ABSTRACT

HUFF, PAMELA MARLER. Teaching Science in Charter Schools: Facilities, Equipment, Teacher Perceptions, and Impact of the COVID-19 Pandemic. (Under the direction of Dr. Melissa Gail Jones.)

Although there has been a significant increase in the number of charter schools, little is known about their science education programs from the science teachers' perspective. Also, the COVID-19 pandemic created limitations for all participants that required new untested approaches that varied depending on circumstances. The first study in this dissertation explored secondary charter school science teachers' perceptions related to their schools' science programs. With the use of the *Science Laboratory Classroom Facility and Science Instructional Materials Survey* and a semi-structured interview protocol, secondary charter school science teachers' (N=105) perceptions of laboratory equipment, safety equipment, facilities, science standards, and autonomy were examined, and a subsample of teachers (n=21) was interviewed. The findings showed that charter school science teachers taught in facilities that were inadequate for science laboratory instruction. Many teachers lacked the most essential laboratory and laboratory safety equipment. Other findings included a high degree of reported autonomy related to instructional decision-making. These results suggested that the quality of charter school science programs could be strengthened by adequately funding science laboratories, equipment, safety equipment, and engaging science teachers in program and facilities planning. The second study utilized a subsample of teachers interviewed in the first study to examine charter school secondary science teachers' online teaching in response to COVID-19. Specifically, this study explored teachers' instructional approaches, teaching constraints, and work-related stressors with a semi-structured interview framed within a Community of Inquiry framework. The findings were that greater planning, training, hardware, and software infrastructure preparation, guidance on instruction formats or standardization, peer support systems, and communication were needed to address future crises such as COVID-19 and to enhance similar urgent transitions to online learning. Implications for future research and pedagogy are discussed.

Teaching Science in Charter Schools: Facilities, Equipment, Teacher Perceptions, and Impact of the COVID-19 Pandemic

by
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DEDICATION

For my mother, Elsie.

BIOGRAPHY

Pamela Marler Huff was born in Anniston, Alabama in November of 1955, which remained her home until leaving to begin undergraduate studies at Auburn University in Auburn, Alabama. Her childhood was filled with exploring her neighborhood and nearby forests with her sister and friends where she befriended animals of all kinds. This led to a pursuit of veterinary medicine through her early college tenure until microorganisms captivated her focus and attention. After graduating from Auburn University with a Bachelor of Science in Microbiology, she spent the next fourteen years working in research laboratories with a research focus of infectious diseases, cancer, and metabolic disorders. Following the birth of her second child, she retired from the scientific community to focus on her family by working in positions that offered flexibility and autonomy. One particularly rewarding position was substitute teaching in science classes. From these experiences she developed a renewed appreciation for K-12 science education. She earned a master’s degree in Art from Duke University in 2010. At the age of 60, she started as a full-time PhD student in STEM Education at NCSU. Here she was introduced to professors, peers, and students and to the world of science from an educator’s lens which she found exhilarating. During her time at NCSU she was given extraordinary opportunities including study abroad in Finland, participating in Science Olympiads, and shepherding high school students around NCSU centennial campus laboratories during Nano Days, not to mention opportunities in undergraduate classrooms as a teacher’s assistant. She hopes to stay closely connected to NCSU in the future as she discovers her next adventure.

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As an older student beginning a doctoral program, I was both anxious and elated about the journey that lay ahead of me. My fears were quickly laid to rest, however as I encountered the supportive people at the university and especially the science education department. My journey was filled with classmates who have become dear friends, professors who encouraged and challenged me, staff who offered time and guidance, life-long friends who offered support and a family who cheered me on. My journey would not have come to a successful fruition had it not been for every single person.

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Introduction

The current overarching goal of science education in K-12 is for students to achieve scientific literacy through a continuous K-12 curriculum (National Research Council, 2012). One of the most fundamental means through which traditional secondary school students experience science education is through learning and exploring in science laboratory classrooms (Hofstein & Lunetta, 1982, 2004).

Public schools are primarily designated as traditional, magnet and charter schools, with the latter being exempt from many state laws and regulations that govern traditional public schools, are often housed in repurposed buildings, and have a unique funding structure (De Luca & Wood, 2016). Due to the many unique features of charter schools, science education programs may not follow the same parameters as traditional public schools so science educators need to understand how their science programs work. One way of assessing a science program is by investigating science teachers' access to available science tools, defined here as laboratory equipment, safety equipment, school facilities, science standards, and teacher autonomy, for determining effective science teaching. Effective science teaching is mediated through the use of science tools, such as science equipment, science language, science facilities and instructional autonomy in face-to-face classrooms (Renner & Fix, 1979; Johnson et al., 2007), and can be challenged during emergency remote learning with constraints, limited instructional strategies, and stress factors (Baired, 2020, Fackler & Sexton, 2020; Fagell, 2020; Hodges et al., 2020; Jevsikova et al., 2021).

While studies have shown an increase in student science literacy through effective science instruction mediated through science tools in traditional public schools (Johnson et al., 2007), there is a need to explore charter school science teachers' perceptions of available science tools in secondary charter schools during face-to-face classroom instruction and constraints, stressors, and teaching strategies used during emergency remote instruction.

This study examined teachers' experiences of teaching science in charter schools, grades 6-12. It is divided into two parts, both of which used the same set of participants and collected data simultaneously. Part 1 of the study examined teachers' perceptions of instruction that occurs in the face-to-face classroom contexts related to: (1) the availability of scientific equipment; (2) the availability of safety equipment; (3) school facility types; (4) science standards used for curriculum development; and (5) teacher autonomy. Part 2 of the study examined teachers' reported experiences in an emergency remote learning context: (1) related to instructional approaches; (2) teaching constraints; and (3) teacher stressors. Taken together, these two studies identified components of teaching science in a charter school setting that are associated with effective science teaching in both face-to-face classrooms and emergency remote learning virtual environments.

Chapter One will present an overview of the study by introducing the background and purpose of the study, the theoretical frameworks, the significance and the limitations of the study.

Background

Science Education

Public education, specifically science education, has been at the forefront of many of the country's most pivotal historical events since the late 1800s (Rudolf, 2019). Steeves (2009) opined that the manner in which the United States government historically responded to the national political, social, and financial crisis was by redirecting financial and human resources towards science education; this served as a precedent for all future responses to similar crises.

That is, from the earliest times in public education history, legislators and the public looked to the schools, specifically science education, for the answers to address our nation's social, financial, and political problems (Rudolph, 2019).

Science Literacy

The goal of science education in K-12, for students to achieve scientific literacy through a continuous K-12 curriculum, has been central to all educational activities (Hurd, 1958) and is stated in *A Framework for K-12, Next Generation Science Standards (NGSS),* and the *North Carolina Standard Course of Study for Science (NCSCoS)*. The definition of scientific literacy, according to the National Research Council (1996, p. 22), is “the opportunity that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences.” Furthermore, being a scientifically literate person implies that scientific issues underlying national and local decisions can be identified, as well as having the ability to describe, explain and predict natural phenomena (NCR, 1996, p. 22).

The purpose of secondary science education is to provide students with the tools that will develop critical thinking skills needed to be productive citizens in the 21st century. *The Next Generation Science Standards* (NGSS) define the rationale for science education as “Science—and therefore science education—is central to the lives of all Americans, preparing them to be informed citizens in a democracy and knowledgeable consumers. If the nation is to compete and lead in the global economy and if American students are to be able to pursue expanding employment opportunities in science-related fields, all students must have a solid K–12 science education that prepares them for college and careers” (NGSS Lead States, 2013, p. xiii). One of the most fundamental means through which traditional secondary school students experience science education is through learning and exploring in science laboratory classrooms.

Effective Science Teaching

Effective science teaching contributes to student science literacy and achievement (Johnson et al., 2007). Specifically, a study by Johnson et al., (2007) found that effective science teaching increases student achievement and closes achievement gaps for all students. In the paragraphs that follow, five determinants of effective science teaching are discussed.

Laboratory Equipment

Adequately equipped science laboratories increase students' problem-solving abilities (Godomsky, 1971) and increase student science achievements (Boghai,1979; Beese & Liang, 2010; Earthman, 1998). Additionally, Renner and Fix (1979) demonstrated that teachers' use of the methodology in a chemistry class, including laboratory equipment, increased student understanding and achievement. The *National Science Education Standards* (National Research Council, 1996) describes effective science teaching as "dependent on the availability and organization of materials, equipment, media, and technology" (p. 44). It also states, "An effective learning environment requires a broad range of basic scientific materials, as well as specific tools for particular topics and learning experiences" (p. 44).

Laboratory Safety Equipment

Laboratory safety equipment is critical to decreasing high rates of accidents and student and staff injury (Hellman et al.,1986). Pekdağ (2020) demonstrated that students who watched a video on how to use safety equipment properly as compared to traditional instruction showed greater improvement in their academic achievement about safety.

Facilities

The physical environment of a science classroom or lab is important for science instruction and student outcomes. As studies have shown, adequate science teaching facilities impact teacher and student outcomes and teacher recruitment and retention (Moore & Lackney, 1993; Tanner, 2000; Cheryan et al., 2014). Earthman (1998) reported that " ...the preponderance of the research cited shows a very close relationship between the built environment and how well students and teachers perform in that environment" (p. 11).

Science Standards

According to Bybee (2014), the "fundamental idea behind science education standards is to describe clear, consistent, and comprehensive science content and abilities. Then, based on standards, reform the essential components of a science education system that includes programs for school science, teaching practices, and assessments at local, state, and national levels" (p. 212). Additionally, studies by Lewis et al. (2019) indicated that the use of *Next Generation Science Standards* practices in teachers' lessons increased their use of inquiry-based instruction and growth as effective science teachers. The use of science standards, such as NGSS for curriculum development, promotes student science skills and understanding (National Research Council 2012).

Teacher Autonomy

Job satisfaction is directly related to an individual's contentment with regard to their job (Spector, 1997). Several studies have found that teaching autonomy, as defined by Husband and Short (1994) as "the ability to control daily schedules, to teach as one chooses, to have the freedom to make decisions on instruction, and to generate ideas about curriculum (p. 60), is positively associated with teacher job satisfaction. This is also supported by other studies (Avanzi, et al., 2013, Skaalvik & Skaalvik, 2014). Teacher autonomy is known to be important for job satisfaction, teacher retention, and quality of life, and may impact the quality of student learning through effective science teaching (Malloy & Wohlsetter, 2003; Ableidinger, J., &

Hassel, B. C., 2010; Guranious, 2017), as well as enhancing teachers' capacity to address students' needs, teacher satisfaction, recruitment and retention (Ableidinger & Hassel, 2010; Guranious, 2017).

While there is no definitive measure of autonomy, Pearson and Hall (1993) gave prominence to the criticality of teachers' perceptions. They argued that autonomy is the perception that teachers have regarding the control they have over their work environment. Therefore, teacher autonomy provides teachers with the perception that they are professional, competent individuals with valuable knowledge, skills, and the ability to create quality instruction with their own means and discovery (Parker, 2015). When teachers are given the freedom by administrators to occupy autonomous spaces in schools, it allows for stronger and authentically experienced teachers (Jiang & Ma, 2012), which some argue is more important than a well-scripted and prescribed lesson plan (Melenyzer, 1990).

Emergency Remote Teaching

Emergency remote teaching was coined by Hodges et al. (2020) as the type of instruction that is being delivered by teachers during the pandemic. It differs from traditional remote instruction in that it is a temporary shift in teaching under unexpected circumstances 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 (Fackler, 2020). The main objective in this type of emergency situation is not to re-create a full educational ecosystem, but rather to provide quick, reliable, and temporary access to instruction (Hodges, 2020). Constraints of emergency remote teaching include inadequate equipment, connectivity, guidance, and training (Alvarez, 2020; Bond, 2020; Kaden, 2020; Francom et al., 2021) and lack of student attendance in online classes (Doucet, 2019). Adequate computer and internet access for all students and teachers are critical for successful remote teaching (Hill, 2020). Also, clear policy and direct guidance need to be provided to teachers in emergency remote teaching on texts, along with increased professional development to support remote teaching (Bates, 2013).

Charter Schools

Most public traditional schools have had years to finance, accumulate, and customize laboratory classrooms where science instruction occurs. This is in part due to the nature of funded programs and facilities by the state and local districts. In contrast, charter schools, a new educational phenomenon, are not given secure facility funding from the state or district and often rely on grants and other sources of fundraising for financial resources for classroom expenses Miron, (2010).

The charter school movement, as we know it today, began in earnest as an effort to improve education after the National Commission on Excellence in Education published “A Nation at Risk" in 1983, along with Budde’s 1988 publication, *Education by Charter: Restructuring School Districts. Key to Long-Term Continuing Improvement in American Education*. (Kolderie, 2005).

According to the National Alliance of Public Charter Schools, (2020), charter school enrollment had grown to 5.9 % of the total number of public-school enrollments by 2016 and in 2018 had grown to 6.3%. In 2021, North Carolina’s charter school comprised 8.4% of school enrollment and included 130,485 students (Public Schools First North Carolina, 2021). Unlike traditional district schools, most charter schools do not receive funding to cover the cost of purchasing or leasing a physical facility (Rebarber & Zgainer, 2019). 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, 2001).

Charter schools also have different structures and requirements in place for teacher licensure and instructional practices (Bankston et al., 2013). Charter schools are allowed to develop their own science curriculum and are not required to have 100% of their teachers licensed. Rather only 50% licensure is required (North Carolina Board of Education, 2019).

Statement of the Problem

The information on essential elements for effective science teaching emphasized above is from studies of traditional public schools. The knowledge gap here is that similar information is not available for charter schools. This information is needed to assess the robustness of their effective science teaching.

Charter schools are a new school choice phenomenon in the public school arena and are growing quickly. Their fast growth and distinctive funding structure for instructional programs make charter schools a key area of study for science education.

It is imperative to know the availability of laboratory equipment and safety equipment to charter school science teachers, in what type of facilities science is being taught, what science curriculum development standards are being used for curriculum development, the level of teacher autonomy, and the challenges to teachers during emergency remote teaching in times of national crisis such at the COVID-19 pandemic in order to gain knowledge of charter school science education programs.

