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# Remote Chemistry Teacher Professional Development Delivery: Enduring Lessons for Programmatic Redesign

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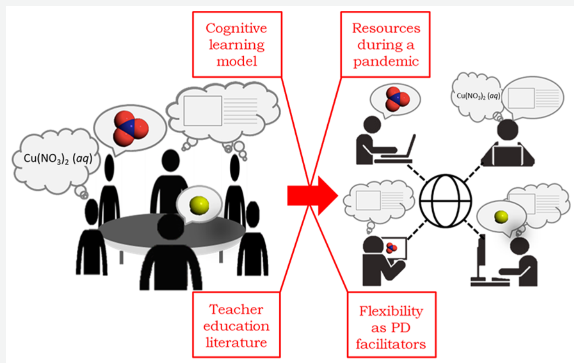
**ABSTRACT:** COVID-19 has thrust educators into a period of uncertainty, complicating conventional ways of teaching and learning. We suspect that the pandemic has magnified the challenges that some high school teachers already experience, particularly when they are the sole chemistry teacher at their school. The pandemic has likely inhibited collegial interactions and access to professional development (PD). Our reflections from redesigning a face-to-face PD program to one that is remotely delivered provide recommendations that advance PD accessibility and interactivity to mitigate isolation and other longstanding challenges teachers may face. In this article, we discuss how the cognitive learning model informed emergent teaching practices that guided the transformation of the PD's implementation for 20 high school chemistry teachers. Our reflections on the PD's strengths, areas for improvement, and insights alongside participant feedback provide enduring guidelines for fellow teacher educators. Specifically, we forward the importance of conceptualizing theory-informed design principles first, and then modifying the delivery with appropriate tools and technologies. As PD facilitators, we also draw attention to the necessity for flexibility. Remaining open to adaptation during implementation is crucial to advance teacher learning and engagement. We hope our process for how and why our PD program was redesigned will inspire future teacher educators to explore new, postpandemic ways of maximizing high-quality PD experiences.




**KEYWORDS:** *High School/Introductory Chemistry, Public Understanding/Outreach, Multimedia-Based Learning, Professional Development, Learning Theories*

The COVID-19 pandemic has indubitably disrupted "business-as-usual" routines, particularly for educators who have been forced to navigate uncharted waters in the form of online and/or remote teaching. Many had to enact emergency remote teaching (ERT),[1] defined as an alternative mode of instruction in response to a crisis. While ERT is a timely and reliable response to the sudden closures of schools and universities, this mode typically lacks the quality of a well-designed course and functions more as a temporary solution.

Communities such as Chemical Education Xchange (*ChemEd X*) and the American Association of Chemistry Teachers (AACT) have aptly responded, providing a plethora of resources tailored for precollege teaching during a pandemic. For example, *ChemEd X* has compiled a list of posts and resources that may be useful for remote teaching,[2] while AACT has recommended technological tools such as Nearpod, Classkick, and Quizizz for effective remote chemistry teaching.[3] The *Journal of Chemical Education* special issue "Insights Gained while Teaching Chemistry in COVID-19" has also provided useful implications from college instructors' reflections on their adjusted practices.[4] These articles and commentaries highlight the necessity of our community's responsiveness and support such that educators can continually adapt to their learners and adjust their pedagogies accordingly.

These accumulated pedagogical resources made available by AACT, *ChemEd X*, and *JCE* furthermore allude to the complications of high school chemistry teaching. The pandemic has both stymied conventional strategies educators may use and illuminated longstanding difficulties like disparities in internet access and resources for instructional planning and implementation. This complexity is also due to deeply ingrained challenges that have recently been eclipsed by the severity of the pandemic.

