) with these revised codes to ensure the new codes were still aligned with the data. The finalized axial and focused codes are presented in Figure 2.

To maintain quality and rigor in our process, we attended to credibility, transferability, dependability, and confirmability—the four criteria for qualitative research that serve as analogues to internal validity, external validity, reliability, and objectivity in quantitative research.[24] The credibility of our study was enhanced through triangulation. Each theme reported appeared through at least one sub-code in each interview. This indicates the themes were representative of the whole data set (data triangulation). Transferability was developed through the purposeful sampling of experienced faculty from one department. Furthermore, the thick, rich description of their experiences outlined below allows the reader to judge the relevance of the participants' experiences to other contexts. Dependability was enhanced through the creation of an audit trail (a record of research procedures and how data was analyzed), use of the code/recode strategy, and investigator triangulation. Confirmability was enhanced through data and investigator triangulation and practicing reflexivity. Specifically, we practiced reflexivity by considering how our statuses, research backgrounds, and positions relative to our participants might affect our understanding of the data.

Our practice of reflexivity leads into positioning the researchers. We are researchers in different branches of STEM education (math, geology, biology, and chemistry). Our varied backgrounds allowed us to see connections to different research methodologies and literature bases. This research effort represents an interdisciplinary collaboration that leverages the existing expertise within our institution.

Three of the four members of the research team are junior faculty or scholars. We acknowledge the power structures that exist in higher education and how research on senior colleagues could affect our future careers. We recognize that teaching online was not the professors' expectation at the beginning of the semester and sought to document the challenges and successes they experienced when shifting instruction.

LIMITATIONS

This research was completed in a short period of time to capture professors' initial reflections on how the semester had gone and initial plans on how they would approach future instruction. However, this snapshot may not be representative of participants' views at another point in time. Inherent to qualitative research of this nature, an increased number of participants or alterations to the interviews

(e.g. more questions, different follow-up questions) might have yielded different or additional themes. Despite the limitations of self-reported practices,[28] our purpose is to examine how professors *perceived* their approaches and changes in instruction, not to make objective claims about the changes made.

RESULTS

The research question driving this study targeted professors' descriptions of changes they made to their instructional practices as a consequence of COVID-19. We highlight instructional practice through our first theme, *teacher practices*. Then, to give context for changes in teacher practices, we provide illustrative examples from our other three themes: personal context, structural and cultural context, and teacher thinking.

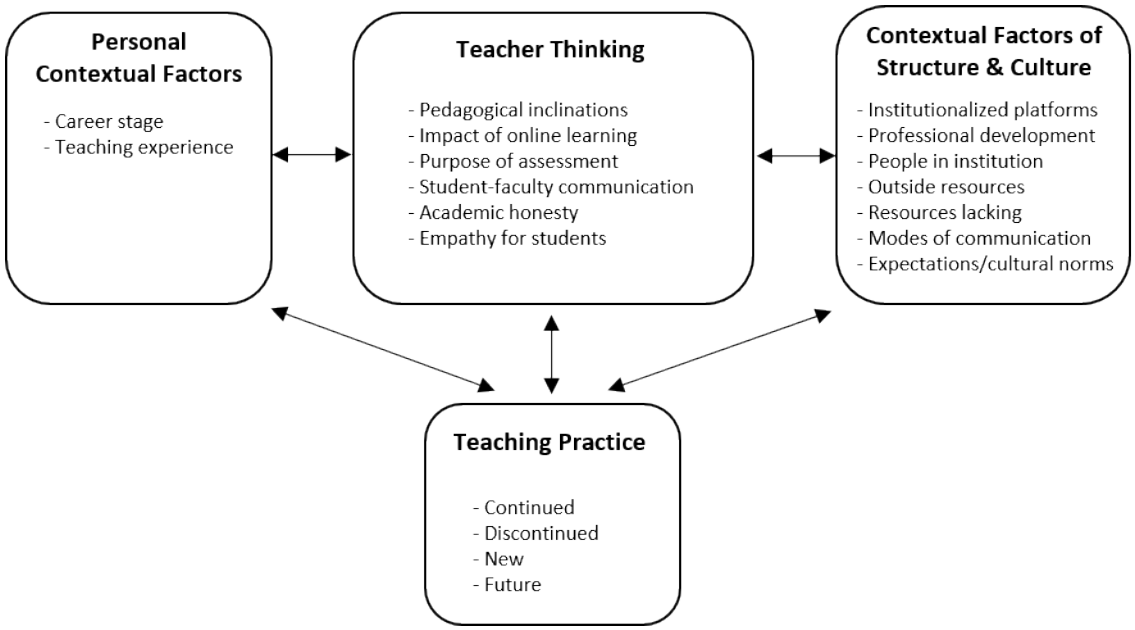


Figure 2: Axial and focused codes, and their alignment within the Teacher-Centered Systemic Reform (TCSR) model[22]

Teacher Practices

When forced to remote instruction, professors continued instructional practices, used new practices, discontinued existing practices, and highlighted other practices they intended to use in future. These codes are summarized in Table 1.