Purpose of the Study

The purpose of the study is to describe charter school science teachers' perceptions of the availability of laboratory equipment, safety equipment, facilities, curriculum standards, and autonomy in a face-to-face setting, as well as teachers' perceptions of instructional strategies, constraints, and stressors during remote emergency teaching as a result of the COVID-19 pandemic. These questions above were answered by a mixed-methods descriptive design. The sample studied were North Carolina secondary charter school science teachers who volunteered after direct email invitations.

Significance of the Study

This study can inform stakeholders of limitations in charter school science programs that, if addressed, could improve effective science teaching and student achievements. The context of this dissertation lies at the intersection of the expanding school choice movement and effective science teaching in secondary science education programs. As the charter school choice movement expands, with the public interest and public funds at stake, it is imperative to better understand how (instructional practices and autonomy), where (facilities), and with what (scientific equipment, supplies, and safety equipment) science is being taught face-to-face. It is also important to understand teachers' perceptions of instructional strategies, constraints, and stressors during emergency remote teaching as a result of the COVID-19 pandemic. Well-planned and supported secondary school science programs promote scientific literacy and student achievement.

Primary research questions

Part 1

1) What laboratory equipment is available to science teachers in charter schools?
2) What laboratory safety equipment is available?
3) What types of facilities are used for science instruction?
4) What are the guiding science standards used for curriculum development?

5) What are charter school science teachers' perceptions of autonomy?

Part 2

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?

Theoretical framework

Three sociocultural theoretical frameworks informed this study, each of which is explained thoroughly in the following chapters. In Part 1, The Activity Theory (Vygotsky, 1978; Engestrom, 1978) and Science Capital (Archer et al., 2015) frameworks were used from a science tools perspective. In Part 2, The Community of Inquiry in an online setting (Anderson et al., 2000; Garrison et al., 2010) framework was used. The two studies, Part 1 and Part 2, both focused on the outcome of effective science teaching as it relates to student science achievement. Specifically, Part 1 of the study focused on the tools, standards, and teacher autonomy during face-to-face instruction using Activity Theory and Science Capital as theoretical frameworks, while Part 2 of the study focused on how teachers overcome the challenges of effective science teaching in an emergency remote teaching context using the Community of Inquiry conceptual framework. While the second study was designed using a remote learning framework, it shared similar tools, such as science language and instructional strategies, and a similar outcome of effective science teaching with the Activity Theory in Part 1.

Limitations

One limitation of the studies was that there was a relatively small number of participants that was a self-selected sample that may not be representative of charter school science or other teachers more broadly. A limitation in Part 2 was that it was a qualitative study designed to gain insight into a sample of charter school science teachers' experiences at a single point in time during COVID-19, and the findings may have differed if sampled at other points in time.

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Teaching Science in Charter Schools: Facilities, Equipment, and Teacher Perceptions

Abstract

Although there has been a significant increase in the number of charter schools, little is known about their science education programs from the science teachers' perspective. This perspective is essential due to the critical role teachers play in orchestrating science instruction to achieve effective science teaching. This study explored secondary charter school science teachers' perceptions of their schools' science programs. With the use of the *Science Laboratory Classroom Facility and Science Instructional Materials Survey* and a semi-structured interview protocol, secondary charter school science teachers' perceptions of laboratory equipment, safety equipment, facilities, science standards, and autonomy were examined. One hundred and six science teachers were surveyed about their experiences, and a subsample of 21 teachers was interviewed. Results showed that many teachers reported lacking laboratory equipment, safety equipment, and facilities for optimal science teaching. While teachers conveyed that autonomy was a significant positive aspect of teaching science in charter schools, teachers also said that isolation and a lack of professional development were negative aspects. All teachers reported using either state or national science standards to develop their science curricula. These findings suggest that effective science teaching in charter schools could be strengthened by adequately funding science laboratories, equipment, and safety equipment, and engaging science teachers in program and facilities planning.

Keywords: Charter schools, Laboratory equipment, Safety equipment, Facilities, Autonomy

Introduction

The charter school movement has rapidly exploded in the United States, and yet very little is known about the nature of charter school science programs. Charter schools have opened in shopping malls, business office spaces, and churches, among other venues (Hassel, 2001). The rapid 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, 2012). Given the critical need for future citizens who can participate in societal science decisions, providing high-quality instruction to all students is essential (DeBoer, 2000). It has been reported that adequately equipped science laboratories with traditional laboratory and safety equipment (Godomsky, 1971; Hellman et al., 1986), as well as adequate science teaching facilities, are related to effective science teaching and student outcome (Cheryan et al., 2014; Moore & Lackney, 1993; Tanner, 2000). This study addressed this need by probing the types of materials, resources, laboratories, and facilities available to science teachers in charter schools. Furthermore, this study examined science instruction, and the advantages and constraints teachers experience teaching science in a charter school.

Literature Review

Charter Schools

Charter schools are independent, public schools of choice, funded from both tax dollars and private donations (Bankston et al., 2013; Villavicencio, 2013) and run by private administrations either as for-profit or non-profit entities with mostly non-unionized teachers (De Luca, 2018). North Carolina Charter schools are exclusively non-profit entities (North Carolina Department of Instruction, 2022). In the North Carolina 2021 budget, $10.37 billion was spent on public education, with $734.7 million allotted for charter schools (Public Schools First, 2021). Charter schools are required to follow a contract (charter) that defines the mission, goals, and guidelines of the school as a condition of exemption from certain state and local laws and regulations that cover traditional schools. These are reassessed by the granting authority, and the charter can be revoked if not followed appropriately (Rafa et al., 2020).

According to data gathered by National Center for Education Statistics (NCES), Irwin et al. (2021) stated that “traditional public schools and public charter schools have experienced different trends in enrollment” (p. 11). Specifically, between the school years 2009–10 and 2018–19, the number of public charter school enrollments in the United States (defined here as the 50 states and the District of Columbia) effectively doubled from 1.6 million students in 2009 to 3.3 million students in 2018. During that same time frame, traditional public school enrollment declined by 0.4 million students.

The United States charter school movement, which began in 1991 in Minnesota and spread quickly to nearly every other state (Bifulco, 2005; Carpenter, 2012; De Luca, 2018; David, 2017, Hui, 2019), now represents more than 3.3 million students attending over 7,500 public charter schools in 43 states and the District of Columbia (The National Alliance for Public

Charter Schools, 2020; Higgins & Hess, 2009). Specifically, North Carolina has 204 charter schools with 126,000 students, and ten schools are scheduled to open in 2022 (North Carolina Department of Public Instruction, 2022). Approximately 8.4 percent of North Carolina's 1.5 million school children attend charter schools, which is slightly greater than the national average of 7%. Of the charter schools in operation, 39% provide reduced-priced lunches, and 53% provide bus transportation. In contrast, all traditional public schools provide reduced-price lunches and offer bus transportation (Public School First, NC, 2021).

Stillings (2017) states that “Charter schools vary greatly in purpose and design, especially because they are subject to different laws and requirements from state to state” (p. 52). However, the premise on which the idea of charter schooling is based is that our schools can be improved if they are granted more local-level autonomy and flexibility (Lockwood, 2004). Charter schools agree to be held to a high standard of accountability in exchange for local-level freedoms and flexibility. These freedoms include the ability to act as singular school districts, to require a lower percentage of certified teachers, to alter the school day hours and days per year, and to hire and fire staff without input from teachers’ unions (Stillings, 2006). The accountability requirements for each charter school are determined by the terms of its charter and are monitored by the state board of education (Cheng, et al., 2017). If schools do not meet the requirements of their charter in terms of student achievement within a set time frame (usually 3-5 years), then they are subject to closure (Hui, 2019). In North Carolina, since 1998, 48 charter schools have voluntarily relinquished their charters, one has been assumed by another non-profit board, ten have been non-renewed, and 17 charters have been revoked by the State Board of Education (North Carolina Department of Public Instruction, 2022). During the 2018-19 school year, 47 charter schools were identified as either low-performing or continually low-performing (North

Carolina Department of Public Instruction, 2022). Since charter schools must attract students to continue to operate and stay viable, they are subject to local market forces as well as the oversight of charter school authorizers (Stillings, 2006).

As determined by each state, charter schools are exempt from many state and local rules and regulations imposed on traditional public schools except for regulations regarding health and safety, disabilities, and assessments required by the state department of education (Wixom, 2018). Additionally, unlike traditional schools, charter schools have flexibility in how they spend their budget, whom they hire to staff the school, what curriculum to use, require only 50% of teachers to be licensed (Hui, 2019), and offer the flexibility to work outside the constraints of the traditional school day and year structure (Wixom, 2018).

Charter schools do not receive funding to cover the cost of purchasing or leasing a physical facility but rather receive a per-student allotment that is specifically prohibited from being used for the cost of the facility (Rebarber, 2014). As a result, charter schools are often housed in non-traditional school buildings where space is at a premium (Hassel, 2001), which limits dedicated space for science classes, potentially impacting specialized laboratory space that has a central and distinctive role in science education (Hofstein & Kind, 2012). The rapid rise 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, 2012). The fast growth and unique funding structure for instructional programs make charter schools a key area of study for science education.

Science Laboratories and Equipment

One of the most fundamental means through which traditional secondary school students experience science education is through learning and exploring in science laboratory classrooms. The laboratory is seen as having a central and distinctive role in science education (Hofstein & Lunetta, 1982; 2004) and, as a learning environment, the laboratory is unique to science disciplines, thus setting it apart from other subjects (White, 1988). In addition, "it is a well-known fact that the quality of education a student receives largely depends on the quality of teaching resources provided. Teaching resources are the things used by the teacher to aid understanding and make teaching successful and effective. They include textbooks, equipment, consumables and the physical learning environments which include the science classrooms and laboratories" (Ibrahim, 2015, p. 186). Moreover, a study by (Ogutu, 2020) revealed that effective science teaching was hampered by an inadequate provision of resources such as a physical laboratory without traditional laboratory equipment. Investigations have shown that the inclusion of laboratory activities with hands-on interactions incorporating materials and equipment in science education instruction has resulted in many positive learning outcomes. These include: improved manual dexterity and laboratory manipulative skills (Hofstein & Lunetta, 1982); increased cognitive, affective, and behavioral measures of learning (Hofstein & Mamlok-Naaman, 2007); increased creativity (Penick, 1976); cognitive skills (Raghubir, 1979); and increased American College Testing (ACT) chemistry subtest scores (Renner & Fix, 1979). Therefore, the availability of appropriate laboratory equipment is critical for hands-on science education and, as little is known about the types and distribution of laboratory equipment in secondary schools, a focus on this area could be useful for understanding student science education and future resource planning.

Laboratory Safety Equipment

Laboratory safety is a critical component of science instruction and cannot be overlooked when science programs are designed. An estimated 32,000 student accidents occur in schools each year, with around 17% directly related to science (Hellman, 1986). The availability of appropriate safety equipment is critical to minimize such accidents. In industrial settings, persons do not assume their duties until they complete mandatory safety training, but such procedures are seldom followed in secondary science education situations (Stroud, 2007).

As one of the 26 Occupational Safety and Health Administration (OSHA)-approved ‘‘State Plans’’ states, North Carolina Occupational Safety and Health (NC OSH) has jurisdiction over all public, charter, and private schools (Stroud, p. 1, 2007) and requires middle and secondary schools to submit their chemical hygiene plans to the safety board, yet schools have been slow to meet these requirements (Stroud, 2007). Despite the important medical and legal implications of not adhering to safety standards, there are no known studies that have examined science laboratory safety equipment available in charter schools. Understanding the availability of science equipment can inform charter school instructional planning.

Science Education Facilities

The onus for procuring charter school facilities lies with the charter school communities, as funding for facilities is not made available from the state or federal governments. One can speculate that when starting a charter school, finding a suitable facility is a daunting challenge faced by charter school stakeholders. Finding and financing a suitable space to house a school is expensive, and since charter schools are a recent phenomenon, financial lenders may see them as a risk and charge higher interest rates for loans. Compounding this issue is the fact that in some states, charter schools do not qualify for tax-exemption status, thus further driving up the cost of facilities (Hassel, 2001). Data from a charter school survey of 118 charter schools demonstrated that the average cost for charter school facilities was $191,553, or $690 per student, which corresponds to about 12% of their total budget (Hassel, 2001).

The types of buildings used by charter schools are broad and diverse and include custom-built facilities (19.1%), former public school buildings (15.3%), offices (12.2%), retail establishments (11.5%), former private schools (10.7%), churches (6.1%), community buildings (4.6%), other public buildings (4.6%), university buildings (3.8%), warehouses (3.8%), factories (2.3%), private homes (2.3%), catering halls (1.5%), convents (1.5%), and nursing homes (0.8%) (Hassel, 2001). In a more recent survey, the 2012 Center for Education Reform (CER) National Charter School Survey, data analyzed from 725 charter schools found charter schools continue to spend around 12% of their total budget on facilities (Rebarber, 2014). The survey results found that 66% of charter school facilities were rented, 30% were owned, and 4% indicated no lease. Of the rented facilities, the most common owners were commercial properties (Rebarber, 2014). The breakdown of costs for spaces within facilities is not available, but given the expense of classroom laboratories and the above information, it is possible that many charter school facilities lack adequate classroom laboratory space. One of the most fundamental means through which traditional secondary school students experience science education is via learning and exploring in science laboratory classrooms (Hassel, 2001).

Teacher Autonomy

As noted above, autonomy and flexibility are key features of charter schools. The ability of teachers to make independent decisions in their classrooms has been a major part of the definition of teacher autonomy according to Feldmann (2011). The merits of teacher autonomy and its history have been well documented in the literature. According to Gurganious (2017), teacher autonomy is related to teacher job satisfaction, teacher professionalism, and teacher motivation. A major shift in teachers' autonomy occurred due to the implementation of the No Child Left Behind (NCLB) Act of 2001 (Gurganious, 2017). While the promise of NCLB was to close the educational achievement gap between children of economically privileged students and poor minority groups and was an ambitious goal, it came with the negative consequences of high stakes testing and "teaching-to-the-test" (Marx & Harris, 2006). Specific to science education, there were concerns that teachers may be pulled toward either supporting science inquiry or preparing students to perform well on high-stakes tests. Moreover, teachers felt pressure to standardize instructional approaches as testing requirements increased, which led to a decrease in professional autonomy (Crow, 2005; Jones et al., 2003), as well as concerns over the use of a script and narrowed curriculum, which would subsequently decrease autonomy (Husband & Hunt, 2015; Moran, 2015; Quartz, 2014). Moreover, the NCLB accountability system has influenced teachers' teaching practices, limiting their professional judgment for their student's educational needs, which undermines teachers' autonomy (Gurganious, 2017). While it can be argued that most teachers have felt the effect of loss of autonomy, charter school science teachers have felt a lesser effect because of their flexibility and autonomy over pedagogical implementations (Malloy & Wohlstetter, 2003).