For instance, isolation (i.e., being the only instructor of a specialist discipline within a single school) is an enduring obstacle that high school teachers confront.[5,6] Isolated teachers, especially those who teach at urban schools, report

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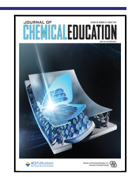







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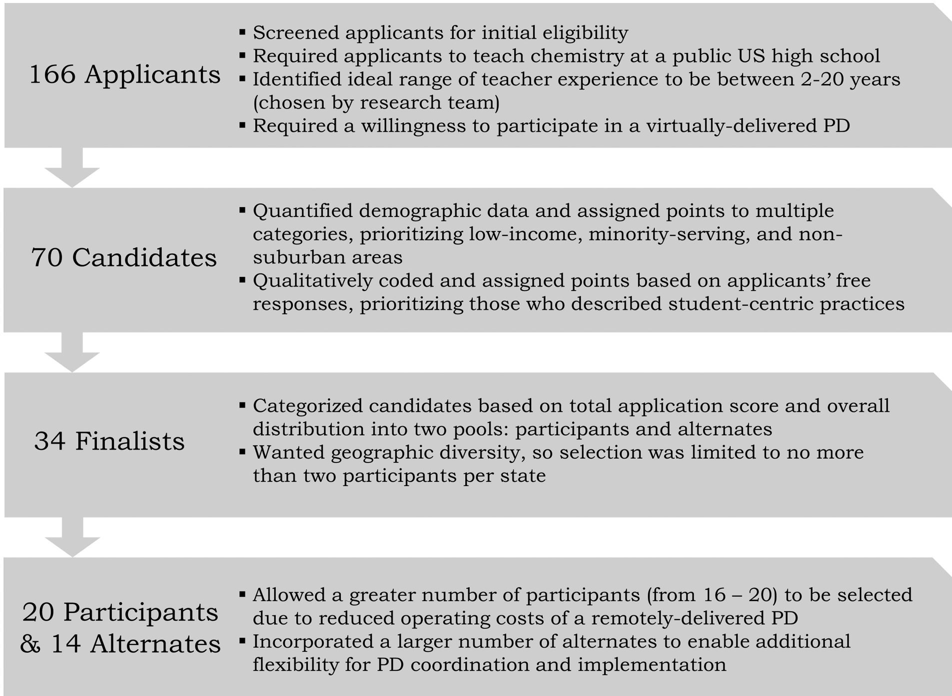


**Figure 1.** Flowchart of the participant selection process for the VCI 2020. Each phase represents the process of how the research team condensed the applicant pool into a list of candidates and alternates. Criteria established by the research team, the weighting of applicant responses, and PD revisions due to remote delivery are listed accordingly.

poor self-efficacy and limited agency.[7] If left unattended, isolation may result in even fewer collegial interactions, limited access to professional development (PD), and reduced student performances.[8,9] Some teachers have recently resorted to social media such as Twitter and Instagram for professional, communal, and affective support.[10,11] Although social media can counter isolation, we suspect that COVID-19 has added stress, especially for teachers in low-income, minority-serving, and/or nonsuburban schools. Because underrepresentation of women and minoritized populations in STEM is a prevailing national issue,[12] there is an increasing need for high-quality PD opportunities to support teachers whose experiences may have been exacerbated by the pandemic. By improving teachers' pedagogies, we can consequently advance their students' learning.

The purpose of this article is to document our decision-making in transforming an originally intended face-to-face PD program into one that is remotely delivered. Although our final product may be specific for our contexts, our process of PD redesign and implementation functions as an informative guideline for teacher educators. We note that the *Journal of Chemical Education* special edition, although timely and responsive, was predominantly focused at the postsecondary level. Our reflection on the PD program's fine-tuning thus serves to address the relative absence of fostering high school teachers' chemistry learning and teaching during and beyond the time of COVID-19.

We play dual roles as both professional developers and researchers. By March 2020, we understood that our responsibility as professional developers took priority. Neither canceling nor delaying the PD program was an option given the circumstances our participants faced. We were thus obligated to redesign our PD. It was imperative to not implement a design reminiscent of emergency remote teaching. Although the PD transformation had to occur quickly, we could not trade efficiency for quality. Our PD program had to remain focused on its chemistry and pedagogical aims to meaningfully serve our teachers. Similar to what Talanquer and colleagues[13] note, we viewed this pivot as both a risk and opportunity to reimagine how teaching and learning in a PD program could be facilitated through the access uniquely afforded by remote delivery.