Table 1: Teaching practice codes and descriptions.

Focus Code	Definition	Examples

Continuing instructional practice	Face-to-face practices employed previously and are retained in the online environment	PowerPoints, lecture, online materials, online homework
New instructional practice	New practice employed for online environment	creating new problems, incorporating animations
Discontinued instructional practice	Face-to-face practices employed previously but not retained after transition to remote environment	using chalkboard, body language, active learning
Future instructional practice	Practices to be retained in the future, new practices to be adopted, future improvements to teaching	start asking students to use cameras, expect return to normal in fall, accelerating online teaching trends

Continuing instructional practices. The professors continued a number of their teaching practices from face-to-face into online teaching. For example, Harley reported: "I purposefully try to make the online experience seem as much like our classroom experience as possible. So things that I didn't have to change, I just didn't change them." Thus, many aspects such as the existence of PowerPoint slides and the use of pre-existing online homework systems continued. The practices largely reflected their value of didactic, teacher-centered teaching practices (discussed further in *Teacher Thinking*).

New and discontinued instructional practices. Most of the changes the professors made involved exchanging in-class elements with online substitutions. Five of the six professors (all but Morgan) transitioned in-person lectures to synchronous video lectures. Four professors (Jackie, Morgan, Robin, Harley) reported recording lectures and making them available for asynchronous viewing. The professors replaced how information was communicated during those lectures by modifying lecture notes (e.g., PowerPoint slides) that were provided to the students. For example, Cameron reported adding animations to replace working on the board:

> I normally would just kind of give an overview and then would supplement that, the basic outline that's on the PowerPoint slide, I would supplement that with, say, graphics on the blackboard….So trying to incorporate some of the stuff that I would normally do using a different medium to try to make that possible [with] the PowerPoint slide itself.

By adding animations, Cameron was able to combine the computations or pictures they would normally draw on the classroom blackboard with the outlines from the PowerPoint that they had used

when teaching face-to-face. In contrast, Robin used multiple pieces of technology when teaching their class:

> ...so what I ended up doing is opening Microsoft Teams on my laptop, joining the Microsoft Team session with my iPad, having a blank PowerPoint deck that I could write in on my iPad. And then record that in Teams. Then I had to save that recording. Well, I didn't have to. But I saved the recording. And then that came off as a MP4 file in Microsoft [Teams]. And then I could put that on Blackboard.

By utilizing this process, Robin was able to draw diagrams live like in face-to-face classes. Robin also recorded classes for asynchronous viewing, which was a new practice.

Some professors reported trying online substitutions for interactions that normally occurred in face-to-face classes. For example, Cameron expressed trying to replace interactive problem-solving with polling:

> ...in a face-to-face mode, I would do a step-by-step solution with the students, and I would ask them to provide information. Okay. Well, first of all, what's the relationship that you need to solve this problem?...Does this answer make sense? So you can ask those types of questions in a face-to-face environment while you're using...a worked-out example from the textbook. That's harder to do in an online environment. So what I would end up doing would be to try to intersperse polling questions. So I would throw a question in related to a concept we just covered. And then give the students an opportunity to respond in real-time in the online environment, and then use those results as a way to determine, "Okay, do they really understand this question?"

Jackie described having difficulty with the polling software in the online platform and thus removed it from their remote instructional practice:

> So usually during the class, we have a lot of questions or problems which students need to discuss with their peers. ... Obviously with online Blackboard Collaborate, nothing of that is possible. Because Blackboard Collaborate has a very primitive...tool for polling. ... Obviously, that kind of activities have to be completely pretty much discarded and discontinued.

Here, Jackie removed an active learning component of their instructional practice when they could not make it work as they wanted. This instructional practice of polling was both added (Cameron) and removed (Jackie) by different professors.

The professors made minor changes to their assessments. All six professors reported keeping the planned quizzes and tests but moved online. However, they also revised their assessments, including having questions appear in a random order (Parker), allowing the book to be used (Morgan), and imposing time limits (Morgan, Robin, Harley, Parker). Cameron discussed changing the types of questions asked:

> …having to restructure individual questions so that they were more thoughtful and weren't something that the student could just look up. I think I've probably spent more time and effort looking at that, changing the actual exams and rewriting the exams themselves.

However, Cameron was an anomaly in this regard, and other professors chose to retain the same format of questions—largely multiple choice—as they had asked in face-to-face classes.

