SECONDARY SCIENCE TEACHERS IN CHARTER SCHOOLS: UNIQUE CHALLENGES OF TEACHING DURING THE COVID-19 PANDEMIC

Pamela Huff* & M. Gail Jones

North Carolina State University, Raleigh, NC, USA

*Address all correspondence to: Pamela Huff, North Carolina State University, Raleigh, NC, USA, E-mail: PMHuff@ncsu.edu

The COVID-19 pandemic restrictions presented teachers, students, and parents with unique challenges that were met with varying degrees of creativity, flexibility, and stamina and were dependent upon specific contexts and available resources. This work utilized interviews to examine charter school secondary science teachers' online teaching in response to COVID-19 restrictions. Specifically, this study explored teachers' instructional approaches, teaching constraints, and teacher stressors with a semi-structured interview within a community of inquiry framework. In addition, there were significant challenges to providing remote instruction due to technology constraints involving hardware, software, and Internet connectivity. Moreover, teachers were ill-prepared for online teaching due to the lack of training, professional development courses, guidance, and communication among peers. Although many of the teachers in the study suffered emotionally and physically, they were generally creative and resilient as they struggled to develop novel pedagogical resources that could be applied to the online setting. The findings suggest that greater planning, training, hardware and software infrastructure preparation, guidance on instruction formats or standardization, peer support systems, and communication could enhance teachers' capacity and skills for online teaching.

KEY WORDS: science education, charter schools, COVID-19 pandemic

1. INTRODUCTION

In the spring of 2020, the COVID-19 pandemic forced widespread school closures in an attempt to stop the spread of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). School districts in the United States responded to the pandemic in various ways based on community needs, socioeconomics, location, infrastructure, and financial requirements (Brooks et al., 2020; Reich et al., 2020). This unplanned and unprecedented disruption of lives changed the work of teachers suddenly and profoundly (Fagell, 2020; Laster Pirtle, 2020). School buildings were closed, and teachers had to find ways to connect with students and transition to untested modes of teaching very quickly (Durden, 2020; Lederman, 2020). The only plausible option to provide students with meaningful educational experiences was to offer classes over the Internet (online or remote learning) (Merrill, 2020;

De Witt, 2020). However, two of the biggest hurdles to moving instruction online were students' inadequate number of digital devices and the lack of high-speed Internet connections at home (Kaden, 2020). Teachers were also confined at home, often in makeshift offices struggling with existing lesson plans that were no longer adequate for online learning and other distractions. They had to adapt quickly to this new environment while learning new technologies, strategies, and coping mechanisms (Baired, 2020).

While all disciplines were affected by this abrupt change, science instruction was particularly disrupted due to the hands-on, inquiry-based nature of science laboratory activities. In a recent national report, 88% of teachers indicated that their students were spending less time on science through remote learning than class time, with only 38% of teachers reporting that students had been engaged in science experiments and investigations through remote learning (Self & National Academies of Science, Engineering, and Medicine, 2021). However, teachers were resistant to abandoning teaching the scientific process and used adapted online classroom activities and assignments that had students developing five of the eight practices of science detailed in *A Framework for K–12 Science Education* (Hill, 2021). These five practices were: (a) asking questions and defining problems; (b) developing and using models; (c) analyzing and interpreting data; (d) using mathematical and computational thinking; and (e) engaging in argument from evidence (Hill, 2021). They accomplished this by adopting practices for online learning that included teacher-led demonstrations for students to observe while encouraging student notetaking or following along; at-home data set analysis provided by the teacher; and utilization of virtual laboratories (Hill, 2021). Teachers also shifted from inquiry-based, hands-on learning activities typical of state and national science standard recommendations to more class discussions and workgroups to facilitate student engagement in science practices (Hill, 2021). Most of the K-12 school districts, private schools, and charter schools worldwide were ill-prepared for full-time online learning in terms of available pedagogy, technology, and financial resources (Pokhrel & Chhetri, 2021). As reported by Francom et al. (2021), teachers in traditional K-12 schools experienced challenges with student communication, setting up online learning courses due to lack of knowledge, Internet access, and lack of parental involvement. While a great deal of information is available about K-12 traditional schools and how teachers, staff, and parents navigated the online learning experience, little is known about how charter schools—with their more limited resources and in many cases new infrastructure—responded to COVID-19 restrictions.

Using the community of inquiry (CI) framework (Garrison et al., 2010), we examined charter school science instruction during COVID-19 in the context of charter schools' unique characteristics, limited infrastructure, and brief history in the educational landscape. The purpose of this study was to identify secondary charter school science teachers' online instructional approaches, constraints surrounding online science education learning, and stressors associated with teaching science online during the COVID-19 pandemic. To better understand how charter school science teachers experienced the transition from face-to-face to online learning, this study aimed to answer the following research questions:

1. What were charter school science teachers' instructional approaches to online science instruction during the COVID-19 pandemic?
2. What were the teaching constraints of online learning in charter school science programs during the COVID-19 pandemic?
3. What stressors did science teachers experience while implementing online learning during the COVID-19 pandemic?

2. BACKGROUND CONTEXT

2.1 Charter Schools

The charter school movement in the United States began in Minnesota in 1991 and has spread into nearly every state within the United States (De Luca & Wood, 2016; Carpenter & Kafer, 2012). According to White (2020), more than 3.3 million students attend over 7,500 public charter schools in 43 states and the District of Columbia. Charter schools are independent, public schools of choice that are publicly funded and run by private administrations, either as for-profit or non-profit entities with mostly non-unionized teachers (De Luca & Wood, 2016). Their funding comes from both tax dollars and private donations (Bankston et al., 2013).