Science Standards

Currently, 20 states and the District of Columbia have adopted the *Next Generation Science Standard* (National Research Council, 2015) as the framework for science curriculum in traditional public K-12 schools. More and more states are altering their state science standards to bring them into alignment with the NGSS standards. These standards emphasize communication, collaboration, and problem-solving by employing crosscutting concepts, science practices, and core ideas that synergize to allow for comprehensive science insights (National Research Council, 2012; Bybee, 2014). Unlike traditional public schools, charter schools are not required to use the national or state standards as a framework for science curriculum (North Carolina Department of Public Instruction, 2018). However, charter schools in North Carolina are required to administer End of Course (EOC) science tests to students in the fifth, eighth, and eleventh grades.

Regardless of the type of school engaged in teaching science, there are standards that must be maintained to support best practices in science education. The National Research Council (2004) identified the four pedagogical practices that define best practices and are supported with substantial empirical evidence: engaging resilient preconceptions; organizing knowledge around core concepts to create a foundation of conceptual understanding and factual knowledge; supporting metacognition and student self-regulation; and cooperative learning that allows students to work and learn together (National Research Council, 1996).

Additionally, best practices of science teaching should be employed in science programs. A partial list of these best practices includes establishing and maintaining classroom environments that: create a knowledge-centered environment to help students make frequent attempts to think and reflect to guide further instruction and are community-centered environments that encourage questioning and a place for safe risk-taking; use empirical approaches for investigation; employ active learning strategies; use inquiry labs with hands-on learning; and discuss the nature of science (National Research Council, 1996).

The information on effective science teaching emphasized above is from studies of traditional public schools. The knowledge gap here is that similar information for charter schools is not available and yet is imperative to a better understanding of the elements of effective science teaching especially given the rapid growth of charter schools, which will encompass large numbers of students.

Research questions

The information on effective science teaching emphasized above is from studies of traditional public schools. This study focused on these critical elements within the context of the steadily growing presence of charter schools, for which little information is available. These critical elements include: adequately-equipped science laboratories that increase students' problem-solving abilities (Godomsky, 1971) and increase student science achievements (Boghai,1979); essential laboratory safety equipment that is critical to decrease high rates of accidents and student and staff injury (Hellman et al.,1986); adequate science teaching facilities that impact teacher and student outcomes and teacher recruitment and retention (Moore & Lackney, 1993; Tanner, 2000); science teaching standards that enhance student science skills and understanding (National Research Council 2012; Bybee 2014); and teacher autonomy that enhances teachers' capacity to address students' needs, teacher satisfaction, recruitment and retention (Gurganious, 2017).

This research sought to examine charter school science programs and to answer the following questions:

1. What laboratory equipment is available to science teachers in charter school classrooms?

2. What laboratory safety equipment is available to teachers in charter school science classrooms?

3. What types of facilities are used by charter schools for science instruction?

4. What are the guiding science standards for charter school curriculum development?

5. What are charter school science teachers' perceptions of autonomy in science instruction?

Theoretical Framework

Science education programs in charter schools are highly variable and are influenced by financial, resource, and facility constraints that operate as a complex social process involving many stakeholders. To address this complexity, this study is situated within two theoretical frameworks. The first, Bourdieu’s theory of cultural capital, focuses on the ways in which people use cultural knowledge to undergird their place in the societal hierarchy (Bourdieu, 1986). Archer et al. (2014) extended this theory to include “science capital” as science-related forms of cultural and social capital. Here science laboratories and resources are examined as a form of science capital. The second theoretical perspective applied in this study is that of Vygotsky’s activity theory (Vygotsky, 1978), which provides a lens with which to unpack and better understand human activity (Hasan, 2014; Barab, 2002), specifically science education programs directed by science teachers. This study is focused on the perceptions of science teachers, given their critical role in shaping educational resources and approaches to the students. These theories are described in the sections that follow.

Bourdieu’s Theory of Cultural Capital

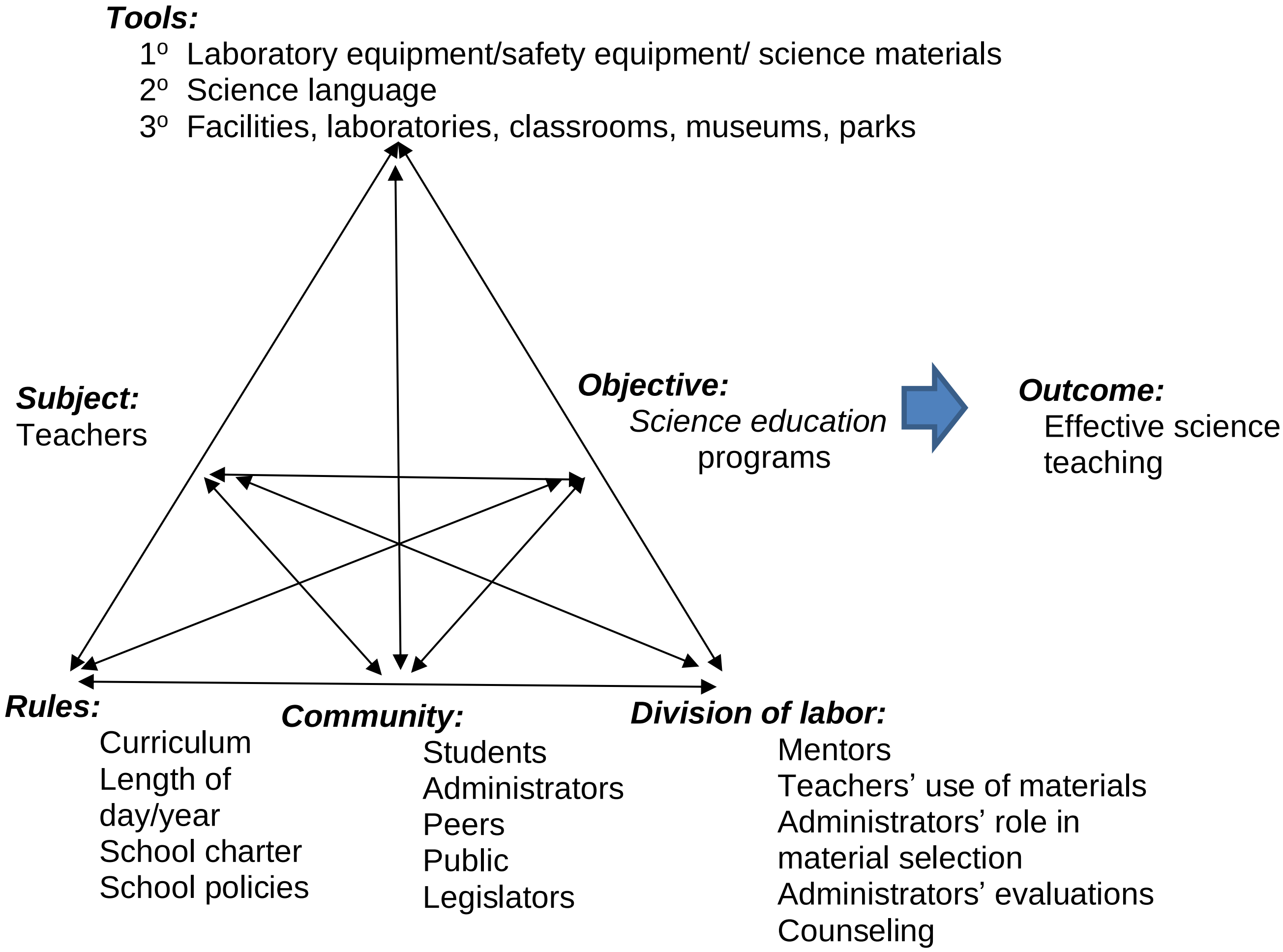
Bourdieu (1930–2002) examined factors that contribute to social stratification and mobility. Within his theory of social reproduction, Bourdieu described capital as a key component (Bourdieu, 2011). In this theory, capital is conceptualized as the legitimate, valuable, and exchangeable resources in a society that can generate levels of social advantage within a specific group. In other words, capital, as described by Bourdieu, can be thought of as the cards a player is dealt and the extent to which the player understands the rules through knowledge and experience. This capital will influence the player's chances of winning or losing (Laureau & Horvart, 1999). Archer et al. (2014) extended Bourdieu's forms of capital to "science capital", which includes science-related forms of cultural and social capital. Science capital can include resources for learning science, access to mentors and teachers, or access to knowledge and experiences. Students' science capital as a factor that influences participation in science has been the focus of previous research (Archer et al., 2015; Cayton, 2018; DeWitt et al., 2016; Wilson-Lopez et al., 2018). This study explored the science capital of teachers as it relates to science classroom resources and instruction within the context of science education programs in charter schools.

Vygotsky's Activity Theory

Another theory that sheds light on resources in educational settings is Vygotsky's activity theory. Vygotsky (1896-1934) suggested that materials, such as resources found in the science classroom, are key cultural artifacts that facilitate learning. Furthermore, Vygotsky embedded his ideas about semiotic tools within a larger activity theory framework. This framework includes access to resources and materials and social processes that relate to resources and materials. The activity theory framework is relevant for this explanatory study, as access to resources and materials for science instruction is a complex social process that reflects the perspectives of a wide range of stakeholders (e.g., students, teachers, administrators, parents, and the community at large). At its core, activity theory provides a lens with which to unpack and better understand human activity (Hasan, 2014). Grounded in the work of Vygotsky (1978), activity theory promotes the notion that "unlike animals, human activity is purposeful and carried out by sets of actions through the use of 'tools' which can be physical or psychological; the latter including language" (Hasan, 2014, p. 9). Activity is both mediated by and mediates action through tools that can be primary (physical - lab equipment), secondary (language, ideas, models, etc. - science language), or tertiary (communities, contexts, or environment - school buildings, parks, museums) (Hasan, 2014) and includes the person being studied (subject), the activity (object), and the outcome. Engestrom (1987) expanded the theory to include the concept of a collective activity system, with the addition of rules (explicit and implicit norms that regulate actions and interactions within the system), community (participants of the community who share the same object), and division of labor (a division of tasks and roles among members of the community in relation to the object). Activity theory allows for the examination of all components involved in the implementation of science programs as well as their fluid interactions. Figure 1 illustrates the relationships among these concepts (Engestrom, 2001) in the context of science capital. The components listed in the figure should be viewed as flexible bands where movement in one component affects the system as a whole.

Figure 1

Activity Theory Science Capital Model Applied to Charter School Science Instruction



Note: Tools are designated here as primary, secondary, and tertiary.

Context

This study, framed within science capital and activity theories, examined secondary charter school science teachers' instructional resources and instruction. This framework allows for the examination of the specific instructional environments and instruction resources of teaching science within the context of charter school science education programs.

Methods

This descriptive case study utilized a mixed method, explanatory sequential design (Creswell & Creswell, 2018), examining charter school secondary science teachers' perceptions of science capital resources along with affordances and constraints of science education programs in charter schools. Secondary charter school science teachers were recruited from North Carolina charter schools for the study. The study began with a quantitative online survey of 105 participants, followed by interviews of 21 of these science teachers.

Mixed methodology was used with a two-phase structure that included collecting quantitative data first followed by qualitative data as described below (Creswell & Creswell, 2017). The study was designed so the qualitative interview data could provide details and context for the quantitative results. As such, the results of the two phases are tied together to clarify any confusion, contradictory, or unusual survey responses (as suggested by Creswell & Creswell, 2017). The Institutional Review Board (IRB) IRB # 20574 approved the survey on 4/17/2020.

Quantitative Phase

Survey Participants

Participants (N=105) in the study were secondary science teachers who taught in charter schools in North Carolina. Science teachers were recruited through a variety of means to participate in the study. First, a list of available 6th-12th grade charter school science teachers' email addresses was compiled using information 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, science teachers associated with North Carolina State University were given a survey link and asked to take the online survey if they taught in a charter school. Finally, an email to all charter school principals in North Carolina was sent with a request for science teachers to participate in the study. A sample of 140 teachers agreed to participate in the survey via email. Originally 132 participants responded to the survey. After cleaning the data as described below, 105 survey participant responses were analyzed. Survey participants were given the opportunity to register for a $100 Amazon gift card upon the completion of the survey.

Table 1 lists the demographics of the participants: for the survey, 72% were female with 28% male, 90% were White, 6% were Black, 2% were Asian, one was mixed race, and 93% were non-Hispanic and 7% Hispanic. In terms of age, 3% were 18-25 years old, 30% were 26-36 years, 43% were 37-47 years, 21% were 48-59 years, and 3% were 60 years and older. The interview participants were 72% female and 29% male. These data are consistent with the findings from the 2012 National Survey of Science and Mathematics Education (Banilower et al., 2013), in which 70% of traditional public school middle school science teachers and 54 % of high science teachers were female, and 90% were white with the majority of teachers being between 26 and 47 years old. The schools for the survey participants were 51% suburban, 32% rural, and 17% urban, and for the interview participants, 43% suburban, 24 % rural, and 33% urban.

Table 1

Teacher Demographics

Characteristic	Surveys		Interviews	
	n	%	*n*	%
Gender				
Female	70	72	15	71
Male	27	28	6	29
Race				
White	86	91	18	85
Black	6	6	1	5
Asian	2	2	1	5
Mixed	1	1	1	5
Ethnicity				
Non-Hispanic	90	93	20	95
Hispanic	7	7	1	5
School locations				
Suburban	50	51	9	43
Rural	32	32	5	24
Urban	17	17	7	33

The survey participants had a wide range of teaching experience as 25% of teachers had 1-5 years of teaching, followed by 24% with 6-10 years of teaching experience, 21% with 11-15 years of teaching experience, 19% with 16-20 years of teaching experience, and 10% with 21 plus years of teaching experience. These participants taught a variety of courses in middle and high schools and had different levels and types of education (Table 2).