Below, we describe the PD's original face-to-face design, the processes undertaken to modify its implementation, and our reflections on its strengths, areas for improvement, and emergent insights based on participant feedback from a Qualtrics[14] survey. Throughout this article, we emphasize two essential steps for redesign: (1) identification of a set of salient theory-informed design principles for effective teaching and learning and (2) development of a plan for the delivery of the PD within the available modality with suitable tools and technologies. Theory-informed design principles are operationalized in our context as information processing procedures which informed the reshaping of the PD's infrastructure. We accordingly present the cognitive learning model and its three design principles: *priming the perception filter*, *reducing cognitive load*, and *linking new ideas with prior knowledge*. We then describe how these design principles helped increase accessibility and interactivity for our PD's restructured delivery plan. We also offer insights and recommendations based on the PD's strengths and areas for improvement as evidenced by participant feedback. Consequently, our implications are intended to be more than pandemic-specific guidelines for effective PD. They are a call to fellow teacher educators to transform these solutions instigated by the pandemic into future, postpandemic offerings of high-quality PD for high school chemistry teachers.


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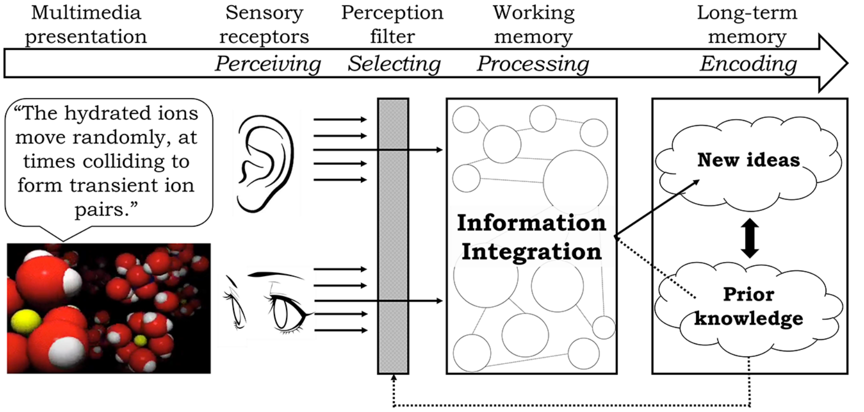


**Figure 2.** Cognitive learning model underpinning the VisChem approach. The three practices used to inform the VCI transformation emerged from processes related to the perception filter selecting information, the working memory processing information, and long-term memory encoding information. Adapted from ref 20, used with permission.

## ■ SETTING

Our PD program, the VisChem Institute (VCI), aims to advance high school teachers' conceptual chemistry understanding and instructional quality by using molecular-level models and addressing associated cognitive challenges with molecular visualizations. In addition, the VCI is aligned with the Science and Engineering Practices and Disciplinary Core Ideas found within the Next Generation Science Standards.[15] An overarching narrative throughout the VCI is modeling the VisChem approach, a pedagogy that involves storyboarding (i.e., drawing representations and describing with captions) what is happening at the submicroscopic level for a chemistry phenomenon and using molecular visualizations to inform subsequent storyboard modifications.[16] The VisChem approach leverages the imagination of structures and processes at the particulate level to interpret changes at the macroscopic level and make sense of the symbolic level of chemistry.[17] Additionally, other VCI activities also draw attention to the limitations inherent within each level, thereby challenging participants to ascertain the strength of using an integrative ensemble of all three levels for chemistry sensemaking. The VCI thus positions teacher participants as chemistry learners through discussions of what constitutes as a comprehensive submicroscopic drawing, observations of particulate animations, and reflections on changes to their storyboards and understanding. The VCI then repositions participants in their native professional roles through discussions of underpinning learning theories, literature about student misconceptions and inaccurate chemical ideas, and opportunities to create their own learning design activities using VCI resources.