Unlike traditional district schools, most charter schools do not receive funding to cover the cost of purchasing or leasing a physical facility (Rebarber & Zgainer, 2014). Rather, charter schools receive a per-student allotment that is specifically not to be used for the cost of the facility. As such, charter schools are often housed in non-traditional school buildings where space is at a premium (Hassel & Page, 2001), limiting dedicated space for science classes that often require specialized laboratory space. Research has shown that laboratory space has a central and distinctive role in science education (Hofstein & Lunetta, 1982, 2004).

The swift development of the charter school movement has required these new schools to adapt quickly without the benefit of traditional school infrastructure to support laboratories and materials for science instruction (Arsen & Ni, 2012). With this fast growth and unique funding structure, charter schools have become an important area of study for science education.

2.2 Online Education

Distance education is defined as an institution-based, formal education, where the learning group is remote and interactive telecommunications systems are used to connect learners, instructors, and resources (Simonson & Schlosser, 2009). Today's schools face significant challenges in moving a classroom to an online instructional mode for the institution (Medina, 2018; Raza, 2018), teachers (Medina, 2018; Ocak, 2010), and students (Broadbent, 2017; Prasad et al., 2018).

It has been argued that the rapid (emergency) change from face-to-face to remote learning seen during the pandemic should not be considered regular online teaching (Fackler & Sexton, 2020; Hodges et al., 2020). Hodges and colleagues coined the term “emergency remote teaching” as the type of instruction that is being delivered by teachers during the pandemic (Fackler & Sexton, 2020). This could be defined by a temporary shift in teaching under an unexpected circumstance and involves fully remote teaching solutions for instruction or education otherwise given face to face or as hybrid blended courses that would return to the original format after the crisis or emergency is resolved. Thus, the main objective in this type of emergency situation is not to recreate a full educational ecosystem but rather to provide quick, reliable, and temporary access to instruction (Hodges et al., 2020). While the literature on emergency remote teaching prior to the COVID-19 pandemic is sparse (Francom et al., 2021), suggestions have been made to help plan for academic continuity during emergency events where face-to-face instruction is impossible (Bates, 2013).

The COVID-19 pandemic required major changes to adapt to learning at a distance (Pokhrel & Chhetri, 2021). Appropriate working spaces (Zhang et al., 2020; Francom et al., 2021) and equipment (Mohmmed et al., 2020) were very difficult to obtain for many teachers. Thus, new educational challenges arose relating to the physical learning spaces, hardware and software needs, lack of instructional methods, learning resources, assessment tools, information technology support, and administrative support (Francom et al., 2021). During the COVID-19 pandemic teachers were often limited to the online tools and protocols provided by their schools, or if allowed they had to find other approaches among the wide variety of web-based educational tools available to develop and adapt to their programs by themselves. These included finding tools or programs for communication, content sharing, learning assessment, and intelligent tutoring (Pokhrel & Chhetri, 2021).

2.3 Practices of Science

Regardless of the type of school engaged in teaching science or the delivery method (e.g., face-to-face or online instruction), the practices of science are a primary objective of science programs. *A Framework for K-12 Science Education* (National Research Council, 2012) identifies the eight practices of science and engineering as essential for all students to learn as follows: (a) asking questions; (b) developing and using models; (c) planning and carrying out investigations; (d) analyzing and interpreting data; (e) using mathematics and computational thinking; (f) constructing explanations; (g) engaging in argument from evidence; and (h) obtaining, evaluating, and communicating information.

3. THEORETICAL FRAMEWORK

3.1 Community of Inquiry

The present study was framed within the community of inquiry framework developed by Garrison et al. (2010). Initially, the framework applied to postsecondary distance education, but has since been used in the K-12 research environment (Sanders, 2020). A community of inquiry is defined as “a group of individuals who collaboratively engage in purposeful critical discourse and reflection to construct personal meaning and confirm mutual understanding” (Garrison & Akyol, 2013, p. 106). It is a social constructivist model of learning processes in online and blended environments and is built upon three dimensions: teaching presence, teacher cognitive presence, and teacher social presence (Fig. 1). For the purposes of this study, we focused on teaching presence. Teaching presence is defined as the design, facilitation, and direction of cognitive and social processes for the realization of meaningful learning in an online environment (Garrison & Akyol, 2013). From the teachers' perspectives, the framework incorporates collaborative engagement with administration, peers, students, and parents; instructional design, organization, and planning of courses; and facilitation, implementation, and instruction of the course (Garrison et al., 2010). For the current study, the community of inquiry included online and blended home/school environments for teachers and students within the COVID-19 context.

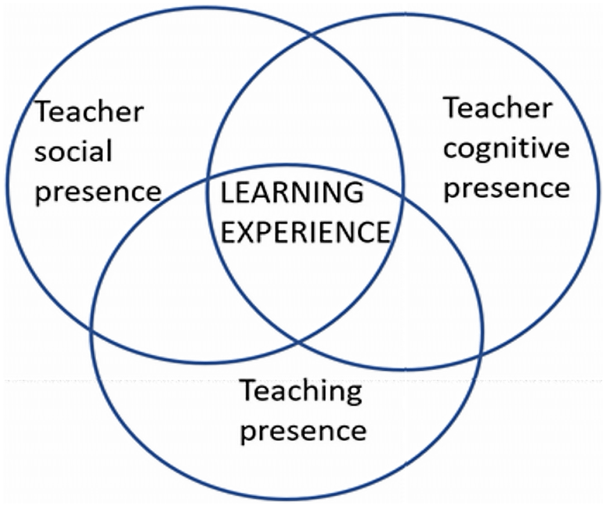

FIG. 1: Community of inquiry framework adapted from the CI model by Anderson et al. (2000)

4. METHODS

4.1 Research Design

This descriptive and exploratory case study (Creswell & Creswell, 2017) focused on the changes to instructional approaches and practices, instructional constraints, and stressors experienced by charter school secondary science teachers who taught online during the COVID-19 pandemic. The strength of this methodology was that it allowed for the exploration of the teachers' voices using a comprehensive, in-depth method of data collection (Miles et al., 2014). Trustworthiness and validity were increased through triangulation (asking the same research questions of different participants), transferability of the findings by utilizing purposive sampling (a form of nonprobability sampling), and confirmability (Miles et al., 2014). Data sources included direct observation (e.g., teacher's workspace when feasible), semi-structured interviews, open-ended conversations, and artifacts (e.g., lesson plans, online planners, Zoom recordings). The scope of the study was based on predetermined themes from the research questions. The North Carolina State University Institutional Review Board (IRB) granted permission for this study (IRB No. 20574) on April 17, 2020.