Table 2

Survey Participants' Course Types and Education

Characteristic	Middle school only		High school only		Total	
	n	%	*n*	%	*n*	%
Course type						
General Science	45	94	5	10	50	48
Life Science / Biology	9	19	19	39	28	19
Physical Science/ Chemistry	10	21	33	67	43	41
Earth/Environmental science	9	19	28	57	37	35
College degree						
Education General	42	69	35	56	62	59
Natural Sciences	28	46	41	66	39	37
Other	5	8	5	8	4	4

Note. The last column "Total" is not additive of the prior groups as it indicates all teachers, including those who teach split classes between middle and high school.

The survey participants also were certified in many areas both within science and in non-science disciplines, as shown in Table 3.

Table 3
Survey Participants' Certification Areas

Certification area	*n*	%
General Science	79	75
Biology/life science	31	30
Chemistry	18	17
Earth Science	15	14
Environmental Science	15	14
Physics	15	14
Other	38	36
Elementary Ed	1	1
Mathematics	7	6
Special Education	1	1
School administration	1	1
Pharmacology	1	1
Agriculture education	1	1
Social studies	1	1
National board	1	1
Lateral entry	10	10

Note. Some teachers were certified in multiple areas.

Survey Questionnaire Development

The instrument used in this study was developed specifically for this study. The survey items were designed to measure teachers': access to laboratory equipment; safety equipment; types of school facilities; use of science standards; status of licensure; extra-curricular science programs (e.g., Science Olympiad, science clubs); instructional spaces; and teacher autonomy, including the amount of control over course goals, selecting curriculum materials, selecting content, topics, the timeline of topics, and skills to be taught. Initially, a pool of 80 items was developed based on existing instruments in the literature, including the 2018 National Survey of Science and Mathematics Education (NSSME+) questionnaire (Banilower et al., 2018). The initial 80-item draft survey underwent multiple iterations of review for clarity and validity, as described below. The draft survey was examined by three science educators who kept or discarded each item based on relevance. Pilot testing of the survey was conducted by three high school science teachers and one middle school science teacher from traditional and charter school backgrounds to establish the face validity of scores on the instrument, to provide an initial evaluation of the targeted constructs of the items, and to improve questions, format, and instructions (Creswell & Creswell, 2017). While these four educators took the survey, they participated by using a cognitive think-aloud approach (Van Someren, et al., 1994). The final survey consisted of 35 multiple choice questions and three open-ended questions asking teachers to comment on the advantages and disadvantages of teaching science in a charter school, as well as their perception of the quality of science education in their charter school. Table 4 shows the constructs measured by the survey, and Table 5 links the study questions with the theoretical frameworks and constructs.

Table 4

Study Constructs

Construct	Definition	Example
Science Instruction Spaces	Traditional labs	Typical classroom laboratory with lab equipment (i.e., fume hoods, lab tables, glassware, chemicals, microscopes, etc.)
	Outdoor spaces	Parks, gardens, nature reserve with surveying equipment such as binoculars, telescopes, shovels, hoes,
	Indoor spaces	Museums, zoos, aquarium, virtual provided specialized equipment.
Safety Equipment	Traditional labs	Goggles, gloves, aprons, lab coats, eyewash station, shower, first aid kit, spill containment kit
	Outdoor spaces	Protective eyewear, gloves, first aid kit, protective headwear (if needed)
Science Standards and Curriculum	Federal Standards	NGSS
	State Standards	NC Essential Science Standards
	Curriculum	Charter-mandated or self-created
Teacher Preparedness	College Degree	Education degree with a focus on science education, Biology degree
	Licensure	Licensure in science
	Lateral Entry	Seeking licensure
Classroom science instructional practices	Classroom strategies	Field trips, project-based learning, hands-on activities, hands-on activities, labs, group projects, online virtual labs

Note. NGSS = Next Generation Science Standards; NC = North Carolina

Table 5

Sample Survey Questions: Framework and Construct Alignment

Survey Question	Framework	Construct
What is the availability of specific laboratory equipment for your science instruction?	Tools - equipment	Laboratory equipment
What is the availability of specific safety equipment for your science instruction?	Tools - safety equipment	Safety equipment
Is your school housed in a building constructed as a charter school or a building built for other purposes? Please explain.	Tools - facilities	Instructional facilities
What are the specific science spaces/resources used for your primary science instruction?	Tools - facilities	Instructional facilities
What standards you use for planning your science curriculum?	Rules - curriculum	Science standards and curriculum
How much control do you have over your science instruction?	Subject - teachers	Autonomy
Open-ended question Do you have unique instructional opportunities not available to science teachers in traditional schools?	Subject - teachers	Autonomy
Open-ended question 2 Do you face unique challenges compared to teachers in a traditional school?	Tools	Laboratory equipment Safety equipment Instructional facilities

The final survey administered was named the "*Science Laboratory Classroom Facility and Science Instructional Materials Survey"* (see Supplement A).

Data Collection

Quantitative data were collected from the study participants using the final online survey using a Qualtrics platform. The data included responses to 35 multiple choice questions and three open-ended questions. Data were removed if the survey did not include: the consent to participate in research (n=1); if only the demographics questions were answered (n=1); the respondent reported teaching a subject other than science (n=1); the respondent reported teaching in a different state (n=1); the respondent reported teaching only elementary school (n=5); or a majority of the questions were not completed (n=18). The final data set included responses from 105 participants.

Data Analysis

Frequencies, means, and standard deviations for age, gender, ethnicity, years of experience, science course types, school location (rural, urban, or suburban), and years of experience in a charter school on the survey were determined. Other analyses that align with the study constructs taken from the research questions included frequencies of laboratory equipment; safety equipment; types of school facilities; science standards used; status of licensure; extra-curricular science programs (e.g., Science Olympiad, science clubs); instructional spaces; and the amount of autonomy, including control over course goals, selecting curriculum materials, selecting content, topics, the timeline of topics, and skills to be taught. The open-ended question responses were coded for themes identified in the research questions (Elliott, 2018), and the frequencies of those themes were tabulated. Additionally, certain themes that were repeatedly noted by respondents and the most frequent ones were included for further analysis.

Qualitative Phase

Twenty-one of the 105 survey participants volunteered to participate in an interview. The interview participants and interview protocol are discussed below.

Interview Participants

The interview participants included a subsample of individuals (n=21) who volunteered to be interviewed by filling out a google form that was linked to the online survey. The mean teacher age of the interview participants was 45 years (*SD* 11). The mean number of years teaching for the interviewees was 15 (*SD* 11). In terms of education, 100% of the interview participants in the study held bachelor's degrees, 19% held a master's degree in teaching, 10% held a master's degree in science, and 5% held a non-education master's degree. Of the 21 teachers, 34% were not licensed to teach science, while the remaining 66% held a teaching license. Forty-three percent of the schools were suburban, 33% urban, and 24% rural. Interview participant demographics are presented in Table 1.

Interview participants taught in a variety of school types that included college preparatory (53%), whole child (43%), and arts (4%). Title 1 schools were uncommon (24%). The student populations at each school ranged from 200 to 2,000, with 67% of the teachers teaching in schools with 500-1000 students. The class size ranged from 10 to 30, with 62% of teachers having 21to 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 to 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. A wide range of courses was taught by the interview participants (Table 6).

Table 6

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.

Interview Protocol Development

The interview protocol was designed specifically for this study based on the five research questions and was designed to deepen the understanding of teachers' survey responses. Initially, the protocol was reviewed by a panel of science educators and scientists for clarity and validity and revised (Franklin & Ballan, 2001). It was then piloted by three charter school science teachers, a high school chemistry teacher, and three educational research scientists for further clarity of language and meaning, thereby increasing reliability (Jacob & Ferguson, 2012), and additional items were modified or removed based on feedback. Finally, after a review of the survey data, the interview protocol was finalized for use. The final protocol consisted of 65 open-ended questions that probed the findings of survey results while illuminating a deeper understanding of specific classroom laboratory equipment, laboratory safety equipment, laboratory spaces, instructional materials, teaching credentials, professional development opportunities, and extra-curricular science opportunities for students in charter schools. Each interview took approximately sixty minutes to complete. Like the survey, the interview protocol was reviewed by science educators, piloted, and revised at each step before being finalized (see Supplement B).

Data Collection

One-on-one interviews with the teachers were conducted and recorded with permission using the Zoom video conferencing platform, using the semi-structured, open-ended questions of the interview protocol. During the interview, participants were encouraged to elaborate on their experiences as charter school science teachers as they answered the questions. Follow-up questions were asked by the researcher for clarity or elaboration and were determined by the participant responses (Dearnley, 2005). Each interview lasted from 45 to 60 minutes.

Data Analysis

The interview transcripts and the open-ended questions on the survey were first transcribed by the researcher using the Zoom transcription generator. The transcripts were then reviewed for consistency and analyzed using a two-step deductive analysis approach (Hayes & Sliwa, 2003), where an extensive literature review of science programs in traditional public schools to identify elements within those programs that promote effective science teaching within the scope of study research questions (i.e., laboratory equipment, safety equipment, school facilities, science standards used, and teacher autonomy), then the use of study constructs defined by research questions were used to identify the effective teaching elements in charter schools (Canary, 2019). A codebook was not used due to the explicit use of the study constructs used in coding the interviews and open-ended questions. A second coder coded 30% of the interview data using the predetermined codes as described below, and subsequently, the inter-rater reliability score was calculated using the formula described in Miles and Huberman (2014): reliability = number of agreements/ number of agreements + disagreements. The interrater reliability score for the survey's open-ended questions was 95% and for the interviews was 90%.

Results

In the sections that follow, the quantitative and qualitative results related to the research questions of laboratory equipment, laboratory safety equipment, charter school facilities, student science enrichment activities, guiding science standards, and teacher autonomy are presented.

Charter School Science Classrooms Laboratory Equipment

In general, high school and middle school teachers reported having access to a wide range of laboratory equipment. Many of the middle school and high school teachers lacked access to basic laboratory equipment such as lab tables, sinks, and balances (Table 7). High school teachers tended to have greater access to equipment such as fume hoods and gas compared to middle school teachers.

Table 7

Non-Accessible Laboratory Equipment

Items	Middle school		High school		All	
	n	%	*n*	%	*n*	%
Lab Tables	16	34	4	9	20	28
Electric outlets	1	2	0	0	1	2
Sink	5	11	1	2	6	13
Gas	47	100	23	49	59	53
Fume hood	47	100	18	38	57	55
Balances	7	15	18	38	8	17
Probes (Temp., pH, etc.)	16	34	16	34	47	46
Thermometers	3	6	0	0	8	17
Microscopes	1	2	0	0	44	43
Glassware	4	9	0	0	4	4
Chemicals	9	19	1	2	12	12
Disposable materials	2	2	1	2	4	4
Meter stick	0	0	0	0	2	2
Stopwatch	0	0	1	2	4	4

Note. Non-accessible means the items are not in the classroom or in the building. “All” includes the responses of teachers who teach K-12 who were excluded from the middle and high school only calculations.

In response to the open-ended question on the survey, “Do you have any challenges teaching science in a charter school,” 45 of 96 (47%) teachers specifically raised the lack of resources and equipment as an issue. As one teacher stated, “We don't have nearly the funding that a traditional school has, so a lot of materials are out-of-pocket expenses for me. I don't have a set of microscopes, for example. I have to borrow them from the high school.” Another teacher echoed these sentiments reporting, “When I taught in the traditional public school, I had more resources and materials to use, even if I had to share them with others. In the charter school, I either have to purchase the materials on my own or change my plans. My resources are much more limited in the charter school setting.” And another teacher noted, “We have very limited lab equipment and supplies and a small budget to buy supplies. So, I need to find labs I can do that only require things that are free or cheap to buy. So, no lab packages were bought from companies. I just scour the internet for free stuff.” Finally, from the interviews, one teacher stated, “We don't have access to some of the more traditional lab equipment that a traditional school has: for example, Bunsen burners, sterile/fume hoods, large chemical supplies, lab-safe benches, more than one sink in a classroom, etc. This forces us to be very creative in how we implement laboratory activities, but at times, I think our students get less exposure to more traditional lab practices.”

Charter School Science Classrooms Laboratory Safety Equipment

Many of the teachers reported they did not have access to basic safety equipment (Table 7). Remarkably, 19% of high school teachers didn’t have access to safety showers, and 13% didn’t have spill control materials, while 13% of middle school teachers didn’t have access to fire extinguishers. High school teachers reported having more safety equipment than middle school teachers.

Table 8

Non-Accessible Laboratory Safety Equipment

Items	Middle school		High school		All	
	n	*%*	*n*	*%*	*n*	*%*
Safety Goggles	4	9	0	0	4	4
Gloves	8	17	2	4	12	11
Apron/coats	23	49	5	11	32	31
Eye Wash station	18	38	0	0	20	19
Shower	24	51	9	19	37	35
Spill Control	29	62	6	13	39	37
First Aid kit	3	6	0	0	3	3
Fire Extinguisher	6	13	0	0	6	6

Note. Non-accessible refers to items not available in the classroom or in the building. "All" includes the responses of teachers who teach in grades K-12 who were excluded from the middle and high school only calculations.

In response to the open-ended question on the survey, "Do you have any challenges teaching science in a charter school?" one teacher commented, "There is more funding in public schools for lab equipment (we get parents to buy most of ours), curriculum, and safety equipment." Another teacher reported, "We don't have science labs or the proper safety equipment, so we have to be creative inside the classroom." These statements were corroborated during the interviews, as noted by this teacher: "We have first aid kits, fire extinguishers [and] the normal building sprinklers…I think that's about it as far as safety goes." Another teacher responded to questions about safety equipment in the classroom, responding "no" when asked if they have access to a first aid kit, a fire extinguisher, or fire sprinklers. Put succinctly, one teacher's statement summarized the problem by stating, "I think if I just had a working sink, that would be probably my top thing; I could make the rest of the stuff [science] happen. It stinks not having running water."

Charter School Facilities

Most science teachers reported teaching in buildings designed for charter school purposes, however, 16% reported teaching in repurposed buildings. These included facilities that were originally designed for shopping malls, a bank, business offices, a car dealership, cotton mills, office buildings, rehabilitation centers, a warehouse, and a church. In response to "Do you face challenges teaching science in charter schools? 15 of 96 (16%) of the participating teachers specifically raised inadequate facilities and lab space as an issue. These statements from two different teachers summarized the feelings that some raised: "I think one of the challenges is space." and "Since facilities are sometimes limited, teachers also share classrooms. It can be very difficult to teach science and move around during the day, especially when setting up labs. We currently do not have dedicated lab space."