This article stems from the first iteration of the VCI in July 2020. The VCI spanned 4 days, resulting in 28 h of PD. The 2020 cohort consisted of 20 high school chemistry teacher participants from across the United States. To be considered for eligibility, applicants had to answer questions regarding their classrooms, teaching experience, pedagogical practices, and PD expectations. The total number of applicants prior to the February 2020 deadline was 166. With such an unexpectedly large sample to select from and the VCI's limited availability, the research team developed a weighted ranking system to target certain desirable characteristics in the applicant pool. Specifically, teachers who described more student-centered practices and taught at schools with higher percentages of students who qualified for the federal reduced/free lunch programs were prioritized. In addition, we identified 2−20 years as the ideal chemistry teaching range. Such teachers would have enough experience to make sense of the chemistry content and would be early enough in their careers to have many more years ahead to positively influence learners. Figure 1 summarizes the steps undertaken and details about the research team's selection criteria. Alternates were also identified in case a participant could no longer attend the VCI. More information about the VCI's daily activities can be found at https://www.vischem.org/basic-page/vischem-institute. In addition, all protocols related to sampling and the PD were reviewed and approved by the institutional review board of the hosting university.

## ■ DESIGN OF THE VISCHEM INSTITUTE

### Cognitive Learning Model

The VisChem approach is informed by a cognitive learning model that is intertwined with multimedia learning theories.[18,19] Adapted from the third author's previous work,[20] Figure 2 summarizes three information processing procedures within the cognitive learning model. The first involves the perception filter selecting information from incoming stimuli. The emergent practice that facilitates this process is *priming the perception filter*. An instructor must accordingly activate attention networks by leveraging prior knowledge, and, if necessary, generating cognitive dissonance. Oftentimes, engagement can be best achieved by using an unusual, creative, and/or emotional activity. For example, one could first draw learners' attention to jars of hydrated copper(II) sulfate appearing blue and anhydrous copper(II) sulfate appearing white. One could then prompt learners to use their observations to surmise why copper(II) sulfate solution is blue. The second information processing procedure relates to working memory. The learner has a limited capacity and may be overwhelmed when incoming information becomes overly complex and abundant. Thus, the second related practice is *reducing cognitive load*. Continuing with the copper(II) sulfate solution example, an instructor could show particulate animations of copper ions and hydrated copper ions, highlighting that the latter contain a different chemical species that accounts for the blue solution color. Understanding learning media, however, can in itself be too complex for novice learners. Instructors could reduce cognitive load by segmenting information, minimizing the audiovisual clutter,

**Table 1. Blueprint of the VisChem Institute**

| Design principles | Engaging Teachers as Learners of Chemistry | Engaging Teachers as Learners of Pedagogy | Adjustments to an Online/Remote Context |
|---|---|---|---|
| Priming the Perception Filter | Drawing on prior chemistry knowledge | Drawing on prior chemistry teaching knowledge | Using different types of questions in Poll Everywhere |
| | Using unusual, creative, and emotional demonstrations of chemistry phenomena | Providing opportunities to relate the VCI to their teaching contexts | Modeling good teaching practice by eliciting feedback via Qualtrics and acting upon it |
| | Generating cognitive conflict by eliciting teachers' misconceptions | Reading literature about students' chemistry misconceptions | Compiling all VCI resources into a shared Google Drive folder |
| Reducing Cognitive Load | Scaffolding chemistry understanding with VisChem animations | Scaffolding the VisChem approach | Setting up tech-check appointments before the start of the VCI |
| | Using synchronous narration | Providing narrated animations for teachers' reference | Mailing physical handouts and hyperlinking digital copies on Canvas modules |
| | Chunking information through replaying VisChem animations and drawing attention to key events | Linking constructs of the cognitive learning model into an overarching narrative | Creating a VCI YouTube channel |
| Linking New Ideas to Prior Learning | Sustaining a space for active learning | Sustaining a space for pedagogical discussion and reflection | Using both synchronous and asynchronous activities |
| | Creating opportunities for teachers to collaborate on their chemistry ideas | Having teachers investigate sample student storyboards | Diversifying activities with various digital platforms (Zoom breakout groups, Google Docs, and Google Slides) |
| | Encouraging application of ideas to novel chemistry phenomena | Encouraging modeling of the VisChem approach in teachers' pedagogy | Boosting formal and informal conversations with Slack |

and providing both visual and verbal direction for more effective information processing and integration. Finally, the last construct deals with long-term memory encoding. This relies on opening channels for peer discussion and encouraging the application of knowledge to new but related situations. At the end of the copper(II) sulfate solution example, understanding of chemical speciation and its importance can be further broadened by considering why patients drink barium sulfate solid suspension before getting an X-ray even though barium ions are toxic. Instructors must then facilitate this consolidating sensemaking process, the third emergent practice we describe as *linking new ideas to prior knowledge*.