4.2 Participants

The study focused on teachers who taught science in charter schools in the United States. Teachers first completed an online survey (Qualtrics, Provo, UT), followed by an option to participate in a semi-structured, open-ended interview protocol. Twenty-one charter school science teachers volunteered to participate, and these teachers were interviewed via Zoom in September and October 2020, using the validated, IRB-approved *Materials and Science Instruction Interview Protocol* described subsequently. This study was part of a larger set of studies of science instruction in charter schools that included surveys obtained over a two-month period in the spring and summer of 2020.

4.2.1 Survey Participants

The survey participants (*N* = 105) consisted of secondary charter school science teachers in North Carolina. Teachers were recruited through a variety of means. First, a list of available grades 6–12 charter school science teachers' emails was compiled using data published on the North Carolina Department of Instruction website. Second, during a North Carolina Charter School Alliance yearly conference, science teachers who attended a science education session were given the link to the online survey and invited to participate. Third, charter school science teachers enrolled in degree programs at the local university were invited to participate in the study. Finally, an email to all charter school principals in North Carolina was sent with a request for science teachers to participate in the study. Survey participants were given the opportunity to register to win a $100 gift card upon the completion of the survey.

4.2.2 Interview Participants

At the end of the survey, all 105 survey participants were given the opportunity to volunteer for an online interview, and twenty-one participants volunteered to be interviewed. The interviews provided an opportunity for an in-depth exploration of the areas addressed in the survey. The mean teacher age of the interview participants was 45 (*SD* = 11). The mean number of years teaching was 15 (*SD* = 11). In terms of education, 100% (*N* = 21) of the participants in the study held bachelor's degrees, 19% (*N* = 4) held a master's degree in teaching, 10% (*N* = 2) held a master's degree in science, and 5% (*N* = 1) held a non-education master's degree. Of the 21 teachers, 34% (*N* = 7) were not licensed to teach science (lateral entry), while the remaining 66% (*N* = 14) held a teacher's license. Forty-three percent of the schools were suburban, 33% were urban, and 24% were rural. The participant demographics are presented in Table 1 and the courses they taught are detailed in Table 2. The percentages of the school types represented in the study were the following: 53% were college preparatory, 43% were whole child educational facilities, and 4% were art schools. Title 1 schools were uncommon (24%). The student population ranged from 200 to 2,000, with 67% of the teachers teaching in schools with 500–1,000 students. The class size ranged from 10 to 30, with 62% of teachers having 21–25 students per class. The total number of science teachers in each school ranged from 1 to 10, with 71% of teachers teaching in schools with 1–5 science teachers. Finally, the number of teachers in the school who taught the same content as the participants ranged from 1 to 8, with 71% of the participants being the only teacher teaching a specific subject.

TABLE 1: Teacher demographics

Participants	Number (*N*)	Percentage (%)
Gender		
Female	14	67
Male	8	38
Race		
White	18	90
Black	1	5
Asian	1	5
Mixed	1	5
Ethnicity		
Non-Hispanic	20	95
Hispanic	1	5

TABLE 2: Courses taught by interview participants

Course Type	Middle School		High School		Total	
	N	**%**	***N***	**%**	***N***	**%**
General science	5	24	0	0	5	24
Life science/biology	3	14	5	24	8	38
Physical science/physics	0	0	7	33	7	33
Earth/environmental science	1	5	5	24	6	29

Note: Some teachers taught multiple subjects.

4.3 Interview Protocol

The interview protocol was designed specifically for this study. Based on the research questions, the interview protocol was designed to gather charter school secondary science teachers' views and assessments on teaching science during a pandemic. Initially, the protocol was reviewed by a panel of science educators and scientists for content and validity (Franklin & Ballan, 2001) and then revised based on their input. It was then piloted with three charter school science teachers, a high school chemistry teacher, and three educational research scientists, and items were then modified or removed based on feedback.

The final protocol consisted of 28 open-ended questions that asked teachers to describe their science instructional practices during the COVID-19 pandemic. Specifically, the questions examined the implementation and facilitation of online laboratory experiments and investigations; scientific inquiry; home safety issues; challenges in technology; resources, including professional development, budget for materials sent home, and technology such as computers and Internet bandwidth; teacher facility with available technology; and personal negative consequences of online teaching. The goal of the questions was to learn how charter school science teachers navigated the pandemic restrictions while continuing to engage students in science. This was achieved by giving the teachers an opportunity to relate how, what, when, and where they conducted science instruction; what constraints affected science instruction; and report the negative personal effects of remote learning. This information may inform new policies and practices in charter schools that can help in future situations that mandate distance learning. Each interview took approximately 60 minutes to complete.

4.4 Data Analysis

Data were transcribed into a verbatim (word-for-word) document (Creswell & Clark, 2017). After the transcription of all interviews, the data were analyzed and coded using a qualitative data analysis (QDA) software program, QDA Miner Lite (Provalis Research, Montreal, Canada). Coding categories emerged by using themes that were predetermined by the interview questions, which included teacher approaches, teacher constraints, and teacher stressors (see Table 3). A second coder coded 30% of the interview data using the predetermined codes. Subsequently, the inter-rater reliability score was calculated using the formula described in Miles and Huberman (1994): reliability = number of agreements/number of agreements + disagreements. Validity and trustworthiness were established using two measures of qualitative validity described by Terrell (2015). The first measure was credibility. Credibility was established by three criteria: prolonged engagement, peer debriefing, and member checking. Prolonged engagement was achieved when the researcher spent a prolonged amount of time with the interview data by self-transcribing. Peer debriefing was achieved when the researcher's peers checked the researcher's understanding and interpretation of the data. Member checking was achieved during the interview process using follow-up and clarifying questions to the interviewees. The second measure was transferability. The findings and the meanings interpreted from these findings were similar to the experiences of others as reported in the literature.