Future instructional practices. When asked to think about their teaching practices for the upcoming fall semester, three professors (Parker, Harley, Jackie) did not yet know whether their courses would be face-to-face or online. Nevertheless, all professors had thought of ways to improve future instruction. Five professors (all except Parker) would explore the different online platform options and capabilities; two professors (Cameron, Harley) would try to find a way to see and hear students more effectively.

Personal Context

Two factors emerged relevant to professors' personal contexts: teaching experience and career stage, summarized in Table 2.

Table 2: Personal context codes and descriptions.

Focus Code	Definition	Examples
Teaching experience	Describing experience in the classroom	having taught the course a long time, experience with Blackboard
Career stage	Views about teaching online related to career stage, investment in teaching related to career stage	nearing retirement, not teaching this online again

All professors interviewed were tenured faculty and experienced teachers, with some professors referencing their decades of teaching experience. However, not all were at the same career stage. Two professors reported being near the end of their career, one of which described retirement as an attractive option if tasked with remote instruction again: "And this...online thing which is total nonsense to me. Anyway, look, I can retire any time I want. Now, if this is too much, which I cannot handle, then I will retire because I can't do this kind of thing."

The other four professors made no mention of retirement plans and made references to preparations for the fall. For example:

> And teaching face-to-face, I mean, I've done that long enough that I don't get real stressed about putting a course together. But I don't want to get caught [laughter], as it were like we were this spring, where somebody says, "Hey, you've got seven days to figure it out."

Thus, two aspects of personal context were salient in interviews: the many years of experience teaching, which all possessed, and career stage, which varied.

Structural and Cultural Context

Structural and cultural contextual factors included codes such as institutionalized platforms, institutionally-provided professional development, people in the institution, resources lacking, outside resources, modes of communication, and expectations/cultural norms. These codes are summarized in Table 3.

Table 3: Structural and cultural context codes and descriptions.

Focus Code	Definition	Examples
Institutionalized platforms	Technology that has been selected and provided by the institution or department that is a resource for faculty or students	LMS, Blackboard Ultra/Collaborate, Microsoft Teams, McGraw Hill Connect
Institutionally-provided professional development	Training available through official organizations, discussion forums, and websites curated/run by the university	Special seminars, Keep Teaching website, Faculty development office
People in institution	Individual contacts on campus able to assist in thinking through and/or approaching instruction	friends, faculty, IT people
Resources lacking	Physical tools, technological tools, or knowledge, desired but unavailable to instructor or student	proctoring services, other meeting platforms, tablet/stylus, students or professor availability

Outside resources	Solicited or unsolicited advertised resources, technology, curricular materials	email advertisements sent by publishers
Modes of communication	Modalities that students and faculty can communicate or interact existing in any teaching context (online or face-to-face)	communicating by chat, raising hand, moving around room
Expectations / Cultural norms	Assertions about how the department/institution functions with respect to teaching and learning	belief that institution requires platform, adherence to the syllabus, communicating with colleagues about instruction

Institutionalized platforms. When choosing online platforms, the professors picked familiar options from those they perceived to be available. Cameron mentioned institutional resources: "…there was a whole website on campus for…the educational resources for keep teaching, keep learning, those websites. And I was aware of a lot of the resources that were available on those sites even if I didn't plan on using them." For example, Cameron stated: "The reason I went with the Teams platform was because it was something that I was already using in other environments and felt comfortable with…" Robin described a more extended process for deciding which platform to use:

> Well, the college mentioned the Microsoft Teams. … The department also got [specific staff member] to give us demonstrations on the Blackboard Collaborate. …So it…more or less came from the college and our department that there were two options that we had available to us.… I tested them to see what would work best for me. And so basically did like a use test to see how it would work.

Jackie used the platform that was demonstrated in the department and perceived this as required: "Blackboard Collaborate was pretty much mandated." Alternatively, Morgan noted that "there were multiple options given by the various sources… but nobody ever said you got to do it this way". Thus, professors held different perceptions about their freedom to choose resources, but largely chose institutionally-provided platforms.

Institutionally-provided professional development. During the shift, some professors sought out professional development. Harley expressed that the resources provided by the institution were very helpful:

> I made a lot of use of the [institutional] teaching website. I thought they did a phenomenal job of collecting information for us. I attended a number of those little educational seminars where they would teach you strategies using different tools.

Robin also reported participating in a three-week online curriculum development course and finding it useful. However, Morgan had a different experience with the professional development offered by the university:

> …every couple of days, I'd get some email from the university, basically saying we've got these folks giving advice and such. That never seemed like it was quite exactly what I was planning to do or wanted to do. Those are kind of hard. I mean, I think they're doing the best they could, but I don't think those were terribly effective.

None of the participants mentioned using professional development from outside the institution. Thus, the professional development the professors accessed when trying to transition their courses was institutional but was perceived as having varied utility.

People in institution. This theme highlighted particular knowledgeable persons that professors turned to when transitioning their classes online. For example, to learn how to perform polling in Teams, Cameron turned to individual IT experts and a specific colleague with prior experience teaching online.