Knowing participants would be positioned simultaneously as learners and teachers, we had to ensure that the design and facilitation of the remotely delivered VCI also mirrors the pedagogy associated with the teacher learning goals. In other words, the PD framework itself had to adhere to the three emergent practices from the cognitive learning model. *Priming the perception filter*, *reducing cognitive load*, and *linking new ideas with prior knowledge* were thus translated into the theory-informed design principles that became the methods guiding the redesign of the VCI infrastructure.

Confronted with the prospects of shifting to remote delivery, we identified technologies and techniques to engage teachers as learners in all three design principles. Our goals specifically involved determining how *priming the perception filter*, *reducing cognitive load*, and *linking new ideas to prior knowledge* could inform PD accessibility and interactions in virtual settings. We also needed opportunities for participants to debrief their experiences. Activities interspersed throughout the VCI prompted participants to discuss and reflect on their chemistry learning as students and on their pedagogy learning as teachers. We prioritized encouraging participants to connect between what they learned in the VCI and what could possibly be enacted in their own classrooms. Table 1 lists the VCI's design principles as informed by the cognitive learning model, how the VCI maps onto participants as both chemistry learners and teachers, and our adjustments for remote delivery.


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## PIVOTING FROM FACE-TO-FACE TO REMOTE DELIVERY

### Priming the Perception Filter

Some of the initial modifications stemmed from identifying how to productively prime participants' perception filters. Garet and colleagues[21] have argued that there is a profound significance of subject-matter focus for high-quality PD. In addition, effective teacher learning necessitates providing a description and rationale for recommended teaching practices[22] and space for teachers to translate what they have learned to their unique instructional contexts.[23,24] These previous studies affirm that we as PD facilitators should appeal to VCI participants as learners and teachers of chemistry. Accordingly, we adjusted our initial plans such that we could capitalize on available digital tools to increase our participants' buy-in with the VCI.[25]

For example, the original VCI plan included activities such as participants' reading, discussing, and reflecting on literature about students' chemistry misconceptions. These literature circles were intended to encourage participants to confront potential gaps in their own understanding and inform their future pedagogical decisions. To better adapt VCI activities into virtual settings, we incorporated Poll Everywhere,[26] an audience response system which visualizes participant input in real time. For example, Poll Everywhere enabled us to evaluate participants' conceptions of redox reactions with regards to submicroscopic depictions and interactions of chemical species. Being able to elicit participants' ideas in the moment allowed for immediate discussion about content and models. Using Poll Everywhere had the additional benefit of modeling formative assessment for participants to incorporate in their own classrooms. Because of the richness of resultant discussions through participants' spoken words, replies in the Zoom chat, and follow-up conversations via Slack, Poll Everywhere appeared to invite participation and interactivity by making the remotely delivered VCI more learner-centered.

We also included additional layers of technology to augment participants' VCI experiences. For example, we administered a mid-VCI Qualtrics survey to ascertain what VCI features needed to be recalibrated. Eliciting feedback in terms of what supports, what hinders, and what could better facilitate participants' learning reiterates our intention of priming participants' attention. We wanted to convey our concern for their learning and demonstrate another example of good teaching practice to enrich participants' experiences as both learners of chemistry and of pedagogy. Finally, we had compiled a list of all salient VisChem instructional materials (e.g., animations, narrations, and storyboard templates) in a shared Google Drive folder. As Borko and colleagues note,[27] digital technologies afford new advantages like a near limitless capacity to store information and an ease of access. All VisChem resources were thus designed to be available to participants after the VCI, seeding further professional growth and incentivizing later implementation within participants' own classrooms.

### Reducing Cognitive Load

The second principle of redesigning the VCI was *reducing cognitive load*. While we had already considered methods of minimizing the complexity that comes with learning from visualizations of submicroscopic phenomena, there were emergent technological obstacles now that the VCI was no longer face-to-face. Previous research has indicated that teaching and learning with unfamiliar technologies can be problematic.[28] A recent study shows that while technology is being rapidly incorporated in teacher education, the level of adoption and teachers' conceptions around technology varies greatly.[29] In addition, Dietrich and colleagues[30] indicate a need to acknowledge high school teachers' working conditions in which required equipment may be unavailable and internet connection speed may be limited. Some teachers' lack of familiarity with recent technology may also explain why PD programs that offer opportunities of modeling technology in the context of specific instructional approaches, such as the one conducted by Bell and colleagues,[31] are perceived to be beneficial.