TABLE 3: Interview themes, coding categories, and examples

Theme/Research Question	Example
Instructional Approaches: Research Question 1	
Coding Categories	
(1) Virtual laboratories	“[I have used] virtual labs such as Gizmos and PBS has some really good stuff.”
(2) Demonstrations/live instructions	“I feel like every day is a battle of what I do, but putting students in smaller groups where they can talk one-on-one has helped … I have been researching using the PBS discovery education so that there is just something that the students can see—it is kind of more real-life versus just looking at me through a screen all day.”
(2a) Disadvantages	“It's been really hard. I demonstrate how things should be done.” “Sometimes it works, and sometimes it doesn't. If it is an epic fail, then [the students] tell me about it.”
(2b) Advantages	“The students loved it, and I loved it because I felt like I was teaching.”
(2c) Group work	“I've had to get creative with group work specifically and how to do that well … to try and force them to engage with each other. Some of them want it, some of them avoid it because they're now becoming so isolated.”
(3) At-home laboratory assignments/activities	“The hands-on labs, like I'm talking about the one with the leaf discs or the M&M's or the Teddy Grahams, the students will physically do that in their home.”
(3a) Materials lists for home	“I did ask students to find materials they have at home. For example, I did one with cups and M&M's.”
(3b) Materials sent home	“I did in the beginning. We had package exchanges for almost the first month.” “Even going into [the school] office was scary for [parents to pick up supplies].”
(3c) Safety concerns	“I did make sure that each parent and student signed off on a safety contract. I modified the safety contract to specifically address concerns for a home.”

(4) Inquiry	“Inquiry is a style of thinking, and so in my mind I can still design practices that require them to think on a higher level. And honestly, I have felt like this year, unlike other years, I've had time to focus on it.”
(4a) Limited inquiry	“Demonstration is a good virtual tool, but it's just not hands-on and hands-on is the whole inquiry process.”
(4b) Physical laboratory (hands-on)	“We did a chromatography experiment … if you have a pen at home and a coffee filter, you can calculate an R.F. value.”
(4c) Prediction	“We do a lot of discussion boards where I just throw out random questions and [the students] have to give me feedback. For example, ‘Why don't we ever run out of water; we are constantly consuming it, so why don't we run out of water’”?
(4d) Reflection	“I'm trying to find lots of different projects or activities that demonstrate whatever we are talking about, and then I have the students write a reflection to see what they felt or how they experienced [the exercise].”
(5) Creativity/innovation	
(5a) Revised lessons	“You have to figure out a new way to do something and then figure out two or three backup plans as well … [because of technical failures].”
(5b) Revised virtual laboratories	“I had [the students] come in shifts to do a gas collection over water lab.”
(5c) Rearranged schedule	“I normally [begin the fall] with chemistry, [but] now I'm postponing chemistry until January; hopefully, we'll be back [in class].”
(5d) Benefit	“I've certainly learned a lot, but I don't think remote learning for high school subjects that I'm teaching is a better approach.”
(5e) Utilize new technology	“All this time that we've dedicated learning the technology and dealing with the challenges when we go back to the classroom … I will utilize and take advantage of this learning.”

Constraints: Research Question 2

Coding Categories	
(1) Technology issues	"I haven't personally [had technology issues], but my kids struggle with technology. Their computers have been provided from school—Chromebooks and they struggle with having more than one tab open at a time."
(1a) Connectivity	"The [students] who are way out in the country have a lot of connectivity issues … they can come and sit in our parking lot [to access the school's Wi-Fi] … however when it was really hot and uncomfortable to sit in a car [the school] opened up part of the media center [to access the school Wi-Fi]."
(1b) Support	"All of our students were given iPads … so all of our students have one-to-one technology."
(1c) Materials	"[Our students] have Chromebooks, but they are at the end of their life … the microphones and cameras do not work … and we repurposed a lot of devices to fill in the gap… . We tried to order new [computers], but they haven't come in."
(1d) Human capital	"[Remote learning] is just all new. I didn't even know how to tell a student to submit an assignment on Google classroom because I'd never used it before." "I do not feel confident [with technology]. I feel frustrated and often dazed; I'm incapable of delivering material that I know how to deliver. It's very frustrating."
(2) Training/professional development (P.D.)	"You mentioned the fire hose earlier. There has been that feeling of there's only so much I can do and so much I can manage … when it's all said and done, I don't have enough hours in the day to do that [P.D.]." "I would have [liked more P.D. on virtual learning/teaching]. Yes, I was expecting to get more clarity and guidance when we got back in the fall, and there was very little."
(3) Administration	"The lack of clarity and structure [from administrators] has been really frustrating and hard." "And there's no standard for how to evaluate teachers who are having to teach virtually because we've never had this."

(3a) Support	“The school has implemented the use of Canvas as the learning management system for the school beginning in the spring. I don't want to use it because all of my stuff is in Google classroom, and it is easier for me.”
(3b) Guidance	“Administrators are not checking in with their teachers. I don't feel like there is a lot of direction from my administrators.”
(3c) Connection with peers	“We have Zoom department meetings, and our Sunshine committee is setting up more support in smaller groups.”
(4) Less science	
(4a) Omitted lessons	“Every single hands-on lab.”
(4b) Extracurricular activities	“No [Science Olympiad], not in this current environment.” (Perez)
(5) Student attendance/engagement	“I still don't really know how to address my students who are struggling and are behind and are not responding to emails, especially while remote.”
(5a) Teacher intervention	“We also had a group of students that we were responsible for calling every day. Every day somebody was going to ask how things are going.”
Stressors: Research Question 3	
Coding Categories	
(1) Work/family balance	“I've been in front of my computer from our school start time of 8:30 am, and I'm still sitting here at 8:30 at night trying to get stuff ready for the next day, or the next week, or to answer emails or check work and it's been a lot.” (Jones)
(2) Students	“I feel like I'm apologizing to my students every day because it's not the way that I want them to learn.”
(3) Testing	“[Eighth Grade End of Grade] I wish we could focus on what's most important, like giving these kids the support that they need.”
(4) General	“The whole view of science right now has been a struggle with questioning my profession.”