Similarly, during the interviews, several teachers reported their frustrations at not being consulted about the lab spaces as they were being designed and constructed in new buildings as well as in repurposed buildings. One teacher noted, "It's especially frustrating when you don't have input … I really wish I had been sought out for some opinions, but the lab tables that we [now] have are just rectangular tables that are normal desk height, they're not elevated." Another teacher added, "[Our science building isn't built yet] which is why we're offering physics and earth, environmental and not chemistry or biology at the present time because of facilities and resources." A middle school teacher reported, "Two of the three middle school science teachers have a room with a sink." Additionally, a teacher responded with, "I have the equipment that I need. I just don't have it in my own room. So yeah, my room is tight. This is a small room." Another teacher, when asked if her space was well-equipped for science experiments responded, "Absolutely not. It's just not a science room." When asked about science spaces used outside the classroom, one teacher stated that the science space inside the school building is "not always [large enough to accommodate students when doing science], so external spaces such as urban parks near the school are utilized." Another teacher reported, "We go outside a lot. We have a creek that runs down through campus, and we go there [for science exploration]. We also have access to a horse barn and wooded areas at our disposal." A teacher who is an avid hiker himself reported, "We hike a lot; we hike in our electives class - we go outside at least three days a week. I teach them about wildflowers and anything we can discover. "

Guiding Science Standards for Charter School Curriculum Development

All teachers reported using either state science standards or national science standards to inform lesson plans on the survey and during the interview. One teacher reported, "[We use] state and national standards." Another teacher stated, "For honors and higher-level critical thinking [we use] standard state standards and for Advanced Placement chemistry, [we use the] textbook."

Student Science Enrichment Activities

A large majority of teachers (82%) reported a number of science enrichment activities for their students in the survey. These included: 19% who reported having Science Olympiad team(s); 31% who reported having other science clubs; 31% who reported having science fairs; and 52% who reported having other types of science enrichment experiences.

Also, during the interviews, teachers were asked, “Do your students participate in Science Olympiad or other science-related clubs or activities outside of school?” One teacher responded, “Yes. We have two or three teams. [We] routinely go with regard to Science Olympiad as well as ocean bowl. We have a dynamic ocean bowl team that does a lot of marine biology-type stuff. And that's one of my other colleagues who has a rich background in marine biology, and he teaches environmental science.” Another teacher said, “Yes, Science Olympiad, Robotics, Science national honors society – science-related community service; a good amount of clubs, biology ...”

Teacher Autonomy

One of the survey questions asked teachers to rate their level of control as complete, moderate, or none for a series of questions that asked about instructional autonomy. Specifically, teachers were asked, “How much control do you have over each of the following for science instruction in your classes?” for each of eight categories (Table 8). The vast majority (83%) reported complete control over the sequence of instruction, and 79% noted they had complete control over instructional time and their instructional techniques.

Table 9

Teachers' Perception of Control

Instructional Control	Middle school		High school	
	n	%	*n*	%
Determining course goals and objectives				
Complete	21	35	20	42
Moderate	24	29	27	56
None	16	36	1	2
Selecting curriculum materials such as textbooks/modules				
Complete	32	53	28	58
Moderate	26	42	17	35
None	3	5	3	7
Selecting content, topics, and skills to be taught				
Complete	25	41	21	44
Moderate	26	43	25	52
None	10	16	2	4
Selecting the sequence in which topics are covered				
Complete	49	80	40	83
Moderate	12	20	8	17
None	0	0	0	0
Determining the amount of instructional time to spend on each topic				

Table 9 (continued)

Complete	46	75	38	79
Moderate	12	20	9	19
None	3	5	1	2
Selecting teaching techniques				
Complete	46	75	38	79
Moderate	14	23	10	21
None	1	2	0	0
Determining the amount of homework to be assigned				
Complete	41	67	29	60
Moderate	19	31	18	38
None	1	2	1	2
Choosing criteria for grading student performance				
Complete	34	56	30	63
Moderate	26	42	17	35
None	1	2	1	2

These results were further supported by 80 of 93 respondents (83%) who emphasized instructional flexibility, control, and autonomy in the survey's open-ended question, “Do you think as a science teacher working in a charter school that you have unique instruction opportunities that traditional science teachers do not have? If yes, what?" Examples included one teacher who stated, "Yes, I have complete autonomy over my curriculum decisions…For my advanced placement course, I am tasked with adequately preparing students for their exams, but how I do that and with what strategies, resources, and teaching approaches are completely up to me. In my other courses, I am given the freedom to design my class as I think would best engage students and prepare them for collegiate science." And another said, "Yes, in my experience charter schools provide teachers the opportunity to teach from the heart in an inclusive family environment which allows teachers to meet the needs of each individual student." And finally, one teacher stated, "Control over what I teach, when I teach, and how I teach. I am treated as the professional expert that I am!"

Instructional autonomy was also a significant finding in the analyses of the open-ended items and the interviews. For example, this teacher noted, "In a public school, we were overwhelmed; we had department chairs, we had academic coaches, we had people from the central office dictating to us what we had to teach and how we had to teach it. We were constantly thrust into workshops. Every week we had to go somewhere to the central office and attend something. Now, it's not that way. It's like I said, we have the power to teach the way we want to, as long as we get the results. And that's where I think having the freedom to do something is what I've always wanted - to do certain things in a certain way. Now I have that luxury, and I have outstanding results with my students and my test scores." Another teacher reported, "I feel like they [the administrators] trust me. They will say, 'you're the chemistry expert here. You do what you think is going to prepare our students well for college and what you think will prepare them well for science down the road."

Additional Information from the Questionnaire and Interviews

Isolation

One finding that emerged from the data was teachers' feelings of isolation that resulted from being the only teacher who taught a particular subject in the school. This was specifically raised by 19% of survey respondents to the open-ended survey question, "Do you have any challenges teaching science in a charter school." As one teacher summarized, "Yes, some of the challenges faced by charter school science teachers include teaching in isolation for your subject, so a lack of a supportive PLC [professional learning community] structure. This experience would be essential for new teachers, in my opinion, and benefits all teachers!" Similarly, another teacher said, "I also don't have anyone else who teaches my content, so I have no opportunity for PLC." From the interview, a teacher stated, "I think the hard piece of being the only biology teacher is I don't really have that mentorship."

Professional Development

Another theme that emerged from the analyses was related to a lack of professional development (PD) opportunities. The survey data were gathered from an open-ended question that asked teachers if they faced unique challenges in teaching science at a charter school, and 6% of teachers noted the lack of PD opportunities as a specific challenge. Interview participants (29%) also responded that they did not have adequate PD opportunities. Of those interviewed teachers who did have PD opportunities, 47% of those opportunities were initiated at the school level, while 53% were teacher-initiated. In other words, if teachers wanted to attend PD opportunities, 53% of the teachers had to seek out these opportunities on their own and were reimbursed by the school. Comments from teachers emphasized this problem. One teacher responded, "I am not part of a larger school district. I do not have the PD opportunities that many larger districts may create for their science teachers... professional development is extremely limited within the school." Another teacher noted, "Being the only middle grades science teacher, I do not have the ability to plan with peers. I have to look for opportunities through conferences and outside PD to bounce ideas and ask questions."

Quality of Science Teaching

The final open-ended question on the survey asked, "Do you think that the quality of science teaching in your school is better, the same, or not as good as in a traditional school?" The responses were overwhelmingly positive, with many teachers saying that they would not teach anywhere other than a charter school again despite the many challenges that they faced. Typical statements by the teachers included comments such as this one, "[It is] better. We attract educators who want to educate. We are treated as professionals, and so we are encouraged to do our best work. We have small class sizes so we can get to know the students and make relationships with them, which enhances their education." Another teacher noted, "I think it is better. The students have consistently scored higher on all state tests, and there has been a large success rate of students moving on to higher education." Finally, this teacher remarked, "I believe it is better as we are given the freedom to conduct fun, engaging, hands-on activities not usually found in traditional classes. Teachers are passionate, and it shows! With smaller class sizes, we can really focus on students and team-approached activities." Consistent with these findings, during the interview, when asked to rank their science programs from 1 (low) to 10 (high), all teachers ranked their programs in the 8-10 range.

Discussion

In summary, this study showed secondary science teachers in charter schools face challenges related to lack of science equipment, lack of safety equipment, and inadequate school facilities. Although charter schools offer pedagogical flexibility to teachers, it became clear that there were additional constraints on science teachers that had negative influences on them. The survey and interview data revealed the shared and different aspects of perceptions and experiences with teaching science in a secondary charter school. These results should be interpreted within the context of the unique structures and framework of charter schools, and the following sections discuss these issues in more detail.

Laboratory Equipment

While the premise for establishing charter schools was to establish educational innovation and pedagogical flexibility (Lubienski, 2003), their unique structure, which requires extensive instructional funding for equipment, may have a negative impact on science programs. Because of the limited resources, many science teachers in this study indicated that they are teaching with sub-optimal laboratory equipment but are attempting to “make science work” with the equipment they have. However, the results showed that a number of teachers needed more equipment to fully implement their science programs. These deficiencies, which included 55% who did not have fume hoods, 43% who did not have microscopes, 28% who did not have laboratory tables, and 13% who did not have sinks, significantly limit the type of experiments available to students and place a burden on teachers to design assignments that fit into the equipment at hand.

This also requires alternative workarounds, such as using online and other teaching tools and doing wet labs without a sink. They also limit the students’ capacities to learn how to do experiments and their exposure to the complete science experience. Specifically, the lack of microscopes in classrooms significantly limits students’ physical experience and the development of skills needed to prepare a sample on a glass microscope slide, mount the slide correctly in the microscope, choose the magnification medium (oil or other), and then focus the lens to interpret the image of the sample. The danger for students without this type of hands-on experience is that they arrive in college and are already behind in science laboratory skills because they do not have the experience of working with real microscopes. Furthermore, the lack of a sink in a science classroom greatly inhibits teachers' options for science activities.

While teacher creativity is a tremendous asset in the science class, it also puts undue stress on the teacher, having to create new ways of implementing laboratory activities that teach the content. The lack of access to fume hoods meant that chemistry teachers were not able to teach traditional chemistry laboratories. This study shows many charter school students do not have the opportunity to experience one of the most fundamental means through which traditional secondary school students learn science, which is through learning and exploring in science laboratory classrooms (Hofstein & Lunetta, 1982, 2004).

Laboratory Safety Equipment

As described above, a surprisingly large number of teachers reported the absence of safety items, including spill control (37%), showers (35%), eyewash stations (19%), and fire extinguishers (6%). Most of these items are considered essential to conducting safe laboratory experiments (Richmond, 2000). Conducting science experiments without proper safety equipment puts everyone at risk and is a medical and legal liability. Students run the risk of serious injury such as eye damage if there are no eyewash stations, chemical burns without access to chemical showers, and burns from fires if there are no fire extinguishers. Because of the lack of safety equipment, science teachers described their lesson preparation and implantation as being creative as they struggled to teach the content while maintaining a safe environment. One of the main issues with not having proper safety equipment in a science classroom is that it inhibits the types of experiments that teachers will explore with their students. For example, experiments that study chemical reactions with either caustic materials or with flammable liquids would not be feasible to conduct in the classroom. A teacher would have to find alternatives such as online laboratory videos to show the reactions. The negative consequence of this from a student's perspective is that they do not gain the science safety skills to handle caustic or flammable materials safely. This again presents a problem for students who have not been exposed to proper safety precautions entering a science field in college, as they will have to both learn the safety procedures while also learning the course content.

Facilities

While minimum facility standards have been defined for NC schools (Safe schools facility planner - NC, 2013), 16% of the teachers reported using repurposed and other buildings that resulted in inadequate spaces for science teaching from the teachers' perspectives. As other researchers have noted (Ainley, 1981; Englehardt, 1968), teachers' access to good facilities is key to fostering inquiry. To adapt to these limitations, teachers reported often holding classes outside or in other facilities. The full implications of having outdoor science instruction (Glackin & Jones, 2012) are not known but could have both advantages and disadvantages, depending on the topic being taught. Some teachers who have the flexibility and teach content relevant to outdoor learning topics, such as ecology, flora, and fauna, indicated that hiking and exploring outside are incorporated into their lessons at least three times a week. Having the flexibility as a science teacher to take students outside and allow them to experience the outdoors using their sense of wonder and curiosity where lab space is limited could be advantageous as it allows for exploration of science in the outdoors. But the lack of laboratory space reported by the teachers in the study could seriously limit the opportunity to learn laboratory skills.

Science Standards for Curriculum Development

The combined survey and interview data revealed that all science programs within the study used state or national science standards for their curriculum development. This was surprising because charter schools are not mandated to use science standards (Wixom, 2018). NGSS and state science standards stress skills such as communication, collaboration, inquiry, problem-solving, and flexibility, which work together to give students a comprehensive understanding of science and support best practices in science education (North Carolina Department of Public Instruction, 2018; National Research Council, 2012).

Student Science Enrichment Activities

Student enrichment programs, also referred to as out-of-school time science activities, have been identified by the National Research Council as having a uniquely positive impact on the field of education because they promote interest in science in the real world (Bell et al., 2009). These activities have also been proposed to motivate students' interest in STEM career development and choice (Krapp et al., 1992; Lent et al., 1994). It is reassuring that many charter school science teachers recognize the importance of student enrichment programs by encouraging their students to participate, as we found in this study.

Autonomy

One of the significant themes that emerged from the survey and the interviews was the autonomy that teachers had in the charter school environment. As noted in Table 8, an overwhelming majority of the teachers reported their extensive autonomy to tailor their approaches to students as a major area of importance. This was described as the primary advantage to teachers of teaching in a charter school. This autonomy gave teachers control over what, when, and how they taught and a sense of being respected as professionals. In terms of implications, teacher autonomy is known to be important for job satisfaction, teacher retention, and quality of life, and may impact the quality of student learning (Malloy & Wohlsetter, 2003).

Isolation

Nineteen percent of survey respondents reported isolation as a disadvantage of teaching in charter schools. The interview data corroborated this result and revealed a lack of peer collaboration and mentorship, which argues for finding ways to encourage teachers to communicate with more experienced teachers and peers via structured collaborative programs. Given the relatively small size of many charter schools (Irwin et al., 2021), it was not surprising that teachers often felt isolated as the only person teaching in a particular area, as others have also discovered (Drago-Severson, 2006). This finding, which came from information in the questionnaire and was also found in the interview results, suggested that teacher isolation did not appear to be a priority for program improvement in the schools. This problem has been addressed in other states by the existence of community support through a learning environment association (LEA) or a charter school network (Rose, 2013).