To improve familiarity and accessibility, we established meetings with all 20 participants prior to the start of the VCI. These 45 min "tech-check appointments" included the participant and one or two of the research team members. Our goal was to orient participants with various digital platforms used throughout the VCI such as Zoom, Canvas, Slack, and Google-related online applications. For example, we had introduced participants to Zoom's key features such as screen-sharing for troubleshooting, using the chat box, and navigating to a breakout room. For Canvas and Slack, we encouraged participants to practice taking pictures of and uploading their work, as this procedure would be frequently incorporated throughout the VCI. Finally, we ensured that participants could readily access and retrieve the resources stored in a shared Google Drive throughout the VCI so they can create VisChem approach-inspired lesson plans both during and after the PD. Establishing appointments before the VCI also led us to identify and reconcile unanticipated problems (e.g., inability to log into Canvas) that required additional contingencies to be devised. These tech-check appointments ideally helped participants feel more comfortable with the VCI-related technologies. We also hoped that by positioning ourselves as not just professional developers but also a source for technical support, we were able to further build rapport with the participants.

Reducing participants' cognitive load also required considering participants' working contexts. Aligned with what Beach recommends for remote teacher learning, we had to design our online resources to be both content-rich and straightforward to navigate for effective future retrieval.[32] One observation during the tech-checks was a lack of printer availability. To ensure that all participants had access to VCI documents essential for their learning and teaching (as drawing is a central activity to the VisChem approach), we mailed packets of handouts. Furthermore, we curated digital copies of all VCI documents on a shared Google Drive with corresponding hyperlinks, organized into intuitive daily modules on Canvas. Another realization was participants' being limited to the Google Chromebook, as this was the same device their students would also be using during class. The Google Chromebook, although convenient, is incompatible with extant VCI resources (e.g., submicroscopic animations) and prompted us to restrategize ways to improve the Chromebook user experience. We thus created a VCI YouTube channel where all of the animations were uploaded and organized by their chemistry topics into smaller playlists. This channel was coupled with a Google Sheets directory that categorizes and hyperlinks all of the VCI YouTube videos.


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### Linking New Ideas to Prior Knowledge

The final principle that guided our VCI redesign was facilitating the linking of new ideas to prior knowledge for long-term consolidation. This principle aligns with one of the key tenets of teacher PD: create a space where teachers can adapt and apply what they have learned in new settings.[33] Effective PD design requires engaging teachers such that they can reflect upon relevancy, authenticity, and usefulness, all in conjunction with their individual school context.[34] However, we were concerned that no longer being face-to-face may fundamentally reduce participant engagement with the VCI. Zhang and Liu[35] report that the quality of PD engagement is a critical factor to multiple dimensions such as teachers' self-efficacy beliefs, motivation, and perceived task value. We suspected that online/remote engagement may not support or even deter participants from establishing those meaningful connections. Similar to the principle of priming participants' perception filters, we had to reconsider engagement for greater integration between participants' ideas as chemistry learners and as chemistry teachers. Such overlap would ideally help participants to translate what they learned during the VCI into enacted practices for their classrooms.

The structure of the VCI engaged participants as learners who experience the VisChem approach and as teachers who then plan for its implementation. Participants would specifically create storyboards during the first half of the day and analyze sample student storyboards during the latter half. There were also opportunities on Canvas for participants to create their own VisChem learning designs, discuss, and then revise on the basis of peer feedback. Alternating between synchronous and asynchronous activities, limiting the frequency of breakout groups, and using a medley of online applications such as Google Docs, Google Slides, and different applications of Poll Everywhere enabled engagement with a variety of tools. Redesigning the VCI involved carefully inspecting each day, ensuring activities were unique compared to other days (see additional information at https://www.vischem.org/basic-page/vischem-institute) and allocating enough time for breaks to combat Zoom fatigue.[36]