(5) Mental health	"Yeah, it's taken a toll on my mental health, I would say. I mean, it's been difficult. And there are days where I'm like, Okay, I can do this, but then there are these other days where it just feels hopeless. Like, I just can't see myself teaching like this."

The analysis of the interviews was described using the themes of instructional approaches, teaching constraints, and stressors for teachers (see Table 3). There were five coding categories (some with subcategories) related to instructional approaches, and these included the following: virtual laboratories (watching experiments on platforms such as Gizmos, PhET, and Flinn); demonstrations/live instructions (the decision to have students do laboratory activities at home with hands-on materials or watch demonstrations from the teacher either live or video); at home laboratory assignments/activities (whether to send laboratory activity materials home or a list of materials home for parents to gather; whether to amend laboratory safety contracts for at-home student safety); inquiry (whether to rearrange lesson plans according to a return to the classroom such that the activities requiring the most hands-on involvement could be delayed); and creativity/innovation (how to engage students in inquiry-based learning without the hands-on activities by creating innovative approaches for student engagement).

The constraint's theme was supported from six coding categories: technology issues (connectivity, support, materials, and human capital); training/professional development (in-house and out-sourced professional development); administration (lack of administrators' support and direction, lack of funds for professional online resources, and lack of a structured peer support system); less science (limited science inquiry-based teaching, planning, and connection); student attendance/engagement (attendance rate and student participation); and connection with peers.

Finally, the theme of stressors was supported by four categories: work/family balance (workload; lack of quality personal life); students (apathy; cognitive and mental student health); testing (end-of-grade testing for eighth-grade students); and general (a general lack of professional community).

5. RESULTS

Analysis of the interview data revealed that teachers faced considerable challenges in providing science laboratory at-home experiences for students while utilizing a wide variety of iterative instructional approaches to facilitate the right fit for their students and themselves. Overall, teachers expressed that having flexibility with how lessons were presented to students was an important component of remote learning.

5.1 Instructional Approaches

5.1.1 Virtual Laboratories

Science teachers used several commercially available virtual laboratories in their instruction. The three most common resources were Gizmos, PhET, and Flinn At-Home. Gizmos are interactive math and science virtual laboratories and simulations for grades 1–3 (https://gizmos.explorelearning.com/). PhET Interactive Simulations is a non-profit, open, educational resource project that creates and hosts explorable explanation projects (https://phet.colorado.edu/). Flinn At-Home is a collection of chemistry resources that includes virtual laboratories to help students stay engaged in science (https://www.flinnsci.com/athomescience/).

Seventeen (81%) of teachers indicated that they used virtual laboratories with their students. Often, one teacher in the school was designated as responsible for multiple classes, which could include advanced placement (AP) science classes. Teachers who taught AP classes were more likely to use virtual laboratory sources for their students. One stated that "with my A.P. class [they watch] a video of a teacher running a lab [and I ask the students to] record the data and then do the analysis … PhET does a really good job." Other teachers used PhET because of its diverse resources. "We use PhET a lot because of their websites' amazing resources." Still, others used virtual laboratories such as Gizmos. For example, "I'm going to walk kids through the first one, and I'll be doing it [with them]. I'll prompt them so that they do more on their own."

5.1.2 At-Home Laboratories or Investigations

When asked if students conducted laboratory activities or investigations at home, four (19%) of the teachers responded *yes*, three (14%) said *no*, and 14 (67%) responded by indicating that they chose to do demonstrations with their students instead of having students do experiments at home. Many of the teachers indicated that while they tried to develop ways to do hands-on laboratory activities and investigations at home, the logistics made it almost impossible. Some examples included one who reported trying to have her students do investigations at home but "the at-home lab with astronomy just didn't go well … it was too ambitious." Another reported that she had initially considered having her students do hands-on demonstrations at home but "it would require the students having the materials and we don't have enough materials for one hundred eighth-graders."

However, the three teachers who continued with at-home laboratory lessons did so by being very creative with their investigations. For example, one teacher had his students do a simulation of gene ferociousness in a population of bears in the western part of the state by using boxes containing chocolate and chocolate chip Teddy Grahams.

5.1.3 At-Home Live Demonstrations/Live Instruction

Teachers reported positive aspects of online laboratory demonstrations. For example, it allowed students to see the experiments and explore the content through written assignments or group discussions, as noted by one who stated, “[They watch the virtual demonstration] and I'll give them a procedure on a lab sheet and then I either allow them to work independently or form their own groups off Zoom. I can also make breakout rooms.” Similarly, another reported that her live online laboratory demonstrations allowed her to “build my credibility as their biology teacher as … someone they know and trust [as compared to a stranger in a video].” One teacher felt particularly positive about the teacher–student interaction of online live demonstrations: “The students loved it, and I loved it because I felt like I was teaching.”

Most of the teachers incorporated some type of group work along with the online demonstrations to get students engaged and communicating with one another. One teacher was particularly concerned about the students becoming so isolated. She stated that the group work was a time where “It's not just me talking to them on their own, especially when they are really isolated at home.” Other teachers used the group work to check in on struggling students. For example, one stated that group work “allowed me to focus on other groups that may be struggling a little bit, so it gave me the opportunity to allow one group to go even a bit further while I was helping other groups to catch up.” However, another teacher who did not offer group work reported that students did not have “a way to communicate well unless they were in [a physical] class together.”