Professional Development

A lack of school-sponsored professional development (PD) opportunities was reported by roughly a third of survey and interview participants. While schools were often willing to offer reimbursements for PD, it was up to the teachers to seek out and arrange for these opportunities. As teachers noted above, they did not have the PD opportunities that larger school districts had for their teachers. While the link between PD and a change in teachers' instructional practices continues to be studied (Luft & Hewson, 2014), teachers do believe that PD can help them become more effective teachers and benefit their students (Whitworth & Chiu, 2015). Moreover, studies have found that PD contributes to teacher growth by allowing teachers to actively engage in their own learning (Desimone, 2009) and reflecting upon their own practice and understanding (Heller et al., 2012). By recognizing the impact of informative PD programs and taking a longer view of them as valuable resources for teachers, administrators may find more effective ways to present meaningful, in-house science-specific programs to their staff. The long-term consequences of inadequate PD could be teachers who become increasingly out-of-date in their approaches and practices (Gardner, 2019).

Theoretical Framework

This study, which viewed the data from an activity theory lens, found that the teachers had many tool deficits when working toward the outcome of effective science teaching. Activity theory as a conceptual framework allows the researcher to inquire and explain phenomena and human activities that are of interest through a set of principles where tools are central to the activity (Kamanga, 2019). The activity setting for charter schools is different from that of traditional public schools. These results suggest that the physical building, classroom spaces, and safety equipment are not priorities for charter schools. Viewing these findings from a traditional public school perspective, many of the charter schools' science programs lacked adequate laboratory equipment, safety equipment, facilities, and professional development opportunities. But if viewed from a charter school movement lens, teachers had the autonomy and flexibility that are often key to the creation of charter schools. These results should be viewed within the cultural-historical context of the charter school movement, where the mission is to create smaller, more flexible schools. In this context, the process of developing effective science teaching in charter schools should be viewed as an active transformative process (Barab et al., 2013, Engeström, 1996; Holt & Morris, 1993; Kuutti, 1996).

If the results are viewed from a science capital framework, this study found that there were many gaps in the science capital of charter school science teachers. Using the definition of science capital as described by Archer (2014), which includes resources such as lab equipment, safety equipment, and professional development opportunities in the context of teaching science in charter schools, we found that science teachers in charter schools are lacking in fundamental science capital, which may interfere with their ability to teach science effectively. Additionally, many of the charter school science teachers lacked access to mentors and other teachers, which is an important component of science capital. While many of the studies on science capital have centered on student science capital as a factor that influences participation in science (Archer et al., 2015; Cayton, 2018; DeWitt et al., 2016; Wilson-Lopez et al., 2018), this study focused on the science capital of the science teacher in charter schools as it related to their ability to be a successful teacher.

Limitations

This study had several limitations. These include a relatively small number of participants from a single state that limited sampling and statistical power, as well as possible non-representative perspectives of the self-selected sample. It is important to note that these data were collected at a single point in time during the COVID-19 pandemic, and it is possible that teachers' impressions may have changed over time. Furthermore, the survey and interviews elicited teachers' reported experiences with teaching science in a charter school and have the typical limitations of phenomenological data.

Conclusions and Implications

This study highlights the unique challenges that secondary charter school science teachers face related to laboratory equipment, laboratory safety equipment, school facilities, isolation, and professional development. The study also documented the important role of autonomy as reported by science teachers in charter schools. The survey and interview data from this study, when viewed together, revealed some parallel findings, but the interviews added nuanced perceptions and experiences within charter school science programs. The findings document the current status of secondary charter school science programs with a focus on physical limitations and teacher perceptions. Overall, charter school science teachers reported that they enjoyed their work, felt appreciated, and were able to be flexible in completing their missions, but many reported needing more equipment, better facilities, and more consultation during the planning stages of facility and laboratory design, and science equipment budgets in meeting their unique needs. These findings suggest that charter school science teachers reported using either state or national science standards to develop their science curricula. The results indicate that charter school stakeholders could better support high-quality science instruction by adequately funding science laboratory equipment and safety equipment and engaging science teachers in program and facilities planning. Given today's technologies, collaborations among charter schools could allow for easier partnerships and the development of mutual support systems that would improve their science teachers' experiences. These proposals, taken together, should enhance current and future investments in charter schools. If charter schools are to continue, it is imperative that the schools support the teachers, who are the mainstay of our science programs, with appropriate safety equipment, laboratories, and materials. More research into how charter schools’ administrators make financial decisions for science programs is needed to better inform school planning and administration.

The implications of charter school science programs lacking adequate laboratory equipment, safety equipment, facilities, and professional development for science teachers are becoming greater as the number of students affected increases. As stated earlier, North Carolina currently has 126,000 students attending charter schools (8.4% of the total student population), with this number rising each year. In an era where science is under fire as never before, science education is vitally important as it gives students an opportunity to participate in the scientific method, learn critical thinking skills, and practice these skills in a classroom environment with peers and mentors. And while the charter school student population is still a relatively small percentage of the total student population, the number of students with suboptimal science experiences is growing. Every effort must be made to ensure that all students have the opportunity to experience effective, well-equipped science programs so that our citizens of the future may have the skills available to make decisions on science societal issues.

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SUPPLEMENTAL INFORMATION

Supplement A

Science Laboratory Classroom Facility and Science Instructional Materials Survey

Start of Block: Consent

CONST

Adult Consent Form Title of Study: Charter School Science Programs (eIRB # 20574)

Principal Investigator(s): Pamela Huff, PMHuff@ncsu.edu, 919-612-7606

Funding Source: None

Faculty Point of Contact: Dr. Gail Jones, gail_jones@ncsu.edu, 919-515-8525 ***What are some general things you should know about research studies?*** *You are invited to take part in a research study.* Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate, and to stop participating at any time without penalty. The purpose of this research study is to gain a better understanding of science programs in secondary charter schools. We will do this through completing a brief online survey and an optional interview.

You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those who participate. You may want to participate in this research because it will add to the growing body of research on science programs in secondary charter schools. You may not want to participate in this research because you do not have the time or feel that it is unnecessary.

Specific details about the research in which you are invited to participate are contained below. If you do not understand something in this form, please ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If, at any time, you have questions about your participation in this research, do not hesitate to contact the researcher(s) named above or the NC State IRB office. The IRB office's contact information is listed in the *What if you have questions about your rights as a research participant?* section of this form.

What is the purpose of this study? *The purpose of the study is to investigate current science programs in charter schools. This study will provide important information about laboratory equipment, science spaces, and science instructional practices in charter schools.*

Am I eligible to be a participant in this study? *There will be approximately 50 – 200 participants in this study. In order to be a participant in this study, you must agree to be in the study and be an active science teacher in a charter school. You cannot participate in this study if you do not want to be in the study, if you are younger than 18 years of age, or if you do not teach science in a secondary charter school.*

What will happen if you take part in the study? *If you agree to participate in this study, you will be asked to do all of the following: Take an online survey about the science program in your current school. We expect that the online survey will take 15 - 20 minutes. If you are so inclined, you may volunteer to participate in an optional interview at a later date that will expand upon the topics in the survey. The interview will take about 30-45 minutes and will be audio recorded. Therefore, the total amount of your time for participating is about 20 minutes for the online survey to an hour (including the optional interview at a later date).*

Recording and images *In order to participate in the interview portion of this research study, you must agree to be audio recorded. If you do not agree to be audio recorded, you may not participate in the interview.*

Risks and benefits *There are minimal risks associated with participation in this research. There are no direct benefits to your participation in the research. The indirect benefits are adding to the growing body of research on science programs in charter schools.*

Right to withdraw your participation *You can stop participating in this study at any time for any reason. In order to stop your participation, please contact Pamela Huff, PMHuff@ncsu.edu, 919-612-7606; Dr. Gail Jones, gail_jones@ncsu.edu, 919-515-8525. If you choose to withdraw your consent and to stop participating in this research, you can expect that the researcher(s) will redact your de-identified from their data set, securely destroy your data, and prevent future uses of your de-identified information for research purposes wherever possible. This is possible in some, but not all, cases.*

Confidentiality, personal privacy, and data management *Trust is the foundation of the participant/researcher relationship. Much of that principle of trust is tied to keeping your information private and in the manner that I have described to you in this form. The information that you share with me will be held in confidence to the fullest extent allowed by law.*

Protecting your privacy as related to this research is of utmost importance to me. There are very rare circumstances related to confidentiality, where I may have to share information about you. Your information collected in this research study could be reviewed by representatives of the University, research sponsors, or government *agencies (for example, the FDA) for purposes such as quality control or safety.*

How I manage, protect, and share your data are the principal ways that I protect your personal privacy. Data that will be shared with others about you will be de-identified.

De-identified

*De-identified data is information that at one time could directly identify you, but we have recorded this data so that your identity is separated from the data. We **do not** have a master list with your real name that connects your information to the research data. When the research concludes, there will be no way your real identity will be linked to the data we publish. If you choose to participate in the interview portion of the study, data that will be shared with others about your responses on the survey will be de-identified because we may want to match your answers from the survey with your interview data.*

Compensation *For your participation in this study, you will be eligible to participate in a drawing for **$100.00 gift** cards; one for participating in the survey, and another for participating in the interview. If you withdraw from the study prior to its completion, you will no longer be eligible for the gift card drawing.*

What if you have questions about this study? *If you have questions at any time about the study itself or the procedures implemented in this study, you may contact the researcher, Pamela Huff, PMHuff@ncsu.edu, 919-612-7606; or Dr. Gail Jones, gail_jones@ncsu.edu, 919-515-8525*.

What if you have questions about your rights as a research participant? *If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact the NC State IRB (Institutional Review Board) Office. An IRB office helps participants if they have any issues regarding research activities. You can contact the NC State IRB Office via email at irb-director@ncsu.edu or via phone at (919) 515-8754.*

Consent To Participate *By electronically signing this consent form, I am affirming that I have read and understood the above information. All of the questions that I had about this research have been answered. I have chosen to participate in this study with the understanding that I may stop participating at any time without penalty or loss of benefits to which I am otherwise entitled. I am aware that I may revoke my consent at any time.*

○ I consent to research

○ I DO NOT consent to research

Skip To: End of Block If Adult Consent Form Title of Study: Charter School Science Programs (eIRB # 20574) Principa... = I consent to research

Skip To: End of Survey If Adult Consent Form Title of Study: Charter School Science Programs (eIRB # 20574) Principa... = I DO NOT consent to research

End of Block: Consent

Start of Block: COVID-19

COVID
PLEASE ANSWER THE FOLLOWING QUESTIONS ABOUT YOUR INSTRUCTION PRIOR TO COVID-19.

End of Block: COVID-19

Start of Block: Teacher Background and Licensure

TEACH The following questions ask about your teaching experience, education, and licensure.

Q1 In which state do you currently teach science?

▼ Alabama ... I do not reside in the United States

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*

Q2 How many years have you taught school including the 2019-2020 school year? Please enter each response as a whole number **in each field**. [Zero is an acceptable number]

- ☐ Any subject at the K-12 level ________
- ☐ Science at the K-12 level ________
- ☐ At your current school, any subject ________
- ☐ Science at your current school ________

Q3 In which grade levels do you currently teach science? [Select all that apply]

- ☐ K -5
- ☐ 6 - 8
- ☐ 9 - 12

Q4 What subject do you currently teach? [Select all that apply]

- ☐ General science at the K–12 level
- ☐ Chemistry
- ☐ Physics
- ☐ Earth Science
- ☐ Biology/Life Science
- ☐ Environmental Science
- ☐ Other ____

Q5 Please select the field(s) in which you have earned a bachelor's and/or graduate degree.

- ☐ Education (general or subject specific such as science education)
- ☐ Natural Sciences (for example: biology, chemistry, physics, Earth sciences)
- ☐ Other ____

Q6 If you selected Education in the previous question, please select the type of education bachelor's degree you have earned. [Select all that apply]

- ☐ Elementary Education
- ☐ Middle school science Education
- ☐ Mathematics Education
- ☐ Science Education
- ☐ Other Education ________________________________

Q7 If you selected Natural Sciences or other in question 5, please select the type of science bachelor's degree you have earned. [Select all that apply]

- ☐ Biology/Life Science
- ☐ Chemistry
- ☐ Earth/Space Science
- ☐ Environmental Science/Ecology
- ☐ Physics
- ☐ Other ________________________________

Q8 Select the area(s) in which you are certified (i.e., have a credential, endorsement, or license). [Select all that apply]

- General Science
- Biology/life science
- Chemistry
- Earth/space science
- Ecology/environmental science
- Physics
- Other ____

Q9 If you are not certified, are you currently enrolled in a teaching licensure program?

- Yes. Please explain ____
- No

End of Block: Teacher Background and Licensure

Start of Block: Science Standards and Curriculum

STAND The following questions ask about curriculum development, instructional practices, and science standards use.

Q10 Please choose the standards you use for planning your science instruction. [Select all that apply]

- ☐ Next Generation Science Standards (NGSS)
- ☐ State standards (i.e., North Carolina Essential Science Standards)
- ☐ School standards determined by my administrator
- ☐ None
- ☐ Other ____

Q11 Select the following types of instructional materials you use for your current science instruction. [Select all that apply]

- ☐ Commercially published textbooks (printed or electronic).
- ☐ Supplementary materials (i.e., worksheets, laboratory handouts) that accompany the commercially published textbooks.
- ☐ Commercially published kits/modules (printed or online).
- ☐ State, county, or district developed instructional materials.
- ☐ Online units or courses that students work through at their own pace (e.g., i-Ready, Edgenuity).
- ☐ Lessons or resources from websites that have a subscription fee or per lesson cost (e.g., BrainPOP, Discovery Ed, Teachers Pay Teachers).
- ☐ Lessons or resources from websites that are free (e.g., Khan Academy, PhET)
- ☐ Units or lessons you created (either by yourself or with others).
- ☐ Units or lessons you collected from any other sources (e.g., conferences, journals, colleagues, university or museum partners.
- ☐ Lessons that were handed down by the previous teacher.
- ☐ Materials from my administrator
- ☐ Other ____

Q12 How much control do you have over **each of the following** for science instruction in your classes? Please select an answer for each choice.