Facilitating informal engagement was especially challenging due to the remotely delivered context. The original VCI had opportunities for participants to eat and live in dorms together, thereby affording moments of informal chats about experiences both within and outside their learner and teacher roles. The review conducted by Lantz-Andersson, Lundin, and Selwyn[37] indicates that off-task interactions (e.g., inside jokes and shared references) are also essential for developing online communities. These casual conversations, which may enable teachers to provide emotional support and share experiences, knowledge, and materials, are fundamentally the glue which sustains online communal solidarity.[38,39] Per these recommendations, we used Slack[40] as our primary communications platform. Slack has features which enable users to share files, privately message, and engage in chat rooms organized by topic. We had created different channels that pertained specifically to the VCI and informal ones where everyone could share amusing stories, images, and general announcements. Through Slack, we have also been able to follow up with participants after the VCI with regular bimonthly meetings to continually support participants during the academic year. These meetings have also positioned participants as fellow resources for their peers, building accountability as they offer their own recommendations for teaching during the pandemic.

## STRENGTHS, AREAS FOR IMPROVEMENT, AND INSIGHTS

We address strengths, areas for improvement, and insights emergent from participant feedback from a midinstitute Qualtrics survey. The survey's purpose was to elicit participants' impressions on the VCI's design and facilitation. Participants' feedback informs our reflection on the VCI's redesign.

We first recognize the success gained from our efforts to create and sustain new avenues of communication: reaching out to participants using a Slack workspace, keeping the Zoom channel open during breaks, and ensuring that we resolved participants' inquiries were prioritized throughout the facilitator agenda. According to participants' feedback, they reported that "time to make connections to teaching", "modeling the VisChem design for the teacher work in the institute", and "support from team/facilitators" were all features that reinforced their learning. Others also reported "colleagues" and "breakouts and learning from fellow participants" as positive VCI features. One participant even mentioned "not enough time for discussion" as something to be remediated for future PD activities. The team's decision to maximize VCI interaction stems from our awareness that meaningful interactions may have been hindered after our transition to remote delivery. Considering and implementing alternative forms of interactions intrinsic to teacher learning is imperative. Educators must invest effort toward identifying and implementing a variety of digital platforms to ensure effective communication with and among learners.[41]

One feature of the VCI that needs to be reconsidered is the accumulation of exhaustion, as identified from participant feedback. "Zoom fatigue", "concentration of work/intensity/amount of info", and "not being f2f/COVID-19/being at home" were described as features that were negatively impacting participants' learning. The stress associated with both the pandemic and prolonged participation in a remotely delivered PD should not be casually dismissed but instead be carefully unpacked and addressed.[42] One potential mitigation includes allocating more time for participants to decompress, whether in the form of additional breaks or well-designed asynchronous activities. The same total hours distributed over more days was also suggested by one VisChem Advisory Board member. Another solution could involve redesigning some of the VCI activities. Now that we as professional developers are better oriented to navigating the remotely delivered PD context, we could revamp the daily modules and increase the novelty so as to further disrupt the possible repetition participants may experience. Finally, resolving the accumulation of stress and anxiety may also require implementing different theory-informed practices beyond the cognitive learning model. One such theory could be mindfulness. Currie[43] describes how mindfulness practice (i.e., paying attention to the present moment without judgment) can be beneficial both to educators and learners' well-being. Employing evidence-based techniques on how to overcome these troubled times may have a positive impact on not only the learning setting but also people's physical and mental health.

Our experiences as VCI facilitators underscore the relative importance of flexibility over preparation. On one hand, we agree that meticulously planning each sequence of the VCI was beneficial. Participants appeared to have recognized our planning steps stating that "organization of activities overall",


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"application of activities", and "instructors keeping things on task and having a good time" were features that supported their learning. On the other hand, our experiences demonstrated that, despite many hours invested into planning, flexibility is needed. There were many moments where the team had to meet during breaks and recalibrate the flow, timing, and instructions of the day's activities. It is therefore even more crucial, especially during online/remote delivery, that we as professional developers remain flexible to adapting to learners' needs at a moment's notice. Our stance is analogous with Russ and Berland's[44] argument for improvisation: Educators must be responsive to learners' emergent constraints, modes of engagement, and questions in the activities the former enact.