5.1.4 Materials Sent Home for Laboratory Investigations or Demonstration Follow-Along

Most, but not all, of the teachers (81%), for a variety of reasons, chose not to send materials home for science investigations or for students who wanted to follow along at home with teacher-led demonstrations. For one teacher, the concern was that parents and guardians were afraid to leave the house and interact with staff or bring outside materials into their homes: “I know some people are grandparents, and there's a 70-year-old, raising a 14-year-old.” One of the teachers tried fruitlessly to have materials available for pickup at the school office: “So, some parents didn't pick up the supplies because [some] don't want to go out into the world to get them because of COVID.” Another contributing factor was transportation, since many parents did not have transportation to go to the school to get materials from teachers. Classroom budgets were not adequate for teachers to prepare individual student science kits. For example, one stated, “I thought earlier this summer about trying to put together some kits, but it just didn't happen. I didn't have enough supplies to be able to get things out to that many students.” Finally, teachers were unable to access school supplies after the state governor mandated the complete shutdown of schools.

5.1.5 Materials List Sent Home

Sixteen teachers (76%) stated that they sent a materials list to parents. This was usually sent in the weekly email from teachers to parents that explained the science lessons for the week with the caveat that the materials in the list were suggested items and not required. Teachers sent the list to accommodate those students who wanted to do the science activities during demonstrations. Safety while doing science at home was another of the reasons given for not requiring the materials. For instance, one of the teachers said, “And my concern is even … those glue sticks. You know … if a small child gets a hold of it and swallows it … it can be harmful.” Additionally, another teacher stated when asked about sending a material list home, “I can, but I have instances where my parents are working, so they're not home [to supervise].”

5.1.6 Safety Concerns/Contract

When asked if they required a new or revised safety contract for online science instruction, most teachers reported not sending or updating the safety contract because students were mostly watching demonstrations and experiments or doing data analysis instead of doing experiments. Some teachers stated they “didn't even think about it” and that “we have a safety contract while we are in person, but since they're not touching anything, I haven't sent a contract to them.” However, out of an abundance of caution, 29% did have parents sign a safety contract. As one explained, “You cannot control the [home] environment … so best to err on the side of safety.”

5.1.7 Inquiry

When asked if they thought inquiry learning was limited by online instruction, 13 (62%) of the teachers indicated that it was limited. However, when asked if they had been able to engage students in inquiry learning, 15 (71%) of the teachers indicated that students had been engaged in inquiry during online learning. The two most common instructional approaches for integrating science inquiry into their online lessons were prediction and reflection, often during group work, where students were asked to discuss the topic with one another.

5.1.8 Creativity and Innovation

Creative and innovative instructional strategies were reported by all study participants. Some areas of creativity and innovation included revising all lesson plans, virtual laboratories, and demonstrations; utilizing new technology; reorganization of classroom structure (group work); and assignment expectations. As one teacher stated, “You have to figure out a new way to do something and then figure out two or three backup plans as well … [because of technical failures].” Most teachers agreed with one teacher regarding utilizing new technologies in the classroom: “All this time we've dedicated ourselves to learning the technology and dealing with the challenges when we go back to the classroom … I will utilize and take advantage of this learning.” Another shared that assignment completion improved when “they [students] took pictures and uploaded documents that way.” Regarding assignments, another teacher reported, “Just like the assignments themselves … I feel like the over-assessment has changed dramatically because I can't give in-person quizzes … so I put more emphasis on homework.”

5.2 Constraints

Many of the instructional constraints related to teaching science as reported by the study participants were issues with technology, online training, and administrative support; less science being taught and lack of materials; maintaining student engagement; and connecting with a community of peers.

5.2.1 Less Science

When asked if there were lessons that were not taught due to the COVID-19 restrictions, 50% of the teachers indicated that they had lost lessons due to the pace of online learning as well as not having the ability to transfer classroom lessons into online lessons. As one teacher stated, “Our pace is much lower this year than last … we are not nearly as far along as we were last year.” Another teacher explained, “… a long list of omitted lessons.” Along with missed classroom science lessons, most schools' extracurricular science programs, such as Science Olympiad, where students get to enjoy science in a competitive and cooperative arena, remained on hold.

5.2.2 Technology Issues

Teachers reported a number of technology issues during the study. Teachers cited the potential for inequitable student learning opportunities due to lack of laptops, inadequate Internet connectivity, and variable home responsibilities such as caring for siblings. One teacher reported that she “worries about equity for students who can't get materials due to monetary or other reasons.”

Although teachers reported wanting to do virtual laboratory assignments, only 10 (48%) of the teachers indicated that their school provided access to outside online science instructional resources such a Flinn Lab, Phet, or Gizmo simulations. This lack of online courses or e-tools created a burden for teachers since they had to video record laboratory experiments and exercises for their students. As an example, one teacher explained that while in the classroom, his laboratory experiments were “recyclable every year which makes things a whole lot easier … but now I am working seven days a week, 60 hours a week [trying to figure things out].”

5.2.3 Human Capital

When asked about their confidence in using the tools and technology while teaching online, three (14%) of the teachers indicated that they were not confident, 11 (53%) of the teachers indicated that they were moderately confident, and six (29%) of the teachers indicated that they were very confident.

5.2.4 Online Training and Professional Development

Teachers were asked about the availability of professional development opportunities specific to online learning, and 15 (71%) of the teachers indicated that they had participated in online learning professional development classes and were encouraged to find on their own professional development during the pandemic. Most schools did not offer specific professional education for online teaching or for the critical programs used for instruction during the pandemic.

5.2.5 Connection with Peers

Unlike public schools, many of these teachers were the only science teacher in their school or one of a few teachers and had no system-wide resources or a community of science teachers to rely on when COVID-19 restrictions made face-to-face instruction impossible. However, three (14%) of the teachers reported having a robust communication community replete with weekly staff meetings and departmental meetings via Zoom.