Resources lacking. As the professors moved forward in the semester under the COVID circumstances, they perceived resources as lacking for instruction. For example, they reported issues with asynchronous video (e.g., slow uploads and limited editing capability-Morgan), inadequate hardware (e.g., tablet and stylus-Cameron), insufficient options for securely proctoring individual exams online (all), and lacking ways to replace engaging with the students (all except Parker).

Harley desired more resources: "I wish that there had been more choices or more tools" and expressed concern that that they did not have the training to adapt assessment appropriately: "There must be ways to it. I just don't know what they are to, say, have an essay question and have students write a couple of sentences to answer a question."

Outside resources. Two professors (Harley, Morgan) noted that they received unsolicited emails from publishers offering resources but did not find these particularly useful. Harley observed:

> …as time moved forward in the spring semester we started getting just a flurry of email from various textbook publishers saying, "Oh, we've made all of our content is free and available." I never can really—Wiley wrote to us, Pearson, McGraw-Hill, everybody, and I never even really used those free resources because it seemed to me that the [institutional] page provided us with so much.

In contrast, others sought out specific resources not provided by the institution. Parker intended to contact the producers of ALEKS, a McGraw-Hill adaptive learning platform, to incorporate into teaching. Harley was also open to investigating other platforms not institutionally provided (e.g., Zoom).

Modes of communication. Professors highlighted specific modalities for communication in face-to-face or online contexts. These included physical or virtual raised hands, chats, and emails. The professors described access to different modes of communication with students when going remote. Specifically, Harley noted, "students seem to really like that chat feature.... everybody can see when you type something in the chat box." Robin highlighted a loss of in-person communication, saying, "whereas if we were in class, I could talk to him, pull him aside and talk to him." Though related to aspects of institutionalized platforms, these modes are highlighted separately because of the number of times the professors addressed ways to communicate, seemingly apart from their choice of platform or instructional practices.

Expectations/cultural norms. The professors were affected by perceived expectations and cultural norms for what their courses should entail, specifically from the discipline's main professional society, university, college, and department. For example, Robin reported the norm of secure, proctored assessments, particularly the professional society's exams:

> The American Chemical Society has standardized exams. But they are very rigorous and strict on how those can be distributed. And each one has a serial code number on it, and they're all tracked…

The professors perceived expectations and norms from within their institution as well. For example, the college explicitly asserted that the faculty should follow the structure of their original syllabus, as it is a contract with the students, making Morgan feel unable to change course structure during the shift online:

> …one of the reasons I think we're kind of stuck…during the Spring is that if you already have say a syllabus where it says we're going to for instance be doing this many tests and this much of the grade will depend, say, on the homework, we're kind of stuck with that.

Within the department, Cameron emphasized the need to cover the same content because of the cumulative nature of learning chemistry and to prepare students for their future coursework: "it's extremely important not just for accreditation but because of the fact that it tends to be cumulative."

There were disparate perceptions about the norms of communication within the department. For example, Harley reported wanting more communication with departmental colleagues.

> I know the faculty in biology periodically got together online and talked about how online instruction was going, but it would have been really nice particularly because this is a new experience for pretty much all of us. … It would have been really nice if we could say gotten together once a week and just shared some experiences or things that worked, things that didn't work, how did you handle this situation.

However, Robin reported a meaningful exchange with a departmental colleague: "…they're just going to give everybody an incomplete because they couldn't do a lab. … So actually I think I talked them out of doing that." Thus, the professors were constrained by the norms they perceived at various levels and left to construct informal networks with colleagues to share practices in the absence of a coordinated departmental effort.

Teacher Thinking

Teachers' thinking addresses knowledge and beliefs about teaching, content, and students. Here, some of the beliefs highlighted included codes on pedagogical inclinations, including didactic and chemistry-specific instructional methods, the impact of the online environment, empathy for students, the value of student-faculty communication, the purpose of assessment, and pervasive academic dishonesty. These codes are summarized in Table 4.

Table 4: Teacher thinking codes and descriptions.