	No Control	Moderate Control	Complete Control
Determining course goals and objectives	○	○	○
Selecting curriculum materials such as textbooks/modules	○	○	○
Selecting content, topics, and skills to be taught	○	○	○
Selecting the sequence in which topics are covered	○	○	○
Determining the amount of instructional time to spend on each topic	○	○	○
Selecting teaching techniques	○	○	○
Determining the amount of homework to be assigned	○	○	○
Choosing criteria for grading student performance	○	○	○

End of Block: Science Standards and Curriculum

Start of Block: Science Instruction Spaces and Equipment

SCI INS The following questions are about the science spaces and equipment that you use for science instruction throughout the year.

Q13 Please select the science spaces/resources used for your primary science instruction (i.e., for most of your science instruction).

- ☐ Traditional classroom with no laboratory stations or equipment
- ☐ Traditional classroom with movable lab stations
- ☐ Traditional classroom laboratory
- ☐ Community science partners' space (i.e., Chef's kitchen)
- ☐ Science Museums
- ☐ Planetarium
- ☐ Aquarium/Zoos
- ☐ Outdoor learning labs/ measuring stations
- ☐ Parks – Community, State, National
- ☐ Community garden
- ☐ Nature reserve
- ☐ Other ____

Q14 Please select the spaces/resources that you have used or plan to use for science instruction that are not part of your primary instruction (i.e., used on occasion). [Select all that apply]

- ▢ Traditional classroom with no laboratory stations or equipment
- ▢ Traditional classroom with moveable lab stations
- ▢ Traditional classroom laboratory
- ▢ Community science partners' space (i.e., Chef's kitchen)
- ▢ Science Museums
- ▢ Planetarium
- ▢ Aquarium/Zoos
- ▢ Outdoor learning labs/ measuring stations
- ▢ Parks – Community, State, National
- ▢ Community garden
- ▢ Nature resurve
- ▢ Other ____

Q15 Indicate the availability of **each of the following** for your science instruction. Please select an answer for each item.	Located in your classroom	Available in another room in your school building	Available in another location outside your school building	Not available
Lab tables	○	○	○	○
Electric outlets	○	○	○	○
Faucets and sinks	○	○	○	○
Gas for burners	○	○	○	○
Fume hoods	○	○	○	○
Balances (i.e., Pan triple beam, digital scale)	○	○	○	○
Probes for collecting data (i.e., motion sensors, temperature probes).	○	○	○	○
Thermometers	○	○	○	○
Microscopes	○	○	○	○
Glassware (i.e., beakers, cylinders, Erlenmeyer flasks)	○	○	○	○

Chemicals	○	○	○	○
Disposable materials	○	○	○	○
Meter Stick	○	○	○	○
Stop Watch	○	○	○	○

Q16 Please indicate the availability **of each of the following** safety equipment items for your science instruction. Please choose an answer for each item.

	Located in your classroom	Available in another room in your school building	Available in another location outside your school building	Not available
Safety goggles	○	○	○	○
Gloves	○	○	○	○
Aprons or lab coats	○	○	○	○
Eye Wash Station	○	○	○	○
Shower	○	○	○	○
Spill Control Station	○	○	○	○
First aid kit	○	○	○	○
Fire extinguisher	○	○	○	○

End of Block: Science Instruction Spaces and Equipment

Start of Block: Science instructional strategies and miscellaneous

Q17 Select the instructional strategies you use to teach science during the year. [Select all that apply]

- ▢ Explaining a science idea to the whole class
- ▢ Conducting demonstrations while students watch
- ▢ Whole class discussion
- ▢ Students working in small groups
- ▢ Students completing textbook/worksheet problems
- ▢ Students doing hands-on/laboratory activities
- ▢ Students reading about science
- ▢ Students writing about science (do not include students taking notes)
- ▢ Practicing for standardized tests
- ▢ Test or quiz
- ▢ Field trips
- ▢ Project-based learning
- ▢ Online-laboratory exercises
- ▢ Other ____

Q18 Select the science-related extracurricular activities your school offers for students. [Select all that apply]

- ☐ Science Fairs
- ☐ Science Olympiad
- ☐ Science Clubs
- ☐ Other ____

Q19 Select the Advanced Placement (AP) courses your school offers. [Select all that apply]

- ☐ Chemistry
- ☐ Physics 1
- ☐ Physics 2
- ☐ Physics C: Electricity and Magnetism
- ☐ Physics C: Mechanics
- ☐ Biology
- ☐ Environmental science
- ☐ None

Q20 Do you have to schedule the use of science equipment and science space in your school?

☐ Yes. Please elaborate. ____

☐ No

Q21 Do you have to share science laboratory space in your school?

○ Yes. Please elaborate. ____

○ No

Q22 Do you have to share science equipment with other teachers in your school?

○ Yes. How many teachers? ____

○ No

End of Block: Science instructional strategies and miscellaneous

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Start of Block: School Characteristics

SCH The following questions ask about your specific charter school. Please answer the questions to the best of your ability.

Q23 Approximately, how many students are in your school?

____

Q24 How many students (on average) are in your science classes?

____

Q25 How many science teachers do you have in your school?

____

Q26 What entity authorized your school's charter?

- ○ Local school district
- ○ School board of education
- ○ Postsecondary institution
- ○ State charter-granting agency
- ○ Independent charter board
- ○ Other ____

Q27 How would you classify your current school setting?

- ○ Rural
- ○ Urban
- ○ Suburban

Q28 Is your school housed in a building that was constructed as a charter school or is it housed in a building built for other purposes (i.e., church)? [Please select one]

- ☐ A building constructed as a charter school
- ☐ A building built for other purposes

Q29 If your school is housed in a building built for other purposes, which of the following best describes the building?

- ☐ Private school
- ☐ Public school
- ☐ Shopping Mall
- ☐ Church
- ☐ Home
- ☐ Other building type. Please explain.

____

Q30 Which one of the following best describes your charter school's primary focus in terms of program content?

- ☐ Comprehensive curriculum with no specialized area of focus.
- ☐ Special curricular focus (e.g., the arts, math/science, foreign language immersion).
- ☐ Curriculum based is based on a particular education educational philosophy (e.g., Montessori, open school).
- ☐ Curriculum based on a particular philosophy or set of values (e.g., Eastern philosophy, religion).
- ☐ Other ____

Q31 Which one of the following best describes the type of oversite entity running your school?

- ☐ **Independent** - A school that is run independently of a management company and the non-profit oversight-board typically consists of local community residents (i.e., Raleigh Charter, and Exploris schools in Raleigh, NC).
- ☐ **Charter Management Organization (CMO)** - a non-profit entity that manages two or more charter schools that are often part of the same network (i.e., Kipp, Cosmos Foundation).
- ☐ **Education Management Organization (EMO)** - a private, for-profit entity that manages two or more schools that are often part of the same network (i.e., Edison Learning, National Heritage Academies, or Mosaica Education).
- ☐ Other ____

End of Block: School Characteristics

Start of Block: Demographics

DEMO Please answer the following demographic questions.

Q32 Gender

- ◯ Female
- ◯ Male
- ◯ Non-binary
- ◯ Other

Q33 Are you of Hispanic or Latino origin?

- ◯ Yes
- ◯ No

Q34 What is your race? **Select all that apply.**

- ◯ American Indian or Alaskan Native
- ◯ Asian
- ◯ Black or African American
- ◯ Native Hawaiian or Other Pacific Islander
- ◯ White

Q35 Please select your age range.

- ○ 18-25
- ○ 26-36
- ○ 37-47
- ○ 48-58
- ○ 60+

End of Block: Demographics

Start of Block: Open Ended Question

OP The next three questions are open-ended so that you may add your personal opinions and experiences.

OP1 As a science teacher working in a charter school, do you think you have unique instructional opportunities not available to science teachers in traditional schools? If yes, what? Please give one or more examples.

____

____

____

____

____

OP2 As a science teacher teaching science in a charter school, do you face unique challenges compared to science teachers in a traditional school? If yes, please explain. Please give one or more examples.

____

OP3 Do you think that the quality of science teaching in your school is better, the same, not as good as in a traditional school? Please explain.

End of Block: Open Ended Question

Start of Block: End of Survey

End This is the end of the survey. Thank you for your time and participation. By completing this survey you are eligible to win a **$100 Amazon gift card** in a random drawing by providing your contact information. Please click on this link or go to the URL below to add your contact information for the gift card drawing. https://forms.gle/uzzdYa1umW6uEtVQ8

We would like to interview a subset of teachers in order to better understand the unique opportunities and challenges of teaching science in a charter school. If you would be willing to participate in a phone or online interview, please provide your contact information by clicking on the google form link below. I will email you to schedule an interview. By participating in the interview, you will be eligible for an additional $100 Amazon gift card in a random drawing. Please click on this link or go to the URL below to add your contact information for the **virtual interview**. https://forms.gle/FnZZaE23bPbexUEKA

End of Block: End of Survey

Supplement B

Charter School Teachers Interview Protocol

Demographics
Gender
Race
Age

Teaching Experience
Years of teaching experience
Science subjects taught

Certification and Education
Licensure areas
Certification

School Characteristics

Number of students in the school

Rural/Suburban/Urban

Grade levels

Total number of teachers in the school

Total number of science teachers in the school

Number of teachers teaching your subject

Free and reduced lunch program student #'s

1. Would you discuss your decision to each science in your current charter school?

a. Why do you think your charter was created? Implicit reasons your charter school was formed.

b. Does your school administrator value science education?

2. Do you teach science in a classroom with specialized science equipment or furniture?

a. If yes, do you have any of the following items: Science tables, laboratory bench, microscope, fume hood, glassware, chemicals, scales or balance, sink, Busen burner, other...

a. Is it large enough to accommodate all of your students during a typical instructional period?

b. Is it well-equipped for science experiments?

4. Do you have any of the following safety equipment in your science classroom? Sink
Eyewash station
Shower
Gloves
Goggles
Lab aprons
First aid kit
Fire extinguisher

Fire blanket
Other:

a. If you are not using a specific curriculum or guide, how do you know what is important to teach?

b. Do you meet with other science teachers as a team to set the curriculum for the year?

i. If yes, do you meet with this team on a regular basis through the year?
What is the goal for the team?

c. How do you address inquiry-based learning?

6. Please describe your typical science class by providing the following information:

a. How many students are in your class?

b. Do you teach in a block or standard schedule?

c. Do you have parents who come in and help? How many?

d. Are the students in your class homogeneous or heterogeneous in terms of their learning ability?

e. Tell me about the diversity of the class

7. What is your overarching goal for teaching science?

a. Have you achieved your goal?

8. What do you think are the advantages of teaching science at a public charter school versus a traditional public school?

a. What are the disadvantages?

b. What would you change?

9. What aspects of teaching science is unique to a charter school?

a. Can this uniqueness be found in any other school context?

b. Does your science program offer students a unique path to further science-related higher education or career opportunities?

c. Do charter schools offer any different resources than a traditional public school?

10. Do you take your students on field trips to science museums or other science centers?

11. Do you students participate in science internships?

12. As a class, do your students participate in any science related research in the community?

13. Do your students participate in Science Olympiad or other science-related clubs or activities outside of school?

14. On a scale from 1-10 with one being the lowest and ten being the highest, please rate your school's science program.

15. Please tell me about the PD opportunities you have as a charter school science teacher.

a. Do you feel as though there are adequate opportunities for PD?

COVID-19 specific questions

16. In the online environment do you do labs or investigations?

a. Where do you find the lab lessons?

b. How do you do labs in the online environment?

i. What are the equipment needs?

ii. Do you use materials found at home?

iii. Do you send materials home?

iv. Do you suggest a materials list for parents?

c. Are you doing paper labs? Virtual labs?

i. Do you have students watch "live la instructions from universities or other science school sources?

ii. Does the school provide resources such as Flinn labs, Phet, Gizmos, online labs?

iii. Please provide a description of the labs.

iv. How are issues of safety handled in the online labs?

1. 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?

v. Do you feel like teaching remotely limits the amount of inquiry you can do?

d. Do you feel like you have been able to engage your students in inquiry?

i. Are there lessons you will not get to teach due to Covid-19 restrictions?

ii. Are there science extracurricular activities that your students normally participate in that they can no longer do because of this Covid-19 environment?

e. Are there examples where you had to be creative or innovative in your instruction? Please explain.

i. What challenges do you face with technology?
Institutional changes? New digital systems?

17. Are parents of students involved in science instruction?

a. If so, how has this changed since the change to all virtual learning?

18. Have you had professional development (PD) opportunities for teaching with virtual science instruction?

i. Who provided the PD?

ii. How long was the training? Days, hours?

iii. What new ideas did you get from the COVID-19 PD for remote learning?

iv. What do you wish you had been able to get that you did not get during the PD?

19. If an outside organization could provide assistance with remote science learning, what would you like to have?
In materials?

In assistance?
In other support?

20. How confident do you feel that you have the tools and technology to teach online effectively?

21. Do you feel you have suffered from any negative experiences as a result of the Covid-19 pandemic?

22. Is there anything you would like to add?

Secondary Science Teachers in Charter Schools: Unique Challenges of Teaching During the COVID-19 Pandemic

Huff, P., & Jones, M. G. (2021). Secondary science teachers in charter schools: unique challenges of teaching during the COVID-19 pandemic. *International Journal on Innovations in Online Education*, *5*(4).

Abstract

The COVID-19 pandemic restrictions presented teachers, students, and parents with unique challenges that were met with varying degrees of creativity, flexibility, and stamina that 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.

Keywords: science education, charter schools, COVID-19 pandemic

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) virus. 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?

Background Context

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.

Online Education

Distance education is defined as an institution-based, formal education where the learning group is remote and where 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 a., 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., 2012), 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).

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, evaluation, and communicating information.

Theoretical Framework

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.

Methods

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.

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 interviews 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.

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.

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% 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 500-1000 students. The class size ranged from 10-30, 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.

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 to 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.

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 software program (QDA), 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.

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 to have them watch demonstrations from the teacher either live or video); at home laboratory assignments/activities (whether to send laboratory activity materials home or whether to send 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 (EOG) testing for eighth-grade students); and general (a general lack of professional community).

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.

Instructional Approaches

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 AP 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."

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 while 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.

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."

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.

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].”

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 stated, 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.”

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.

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.”

Constraints

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

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.

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]."

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 teacher indicated that they were moderately confident, and six (29%) of the teachers indicated that they were very confident.

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 that they 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.

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.

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."

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 lab 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.

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).

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., 2020; 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).

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 COVIDS-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.