5.3 Stressors

Almost 75% of the teachers indicated adverse experiences with COVID-19, such as stress due to teaching under the pandemic restrictions and serious mental health issues. Stress was experienced by most teachers due to the overwhelming workload that was required to transition quickly to online learning, while other teachers experienced more severe mental health challenges. Examples included: feelings of despair, “It just feels hopeless”; increased lack of interest, “My motivation is not as high”; exhaustion and confusion, “… it's been kind of in overdrive and that it takes its toll. Like I spend a lot of time on the weekends working, weekends are not really restful”; and finally, isolation, “You know, being isolated and alone … while trying to navigate the online learning environment.” Further statements by the teachers confirmed the distress: “It's [workload is] taking time from my family”; “Yeah, it's taken a toll on my mental health, I would say”; and “I'm just not cut out to be an online teacher.” One veteran teacher summed it up nicely by stating:

> Me personally, I wasn't to the point where I was going to quit. But there were days where I was in tears, and I have literally sat in front of my computer … at 8:30 am, and I'm still sitting here at like 8:30 pm at night trying to get stuff ready for the next day or the next week or answer emails or check work and, you know, it's been a lot.

6. DISCUSSION

As of July 2020, 98.6% of worldwide learners were affected by the COVID-19 pandemic, representing 1.725 billion children and youth from pre-primary to higher education in 200 countries (United Nations, 2020). Teachers, parents, and administrators all scrambled to move learning online without the benefit of a well-planned strategy (Pokhrel & Chhetri, 2021). While every discipline was affected by the abrupt switch to online learning, science was particularly impacted due to its physical nature (Touchet et al., 2020). Online science learning presented many logistical challenges, such as adequate student and teacher at-home computers, Internet, and device connectivity; device camera and microphone access; learning management platform access; student access to materials and resources for laboratory experiments; student at-home safety during laboratory activities; inequity (Henderson et al., 2021); and accessible at-home workspaces (Noor et al., 2020). Equally important from a pedagogical perspective were the challenges of maintaining student engagement and attendance, providing emotional support for isolated students, forming meaningful interpersonal connections, maintaining inquiry-driven lessons, providing meaningful assessments and feedback on assignments, and covering standards materials (Touchet et al., 2020).

This study found that secondary science teachers who teach science in charter schools faced significant challenges because of COVID-19 pandemic restrictions while revealing the complex nature of teaching science during uncertain times. The study results parallel those from other studies of teachers' difficulties in identifying and conducting appropriate online science programs and lessons (Wu et al., 2020; Noor et al., 2020). Nonetheless, teachers responded to this uncertainty with remarkable resiliency and creativity (Fackler & Sexton, 2020). Taken together, the current published studies and the data here show that despite many constraints and stressors, teachers were generally successful in adapting their curriculum to the online platform using various instructional strategies.

6.1 Instructional Strategies

Teachers in this study identified multiple issues with remote instructional strategies and quickly adapted their approaches (Table 3). Overall, all of the 11 coded categories defined in charter schools within this theme—the use of virtual laboratories, demonstrations, at-home laboratory activities, materials lists, materials sent home, safety, inquiry-based learning, revised lessons, revised laboratory assignments, rearranged schedules, and the use of new technologies—which were studied here, have been identified as issues and approaches by teachers in non-charter schools in prior studies (Hill, 2021; Kaden, 2020; Noor et al., 2020).

As reported in the literature, many science teachers began with an at-home laboratory attempt but soon realized that this was not possible and quickly reverted to demonstrations, group work, and virtual laboratories (Hill, 2021). Research has long identified home learning as a weakness of online learning due to the "non-conducive environment for learning at home" (Pokhrel & Chhetri, 2021, p. 134). The realization that inquiry-based learning was difficult, if not impossible, for some teachers during online learning allowed many teachers to find creative ways to incorporate inquiry learning in their lessons (Pokhrel & Chhetri, 2021).

6.2 Constraints

Many constraints to online teaching were identified in this study (Table 2), and all of those seen here have been identified previously in non-charter schools (Kaden, 2020; Noor et al., 2020; Pozo-Rico, 2020; Tosun et al., 2021; Jevsikova et al., 2021). Limitations in device and Internet connection access were the issues most referred to by teachers as they described the problems encountered by students, especially those living in rural areas or in less-than-ideal living conditions. During the early days of the pandemic, all stakeholders in education were caught off guard, and technical problems were to be expected. However, according to the 2020 Census, 83% of households had computers, and 82% had broadband Internet service. Additionally, the lack of school-provided resources and school-led initiatives in charter schools that aid in teacher productivity was also noted in our research. The lack of resources included e-tools, such as online science laboratories for students, as well as school-led professional development courses specifically designed around school learning and communication platforms. E-tools have been one of the most critical assets during the pandemic in helping teachers facilitate student learning in the online environment (Subedi et al., 2020). As prior studies have indicated, teachers who find themselves uncomfortable with technology require substantial professional development training to achieve success in the online environment (Pokhrel & Chhetri, 2021). While the comfort level of using technology during online learning was very low for most teachers, there were others who reveled in the challenge of finding new ways of teaching. In addition, many teachers identified a decrease in student attendance, which could be explained by several factors. Similar studies in the literature reported the low attendance of students as a constraint or problem with distance learning (Alvarez, 2020; Jones & Korula, 2021; Nathwani et al., 2021).