Focus Code	Definition	Examples
Pedagogical inclinations	Purpose of instruction, value of various pedagogies (how to teach, what tools to use)	best way to teach, best tools for content delivery

Impact of online environment	Perceptions of online learning as inferior, difficult, unpleasant, or superior to face-to-face learning	more effective in person, need for full sensory experience (smell, sound, touch)
Empathy for students	Concern or lack of concern for student needs, preferences, challenges, or negative views of students	students are trying, students have technology limitations, students are taking advantage of circumstance
Student-faculty communication	Importance/value of communication, feedback between student & faculty	audio-visual cues, body language, discussion
Purpose of assessment	A belief about the purpose or nature of assessment	process is more important than answer, the point of homework is to learn, the purpose of assessment is to rank students
Academic dishonesty	belief or perception (by instructor or students) that students are cheating	answers available online, belief that students are using online resources during exams

Pedagogical inclinations. A persistent theme across the professors is a value for didactic forms of instruction, or teacher-centered, "telling" of information to students.[29,30] Here we used the term didactic as opposite to constructivist practices where students engage in building meaning prior to receiving content from the instructor. Parker and Jackie viewed their role as delivering content, while Morgan viewed their role, increasingly, as providing didactic content to refine learning. For example, Parker expresses: "I tell them. I show them how to do it…"

The other professors (Cameron, Morgan, Robin) present a transitional view of instruction, where didactic is necessary, but not sufficient. Morgan echoes the belief in didactic instruction and the role of a professor: "I think there's still an important purpose to have someone actually talking in the class about the material in general, and the idea of just replacing all of the professors with videos just isn't going to work." However, they subsequently described how the role is changing over time:

> The professor just kind of—almost is like an advisor telling you where to go and if you've got problems…here's how to do some examples that we can go through with class….away from just kind of the general overview of the material to the nitty-gritty mechanics of how you solve problems and things like that.

Despite mentioning a few *Teaching Practices* that engage students (e.g., polling), the dominant belief about teaching across the study sample involved didactic pedagogies.

Participants also highlighted beliefs about the nature of instruction that were specific to chemistry. Robin reported that chemistry is "a very visual topic… we have to draw a lot of chemical structures." Robin and Harley both believed using all the senses (e.g., smell, sound, feel) is necessary to learn chemistry, and Harley specifically related this to "developing chemical intuition".

Impact of online environment. The professors had dichotomous views on the online environment. Two professors (Parker and Jackie) expressed purely negative views of online learning. Parker referred to online learning as a "disservice to our profession" and "not the true way of learning". Jackie expressed that they "don't feel that [online] will be able to replace face-to-face teaching efficiently."

Others highlighted specific problems with the online setting. For example, Robin stated:

> I think there's a lot to able to read people and have students ask you questions in real-time and more or less building a sense of community in a classroom when students attend regularly, and they can interact with the instructor but also interact with the other students as well in person. So I like that. I think that's very beneficial to everybody.

The faculty also valued interaction because they believed students need to have social interaction with peers and help each other. Harley suggested that students scaffold one another's learning: "One of the things that somebody brought up was that they didn't always necessarily know what question they wanted to ask, but they liked hearing the questions that other people asked."

While the consensus view of all professors in this study was that student-faculty interaction in the online environment was inferior to interaction in face-to-face instruction, some professors saw advantages to the online environment. Robin viewed online learning as an opportunity:

> But the online, I think has a different appeal to it, where you can maybe bring in students who wouldn't normally be able to attend a class, say from 1:00 to 2:00 on Monday, Wednesday, Friday. There's more flexibility with having a portion of the class being asynchronous.

Harley remarks that online instruction, "certainly is convenient". Morgan perceived the pandemic as "accelerating" the use of a flipped learning model where synchronous time is spent interacting with students and "an awful lot of the stuff gets done online".

Empathy for students. Some professors displayed skepticism about students' effort while others presented great empathy. For example, Parker believed students to be lying: "They all had to give excuse[s], 'Oh, I had to work.' And everything is closed. How can they tell a lie that they had to work?" In contrast, Robin displayed a great deal of trust in students:

> I just thought there's probably some problem going on. Either they don't have a good access to the internet, or there might have been some other issue with their home life which I don't know of. So to me, it was like a warning sign, or something is not right.

Similar levels of empathy for students were reported by other professors who see students struggling with new challenges but nevertheless persisting. Cameron observed shifts in what students navigate in general and especially with regard to online resources over their time teaching:

> They face different challenges now than they did before, but they still have the same aspirations….I think my appreciation for what they have to deal with has changed. I mean, I know that students today, even before the pandemic, have a completely different set of challenges than students twenty years ago….I was aware that social media was an issue, but what I was not aware of was all of the other resources that students have available online. And some of them utilize this, and some of them don't. And I think when they're faced with that level of accessibility, using it effectively, using it in the way it's intended, and to achieve the best outcome, not necessarily in terms of your grade on an exam, but the ability to really learn the material. That's much more of a challenge now than I think it was say ten years ago.

Harley especially highlighted students' perseverance in the Spring semester:

> I did not have a single person withdraw. I know that they were able to do so if they wanted to. Everybody stuck it out to the end. And I think that they really tried their best to deal with the strange situation… they showed persistence, tenacity, interest, willingness to have to do things in ways that they weren't used to.

These examples demonstrate that these professors predominantly viewed students as struggling but driven.

Overall, there were two dominant patterns in views of students: professors who believed students were making excuses and lacked effort, versus professors who believed their students had myriad challenges and persisted despite these hurdles.