## ■ CONCLUSIONS

Faced with a global pandemic, chemistry educators have responded with a variety of resources and strategies. Although the depth and breadth of this support is inspiring, it nevertheless alludes to the difficulties teachers face and the variety of teaching-related needs in our community. For example, teachers may feel further isolated due to COVID-19 and require high-quality PD that is both accessible and interactive. Our experiences pivoting from an originally intended face-to-face PD program to one that was remotely delivered offer solutions which can address this demand.

We first showcase the importance of identifying research-based design principles for effective learning and teaching before adjusting the mode of delivery. The VCI incorporated a cognitive learning model that involves *priming the perception filter*, *reducing cognitive load*, and *linking new ideas to prior knowledge*. We therefore used these emergent practices translated from the cognitive learning model as design principles to facilitate our transition to remote delivery. Promoting the accessibility of online resources on Google Drive and YouTube, establishing tech-check appointments to troubleshoot issues, and keeping synchronous and asynchronous activities diverse were just a few of our readjusted strategies. VCI participants appeared to have responded well, providing positive feedback on the ways we had implemented the PD.

Reflecting on our adjustment of the VCI yielded strengths, areas for improvement, and insights. Although our use of different platforms to facilitate communication and collaboration was successful, we still need to address the issue of participant exhaustion in future VCI iterations. These reflections highlight a crucial insight we wish to share with fellow teacher educators: the necessity of flexibility in conjunction with preparation. Although planning every activity of the VCI down to the minute was productive and positively received by participants, it was more pragmatic to accept that our plans would nevertheless need adjustments. This acknowledgment thus encouraged us to embrace the notion of flexibility, to know that even with sudden changes the PD can still be successful as long as we appropriately adapted. Promptly adjusting the VCI also legitimized participants' feedback and concerns, thereby promoting communal engagement and belonging. Our emergent insights as PD facilitators, similar to those of Russ and Berland,[44] underscore the value of real-time improvisation as a productive step toward effective teacher learning.

Although the *Journal of Chemical Education* special issue predominantly offered insights at the tertiary level of chemistry teaching and learning, we nevertheless value and endorse these recommendations, especially when repositioning high school teachers as learners of both chemistry and pedagogy. Learner dissatisfaction with lack of engagement,[45] the monotony of distance learning,[30] and the importance of accessibility[46] have similarly been discussed. These findings serve as a productive foundation for conceptualizing best practices for teacher learning. Contributing to this body of literature, we echo the need to recognize the long-term potential of technology-related strategies instigated by COVID-19. Ertmer and colleagues[47] have reported that teachers' existing attitudes and beliefs toward technology act as the strongest barriers preventing the integration of technology and teaching practices. Such perspectives toward technology may have worsened as a result of COVID-19 and the sudden shift to emergency remote teaching. While it may be easier to revert to traditional face-to-face practices in postpandemic circumstances, we recommend moving beyond the uncertainty and trepidation that may be associated with new technology. It is sensibly a more productive endeavor to continually reimagine how technology and its connection with learning theories can create novel opportunities for meaningful interaction and sensemaking. Strategies developed during the pandemic can be leveraged for future applications. As shown with our redesign process, our considerations have implications for enduring, postpandemic solutions that can maximize PD accessibility and participant interaction.

We attest that pivoting to and implementing a remotely delivered PD was difficult. A great deal of effort was expended to correspond with participants and sustain their chemistry content and pedagogy learning, and yet, all of this was absolutely necessary due to high school teachers who may lack supportive networks during this period. When society eventually returns to some semblance of "normal", issues like teacher isolation will persistently hinder high school chemistry teachers' experiences. Advancing research-based instructional strategies at the high school level starts with acknowledging these teachers' contexts. We hope our rationales for how and why the VCI had been redesigned resonate with and inspire fellow teacher educators to explore ways of supporting high school chemistry teachers through future offerings of high-quality PD.

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## Notes

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 National Science Foundation.

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A PDF synopsis of the daily activities in the 2020 VCI can be found at https://www.vischem.org/basic-page/vischem-institute.

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