6.3 Stressors

The various stressors noted in charter schools, including work/family balance, student welfare, standardized testing, general issues, and mental health, have been identified in prior studies of non-charter schools (Kaden, 2020). While teachers around the world acknowledged that the COVID-19 pandemic had afforded them the unique opportunities to collaborate with other teachers at the local level to improve online learning (Doucet et al., 2020), charter schools generally lacked this collaboration among science teachers. Partly because of their small size and limited staff teaching a particular subject, the charter school science teachers in this study reported that they felt isolated as they searched for lesson plans and materials to present to their students. It has been documented that being part of a community of peers who share ideas and anxieties fosters good mental health and productivity (Fackler & Sexton, 2020). The isolation that is occurring during COVID-19 does not foster good mental health. The feeling of isolation, as well as the lack of support from school administrators, created undue stress and emotional distress for charter school science teachers. However, on the other end of the spectrum, Schools (2020) found that a charter school network consisting of 10 area schools serving the Chicago area, which developed social support and improved communication, was crucial to connecting with families during remote learning. In this case, social workers, special education staff, and staff banded together to attend to students' social and emotional well-being and ensure that their basic needs were being met, indicating that this charter school system had support and communication options for their teachers.

6.4 Implications and Limitations

The goal of this study was to examine science instruction in charter schools during the COVID-19 pandemic. The results presented here can inform education researchers, state and district policymakers, and charter school administrators about ways to prepare teachers to face instruction in similarly difficult situations. Although the COVID-19 pandemic was a highly unusual challenge for educators, it is not uncommon for schools to face adverse weather or environmental threats (e.g., hurricanes, fires, tornadoes, floods, or heat waves), or other school safety challenges, which may be increasing in frequency and severity in the future. Preparing teachers to move quickly and effectively to online teaching could prove beneficial when future adverse events occur.

The study revealed many areas in charter school science programs that could benefit from enhanced planning and information technology infrastructure as well as other structures to provide teachers with support for physical and emotional health. Specifically, science teachers need to have a community of other teachers that will foster connection and deter the feeling of isolation that many teachers face. This community could contribute to teachers' capacity to respond quickly and creatively when education is disrupted due to unexpected events. Additionally, these results suggest that an investment in charter school professional development programs to address e-tools and technology could have positive benefits in the future (Morina et al., 2021).

Additionally, no teacher should be working and performing in isolation during challenging times. Essentially, forming professional learning communities with teachers in the same grade band or other teachers of the same content area to share ideas and responsibilities is a best practice and will be essential moving forward as other challenges to education arise (Keefe, 2020; Woods et al., 2020).

Although some of the positive aspects of the COVID-19 pandemic/teaching paradigm will certainly be applied to the new normal of teaching after the pandemic, it is likely that teaching soon will return closer to the pre-pandemic states of in-classroom learning. Nonetheless, it is important to acknowledge that charter school science teachers rose to the occasion when asked to tackle the impossible demands thrust upon them by the COVID-19 pandemic, as others have noted (Fackler & Sexton, 2020). As most teachers agreed, “we are going to make this work because our students deserve the best, we can give it to them.”

It is important to note that this exploratory study had several limitations, and care should be taken before generalizing beyond this study sample. First, the number of participants was relatively small, and this limited the capacity for statistical comparisons among sociodemographic groups. Second, it is not known if the perspectives of this self-selected sample are representative of charter school science or other teachers more broadly. Furthermore, this was a qualitative study designed to gain insight into a sample of charter school science teachers' experiences at a single point in time during the COVID-19 pandemic, which occurred before vaccinations or more effective therapies were available and before the Delta variant arose, and it is possible that teachers' impressions may have changed over time.

7. CONCLUSIONS

The impacts of the COVID-19 pandemic on the capacity of teachers, students, and parents to continue to make progress in their science education goals have been enormous. This study identified many instructional strategies, constraints, and stressors common to charter school secondary science teachers in North Carolina and several ways that they adapted to their challenges. These findings suggest that greater planning, available professional training programs, improved hardware and software infrastructure preparation, guidance on instruction formats or standardization, and accessible peer support and communication systems would be helpful in addressing future similar crises and enhancing similar urgent transitions to online learning. Also, this study emphasizes that more research is needed to define best teaching practices for online science class management and instruction.

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APPENDIX A. COVID-19–RELATED INTERVIEW QUESTIONS

In this study, the participants were asked the following interview questions:

1. In the online environment do you do labs or investigations?
    a. If, so where do you find the lab lessons?
    b. Where do you find lab activities in the online environment?
    c. What are the equipment needs?
    d. Do you have students use materials found at home?
2. Do you send materials home?

3. Do you suggest a materials list for parents?
4. Are you doing paper or virtual labs?
5. Do you have students watch live lab demonstrations?
6. Does your school provide subscriptions to resources such as Flinn labs, PhET, Gizmos, or other online labs?
    a. If yes, please provide a description of the labs you use.
7. How are issues of safety handled in the online labs?
    a. Do you have the parents or students sign a modified (for science at home versus in the school) safety contract at the beginning of the year?
8. Do you feel like teaching remotely limits inquiry learning?
9. Do you feel like you have been able to engage your students in inquiry-based learning?
10. Are there lessons you will not get to teach due to COVID-19 restrictions?
11. Are there science extracurricular activities that your students normally participate in that they can no longer do because of this COVID-19 environment such as Science Olympiad?
12. Are there examples where you had to be creative or innovative in your instruction? Please explain.
13. Did you or your students face challenges with technology?
    a. Did you have any major institutional changes such as new learning platforms? Please give examples.
14. Are parents of students involved in science instruction?
    a. If so, how has this changed since the change to all virtual learning?
15. Have you had professional development (PD) opportunities for teaching with virtual science instruction?
    a. Who provided the PD?
    b. How long was the training?
    c. What new ideas did you get from the COVID-19 PD for remote learning?
    d. What do you wish you had been able to get that you did not get during the PD?
16. If an outside organization could provide assistance with remote science learning, what would you like to have? Examples: materials, assistance, other support?

17. How confident do you feel that you have the tools and technology to teach online effectively?
18. Do you feel you have suffered from any negative experiences as a result of the COVID-19 pandemic?
19. Is there anything you would like to add?