Student-faculty communication. Three professors (Cameron, Harley, Robin) reported valuing face-to-face interaction because they felt they could read students' body language and use this feedback to guide instruction. Harley also discussed using online tools to facilitate student-faculty interaction, yet remained concerned that it was insufficient:

> I still think that having the students interact with me while I'm talking about the material, I think is critically important, and it's much more difficult to do online. Like I said, some of them would do a chat message and I could address their question while I was talking. But I don't know. I really think that—I think it's harder for students to really engage with the information if they're not interacting with me more.

Overall, professors described difficulties in communicating with students online, specifically missing being able to see body language and observe questions in real-time.

Purpose of assessment. All professors seemed to agree that assessment should say something about what students learned. For example, Harley observed, "The only thing that was really awful was how to deal with exams. I don't think that I got a true assessment of what the students learned this semester," showing a connection between exam performance and measuring student learning.

However, there was more variety in the finer-grain perspectives. Cameron used assessments to determine what parts of the process students could and could not do:

> So am I really more interested in the answer or am I interested in how they achieve that answer? ...maybe structuring the question in a little bit more details so I can determine specifically what is it that they understand, what is it that they don't.

In contrast, Parker held a binary view of learning, in which students were correct or incorrect: "…this is not right. This is correct. What you're doing is correct but what you're doing, the other one is not correct" and discussed student assessment in terms of the number of answers correct or incorrect.

Academic dishonesty. All six faculty expressed the belief academic dishonesty was rampant. Jackie felt "all this online exams was a sham. No, it was not really a way to test the knowledge because I

know for sure…students were copying with each other." Harley expressed positive feelings about the students but echoed the belief: "I had a really nice group of students, but I'm absolutely certain that when they were taking online exams some of them probably had their phone with them and were Googling answers."

However, the professors diverged substantially in their beliefs about why students cheat. Jackie ascribed cheating to students' lack of maturity or awareness that they will need the knowledge. Morgan attributed cheating to peer pressure or competition: "it's not so much that I think a lot of students would cheat as I think a lot of students would worry about other students cheating and feel depressed that they weren't cheating." Robin speculated that changes in grades could have explanations besides cheating:

> You have to draw a lot of chemical structures. A lot of hexagons and pentagons and link things together…some students have a really hard time with that. So some of those students were - oh, I don't know - maybe getting 20% on an exam when they had to draw everything out themselves in an in-class paper exam. When we moved to online, all of a sudden, the student who was getting 20% is now getting 80%. So it makes me wonder if it was just the fact that they couldn't draw the structures on paper and now we've moved to a different form of an assessment, or they could possibly have been cheating.

In summary, a number of beliefs about teaching and about students were articulated by participants. These beliefs included views of didactic instruction being the best way to teach as well as openness to other forms of instruction, positive and negative views of students, and general dislike of interacting online.

DISCUSSION AND CONCLUSIONS

In the discussion, we first use the TCSR model[22] to address our research question and highlight connections between what the professors reported doing (i.e., teacher practice), then contextualize why they did so with the other themes of personal context, structure and culture, and teacher thinking. Then, we consider how a reform model can be useful for conceptualizing the changes in instruction necessitated by the Spring 2020 pandemic.

Connecting the Other Themes to Teacher Practices

Based on our results above, we see the ways in which personal context, structural and cultural context, and teacher thinking appeared in Spring 2020. We now turn to how these aspects informed teachers' practices; equivalently, we now address the arrows from the other three themes connected to teacher practices in Figure 2. Although aspects of personal context were relevant to changes in instruction, aspects of structural and cultural context and teacher thinking were more salient in the interviews.

The main aspect of personal context that arose related to career stage, especially if professors were near retirement. Professors planning or eligible to retire made minimal instruction changes. In contrast, professors who made no mention of retirement made greater changes. This suggests that even senior professors are amenable to systemic reform, as long as they are not anticipating retirement.

Many aspects of the structural and cultural context shaped Spring 2020 instruction, and resources made available by the institution or department seemed most impactful on teacher practices. The platforms used both aided and constrained instruction in various ways, but most comments focused on the latter. Most professors found interactions more difficult online because they could no longer read body language, or because students could not easily discuss with each other. Of note, prior research has shown synchronous online classes to be more or less effective than in-person counterparts, depending on how they are taught.[1] Within chemistry specifically, several studies have shown online courses to have similar outcomes to in-person counterparts[31,32] or be more effective than in-person classes. Prior studies indicate the nature of individual interactions is indeed a strong factor influencing student outcomes.[4,33] Although the perturbation in Spring 2020 did not allow time for faculty to seek out resources to implement radical changes in practice, the summer provides time to seek out resources so they can align with evidence-based practices.