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., 2020).

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.

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 systems, 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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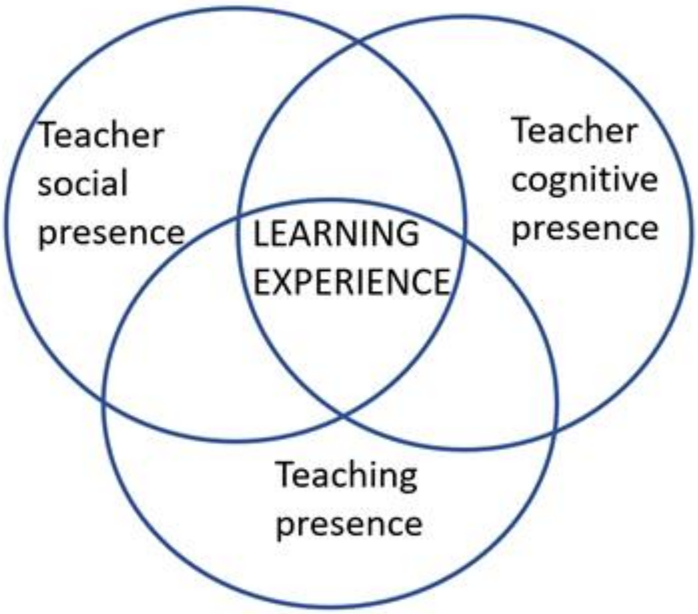
Figure 1

Community of Inquiry Framework



Note. Community of Inquiry framework adapted from the Community of Inquiry model by Anderson et al. (2000).

Table 1

Teacher Demographics

Participants	*n*	%
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.

Table 3

Interview Themes, Coding Categories and Examples

Theme - Research Question	Examples
Instructional approaches - Research Question 1 **Coding Categories**	
1) Virtual labs	"[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 labs/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) Home materials	"I did ask students to find materials they have at home. For example, I did one with cups and M&M's.
3b) Sent materials	"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 lab (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."

Table 3 (continued)

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 labs	"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) 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 WIFI] … 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 WIFI]."
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."

Table 3 (continued)

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
Stressors - Research Question 3 Coding Categories	

Table 3 (continued)

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) Testing	“[Eight grade End of Grade] I wish we could focus on what's most important, like giving these kids the support that they need.”
3) General	“The whole view of science right now has been a struggle with questioning my profession.”
4) 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.

SUPPLEMENTAL INFORMATION

Supplement A

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 do 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 with 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?

Conclusions

This chapter summarizes the key research findings in relation to the research aims and questions and discusses the value and contribution of each. It also reviews the limitations of the study and proposes opportunities for future research.

This study was divided into two parts. Part 1 investigated charter school science teachers' access to and availability of laboratory equipment, safety equipment; the types of school facilities being used; the science standards used for curriculum development; the extent to which teachers have autonomy over instruction and planning. Part 2 assessed the teaching strategies, constraints, and stressors during the COVID-19 pandemic. Three sociocultural theoretical frameworks bound this study. The first was Vygotsky's Activity Theory, through which the activity of teaching science was mediated via the use of tools (equipment, language, facility) as a goal for charter school science programs with the outcome of effective science teaching. The second, Archer et al., Science Capital, complemented Activity Theory through the specification of science tools as science capital for teachers. The third, Anderson's Community of Inquiry, framed Part 2 of the study within an online context where teachers used the meditation tools of science language and online instructional strategies for science lessons. The overall study design was to address the mediating tools of science teachers in charter schools and their direct influence on effective science teaching in both the face-to-face environment and the emergency remote teaching environment.

The research outlined in this dissertation answered the eight research questions, which were aimed at determining the availability of tools for effective science teaching in charter schools during face-to face instruction as well as during emergency remote teaching as it relates to effective science teaching.

Part 1 Research Questions and Findings

1) What Laboratory Equipment is Available to science teachers in charter schools?

Based on the Activity Theory (Vygotsky, 1978) and Science capital framework (Archer et al., 2015), science tools in the form of laboratory equipment were evaluated with the following findings. While high school and middle school teachers reported having access to a wide range of laboratory equipment, they often lacked access to basic laboratory equipment such as lab tables, sinks, and balances. Based on available data from traditional public schools, these deficiencies likely limit effective science teaching in charter schools (Hellman et al.,1986; Pekdağ, 2020). The ultimate aim of science programs is to provide students with experiences and information that lead to grade-level scientific literacy, and without the proper tools, science teachers may not be as effective.

2) What Laboratory Safety Equipment is Available?

Science tools in the form of safety laboratory equipment were evaluated in this study with the following findings. A large number of teachers lacked safety items, including spill control, showers, eyewash stations, and fire extinguishers. These are usually considered essential to conducting safe laboratory experiments, and their absence puts everyone at risk and is a medical and legal liability (Richmond, 2000). The risks include serious injuries, such as eye damage if there are no eyewash stations, chemical burns without access to chemical showers, and burns from fires if there are no fire extinguishers. The lack of safety equipment caused science teachers to struggle to teach the content while maintaining a safe environment, and it also inhibited the types of experiments that teachers could explore with their students.

3) What Types of Facilities are Used for Science Instruction?

Science tools in the form of spaces where science is taught were evaluated with the following findings. A number of the teachers reported using repurposed and other buildings that were inadequate spaces for science teaching from the teachers' perspectives. To adapt to these limitations, teachers reported often holding classes outside or in other facilities. But the lack of laboratory space reported by the teachers in the study could seriously limit the opportunity to learn laboratory skills. As others have reported (Ainley, 1981; Englehardt, 1968), teachers' access to good facilities is key to fostering inquiry. Adequate science teaching facilities have been shown to impact teacher and student outcomes and teacher recruitment and retention (Moore & Lackney, 1993; Tanner, 2000; Cheryan et al., 2014). Earthman (1998) states that a common belief held by educators and architects is that the building does indeed have an influence on how well students and teachers perform.

4) What are the Guiding Science Standards Used for Curriculum Development?

Science standards were explored within the frameworks of Activity theory and Science capital with the following findings. The combined survey and interview data showed that all science programs reported here used state or national science standards for their curriculum development. This was surprising as charter schools are not required to use science standards in the implemented curriculum (Wixom, 2018).

According to Bybee (2014), the "fundamental idea behind science education standards is to describe clear, consistent, and comprehensive science content and abilities. Then, based on the standards, to reform essential components of the science education system – programs for school science, teaching practices, and assessments at local, state, and national levels" (p. 212). Additionally, studies by Lewis et al. (2019) indicated that the use of *Next Generation Science Standards* (NGSS) practices in science teachers' lessons increased their use of inquiry-based instruction, which led to growth as an effective science teacher. NGSS and state science standards also stress skills, such as communication, collaboration, inquiry, problem-solving, and flexibility, which work together to give students a comprehensive understanding of science, enhance student science skills and support best practices in science education (North Carolina Department of Public Instruction, 2018; National Research Council, 2012).

5) What are Charter School Science Teachers' Perceptions of Autonomy?

An overwhelming majority of the teachers in this study reported extensive autonomy to tailor their approaches to students as a major area of importance and was the primary advantage of teaching in a charter school. Teachers described their control over what, when, and how they taught and a sense of being respected as professionals as critical to them. In terms of implications, teacher autonomy is known to be important for job satisfaction, teacher retention, and quality of life, and may impact the quality of student learning through effective science teaching (Malloy & Wohlsetter, 2003; Ableidinger & Hassel, 2010; Guranious, 2017).

Part 2 Research Questions and Findings

1) What Were Charter School Science Teachers' Instructional Approaches to Online Science Instruction During the COVID-19 Pandemic?

The science tools of language and equipment were evaluated with the following findings. Many teachers chose not to send materials home for science investigations for teacher-led demonstrations, however, many teachers sent a materials list to parents for students who wanted to follow along. Many teachers indicated that while they tried to develop ways to do hands-on labs and investigations at home, the logistics and lack of materials made it almost impossible. Therefore, most science teachers used teacher-led demonstrations that incorporated group work along with the demonstrations to secure students' engagement and communication with one another. While inquiry was reportedly limited by the majority of teachers, all teachers used creative and instructional strategies as a means to facilitate as much inquiry as possible. These instructional strategies included: revising all lesson plans, virtual labs, and demonstrations; employing new technology; reorganizing of classroom structure (group work); and altering expectations from student assignments. Teacher presence during online demonstrations was critical, as was the use of science tools for instruction as a means for effective science teaching.

2) What Were the Teaching Constraints of Online Learning in Charter School Science Programs During the COVID-19 Pandemic?

An examination of the constraints of teaching remotely found the following. Teachers were faced with a myriad of constraints during online teaching that made teaching science difficult but not impossible. The major constraint was technology issues that ranged from lack of connectivity and bandwidth to lack of equipment such as computers and tablets, all of which contributed to inequity among students. Other constraints included: inadequate professional development for online instruction; lack of administration guidance; missed science lessons resulting in less science for students; lack of science materials for at-home demonstrations; lack of student engagement; and lack of connection with a community of peers. Some science tools used for online science instruction were different from face-to-face tools, such as traditional laboratory and safety equipment, but the tools of science language used for instructional communication, instructional planning, and implementation were the same. Effective science teaching was challenged during the extreme conditions of online teaching but prevailed nevertheless through the innovation and creativity of teachers with autonomy.

3) What Stressors did Science Teachers Experience While Implementing Online Learning During the COVID-19 Pandemic?

Teachers reported stress from many sources and experienced work-life issues as a result of having to teach remotely. Mental health issues due to the stress of an overwhelming workload that required teachers to transition quickly to online learning were very prevalent. Teachers spent up to sixty hours a week teaching online and working on lesson plans as they adapted to online teaching. Science tools were used while teaching and planning regardless of the fatigue and stress of the job as they worked towards effective science teaching.

Relevance and Implications for the Field

As the school choice movement continues to grow, charter schools will increase in number across the United States, presenting educators and stakeholders with the opportunity to optimize student learning in general but also in science. The discipline of science necessitates unique space and equipment requirements, which entail larger budgets compared to other disciplines. As such, particular attention must be paid to school facilities and equipment in K-12 schools. One approach to optimizing science programs is by investing wisely in science resources via collaborations with school science teachers who are responsible for effective science teaching. Such an alliance gives science teachers a voice in the critical decisions regarding facilities, equipment, and safety equipment.

Additionally, science teachers indicated that they used creative and innovative methods to overcome the deficiencies mentioned above, especially in response to the change to remote learning during the COVID-19 pandemic. However, factors such as teacher autonomy and flexibility in the classroom were major advantages that tended to offset deficiencies in the science programs.

While charter schools currently make up only a small portion of public schools, they will become increasingly relevant as more students and teachers transition to charter schools with possible suboptimal science education programs. Ultimately, science teachers in charter school programs significantly impact the science literacy of their students. Considering the need for a scientifically literate citizenry capable of driving local and national policy, dispelling scientific misinformation, and using critical thinking skills, strong K-12 science education programs with effective science teaching are critically needed. Addressing deficiencies in facilities, laboratory equipment, safety equipment, and preparations for emergency online teaching could improve secondary charter school science programs. Also, although the COVID-19 (Part 2) study was a description of a certain event and time, these findings may have a larger and more generalizable set of implications on science education after the pandemic ends. For example, it is feasible that teachers will incorporate many of the teaching strategies that were developed for online learning into their face-to-face lessons because of their efficiency and efficacy. Also, newly found online resources may be incorporated to enhance science lessons. Increasingly, technology can be upgraded and monitored on a continuous basis so as not to be unprepared when a weather emergency or another public health disaster strikes that necessitate remote online learning. And finally, a degree of teacher autonomy should be considered essential for all science teachers.

Limitations

The limitations of the study included: a relatively small number of participants; a self-selected sample that may not be representative of charter school science or other teachers more broadly; and that it was a qualitative study designed to gain insight into a sample of charter school science teachers' experiences at a single point in time during COVID-19 and impressions may have changed over time.

Further Discussion and Research Possibilities

Currently, we have a dual public education system in which traditional school science teachers have access to adequate laboratories, safety equipment, materials, and peer support, along with another system of charter school teachers who, in many cases, lack these resources for instruction. As such, one could ponder the implications of this both financially and socially. Specifically, does it make sense to have school buildings with no laboratory classrooms and buildings with laboratory classrooms within the same school district? For instance, within miles of each other, one rural public high school has almost empty halls due to the migration of students from traditional schools to charter schools. Would society be better served if the traditional space that was built with public funds was used instead of sitting virtually empty or if some of the attributes of charter schools could be woven into traditional public-school designs? These dual school systems raise questions about the issues driving the creation of the concurrent systems and whether an improved outcome can be achieved within a single system that incorporates the advantages of each, allowing adequate equipment, facilities, and teacher support as well as more instructional autonomy and flexibility?

Charter schools, as viewed from different perspectives, may serve many educational goals. For example, from a parent's perspective, such as mine, the opportunity to enroll my son in a public charter school that focused on the whole child through project-based learning activities, group projects, out-of-school experiences, as well as inclusivity for students with individual educational plans, was unparalleled in our community. Without charter schools as an option, I would have resorted to homeschooling, which would not have served my son or me well. The charter school option allowed my son to experience learning by using his innate assets instead of trying to learn in an environment not well-suited for his abilities. From a teacher's perspective, it is clear from my study results that teachers greatly value autonomy and relate it to how they are viewed professionally by their administrators. One could speculate that teacher autonomy could lead to more teacher retention and, from that, a more stable school environment and improved student learning. If this is the case, then could traditional school teachers also benefit from more instructional autonomy and flexibility? Within the current traditional school paradigm, however, would giving teachers more autonomy and flexibility alter other factors in the school ethos that could have additional unanticipated positive or possibly negative impacts?

Further research examining specific components of charter schools, such as teacher autonomy and flexibility, and how these might be better incorporated into traditional schools could inform and improve public education. Studying such changes in traditional schools is needed to improve public school teacher retention, parent support, and, ultimately, student learning.

It is clear that charter schools are expensive to implement, duplicate many of the resources of traditional public schools, and reduce student enrollment in traditional schools. At the same time, there is growing evidence, including that given by the teachers interviewed in this study, that charter schools provide flexibility and support that are highly valued by teachers and by parents who drive the charter school development process. From a policy perspective, we need to understand the motivations and needs of all the education stakeholders to minimize duplication of educational systems and better meet the needs of our children and their families.

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