Teacher thinking, including knowledge of content and beliefs, also had strong impacts on Spring 2020 teaching practices. Professors largely espoused a belief that didactic instruction was the best way to teach, so they continued to lecture online in some way. This aligns with previous research on a top-down change in the AP chemistry exam, where most teachers' classroom practices did not change

substantially in the first two years after reform.[34] In contrast, professors' views of students and academic dishonesty were divergent. Although most professors observed an increase in test scores in the online context, only some complained about cheating or wished they had outside resources, like proctoring services, available in future (e.g. Parker, Jackie). Others enacted changes themselves, such as changing question formats (Cameron) or seeking professional development on writing online assessment items (Robin, Harley).

Pandemic as a Catalyst for Change

Taking a larger view of the framework, the changes imposed on chemistry professors by the pandemic might be viewed as perturbing the system of instruction with an unintentional reform initiative: incorporating online instruction. As presently implemented, this reform has largely produced first-order changes.[22] Examples of first-order changes include changes to increase the efficiency or effectiveness of existing educational goals. Within this study, making lectures available for synchronous or asynchronous viewing, or moving assessment questions verbatim from paper to online platforms would be examples of first-order changes; these are examples of "change without difference."[22] However, because professors recognize that changes of some type must happen when teaching online, this situation provides an opportunity for second-order change as well. Second-order changes are transformative changes that reconsider existing goals and structures and seek to create new ones better aligned with stakeholders' needs.[22] Second-order changes could include shifts to pedagogies that concretely support students' active construction of knowledge rather than use of didactic methods alone. This notion started to emerge, when one participant, Morgan, described how a professor should be an "advisor" helping with problem solving rather than providing overviews of general content. However, implementation of sustained second-order changes requires many supports to be in place.

Previous research in change theory[35] suggests that supports from four frames are necessary to sustain a change: structures, symbols, people, and power.[36] Structures include incentives and supports for change; symbols include attitudes and beliefs within the institution and/or department that give meaning to structures (e.g. norms and values); people highlights that individuals have unique perspectives but there is a need for a shared vision of change among all (or at least most) people in the

department; and power recognizes the gatekeeping role that can be played as well as the role of explicit and implicit wielders of power in the department and institution. Data from this project suggest possible avenues for putting these supports in place.

With respect to structures, Robin chose to use an extended institutional professional development opportunity that aided in rethinking their approach to a summer class. This contrasts with professional development focused only on the use of tools, such as the introduction to Blackboard Collaborate, provided to the department in Spring 2020. To support changing instruction, value must be placed on professional development that focuses on teaching approaches. Incentivizing such meaningful professional development through tenure and promotion expectations could encourage larger groups of faculty to use such resources.

Symbols could be addressed by changing norms of communication around teaching in the department. Harley expressed a desire to discuss what they and others had done to shift instruction online. Furthermore, Cameron added poll questions to their class in Teams and seemed satisfied with how it worked. Conversely, Jackie felt they were required to use Blackboard Collaborate for teaching and tried to retain poll questions from the face-to-face environment but was not satisfied. Great communication around teaching in the department might have helped Jackie address one of their teaching concerns; such discussions around teaching hold potential to affect faculty beliefs around teaching. Furthermore, some individuals interested in change already appear to exist in the department. Morgan and Robin seem open to flipped instruction and Robin helped a colleague, who was planning on giving all students incompletes, to consider the students' perspective. Additionally, prior research suggests that talking to colleagues is one of the three most commonly cited resources influential to faculty's teaching.[37] Although faculty's past experiences as teachers and learners cannot be changed, present and future discussions with colleagues can be—especially if colleagues interested in reform are given tools to support their growth. Thus, it seems the department would benefit by creating a community of practice around *teaching* chemistry in which department members would establish "shared ways of engaging in doing things together" and knowledge of "what others know, what they can do, and how they can contribute" (p. 125).[38]

Gathering people around a shared vision of change might be addressed from an assessment angle. Most interviewed professors expressed dissatisfaction with online assessment. Based on this shared recognition of issues with maintaining old ways of assessing and a lack of satisfaction with their initial solutions in Spring, there seems to be common ground for exploring new possibilities. Such changes could include learning techniques for writing exam items so that items used do not have solutions readily available online.

Finally, any reforms require gatekeepers to be willing to assist. This means that people with official administrative roles and highly-respected researchers and teachers in the department would need to be on-board for changes to be sustained. Thus, engaging these high-powered people early in the process, and obtaining early victories to sustain momentum, are important considerations. Because we interviewed tenured faculty, our sample represents a group with power in the department. The existence of participants open to change suggests their power could be used in reform efforts.

IMPLICATIONS FOR RESEARCH AND PRACTICE

As an institution that is pre-reform, we recognize the need to know current faculty instructional practices and beliefs in order to plan reforms. Our results provide several implications for practice in our department, including: the existence of tenured professors interested in change, the existing desire for greater communication in the chemistry department, and the common ground of addressing perceived failings of assessment in the online environment. We believe this is important for any department desiring to make change, and we encourage continuing research into instructional practices and beliefs of experienced professors who may serve as change agents. We highlight that this research moves faculty to reflect on their instructional practices, which itself may help to spark change.

ASSOCIATED CONTENT

Supporting Information

Interview questions (PDF)

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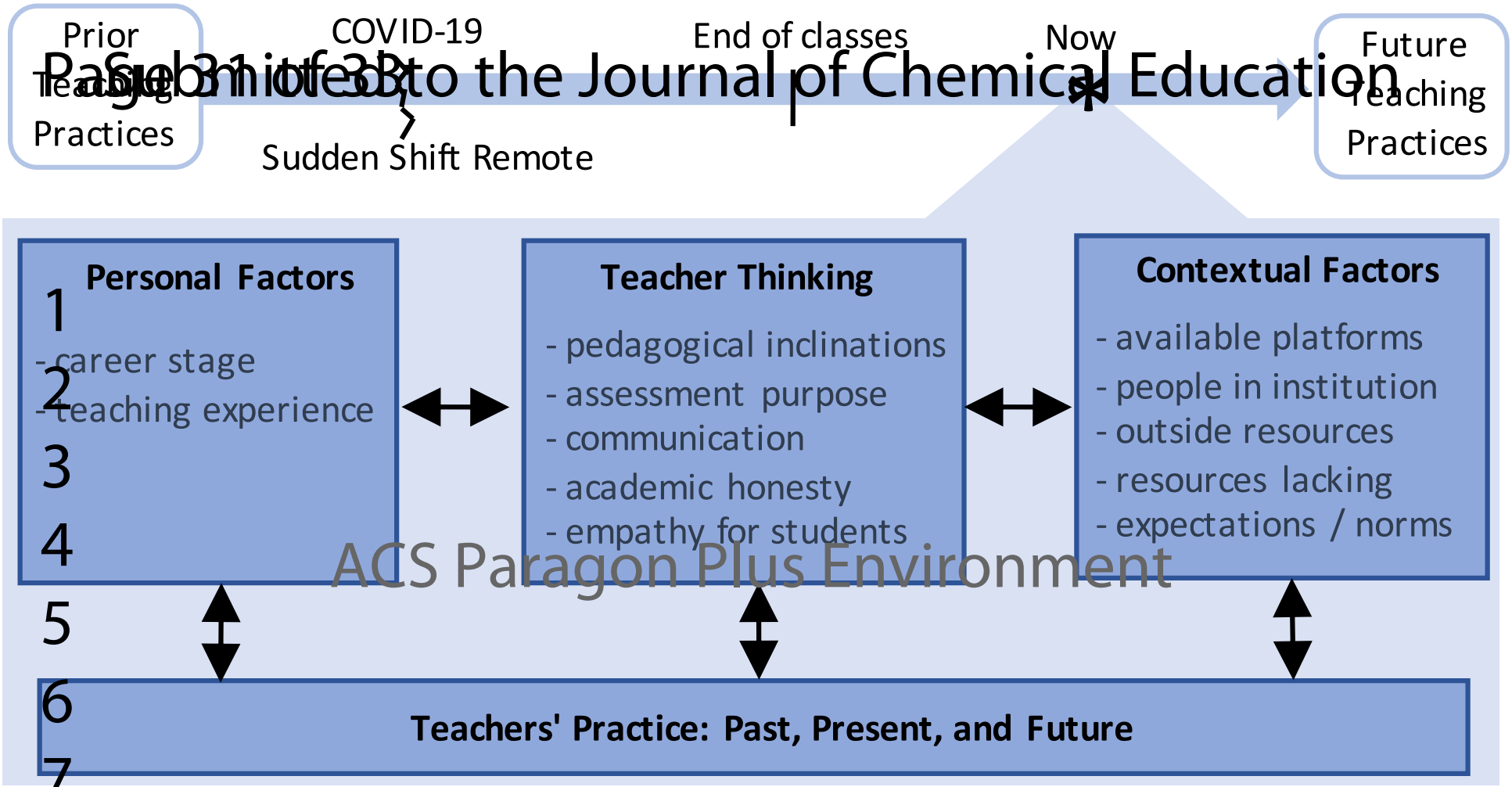
Prior Teaching Practices
COVID-19
Sudden Shift Remote
End of classes
Now
Future Teaching Practices
Personal Factors
- career stage
- teaching experience
Teacher Thinking
- pedagogical inclinations
- assessment purpose
- communication
- academic honesty
- empathy for students
Contextual Factors
- available platforms
- people in institution
- outside resources
- resources lacking
- expectations / norms
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Teachers' Practice: Past, Present, and Future