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Rural High School Chemistry Teachers' Perceptions and Implementation of Inquiry-Based

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The foundation of inquiry-based instruction is constructivism; students must *do* science to understand it. Instruction using inquiry has been written into the Next Generation Science Standards along with many state standards, like the Georgia Standards of Excellence (GSE). Teaching inquiry within a rural public high school chemistry setting has its own set of challenges unique to the rural context. Research is needed to give those educators a voice regarding teaching inquiry. This study utilized a mixed-methods design of survey and interviews to allow these rural public high school chemistry teachers a platform to discuss the feasibility of teaching standards through inquiry, planning, and professional development required to teach an inquiry-based unit, including laboratory activities. Almost two-thirds of Georgia's rural public high schools had at least one participant who completed the survey. The survey data showed that most participants used inquiry in their classrooms in some form, but desired more time and resources to implement inquiry-based instruction. Methods used to integrate inquiry in the classroom and lab varied, as expected. Many interview participants seemed to perceive students planning and carrying out investigations as reserved for wet labs. Interview data also emphasized how much time and personal funds teachers spend on their classrooms for labs and professional development. A desire for chemistry-specific professional development resonated among survey and interview participants. The findings brought forth in this dissertation can be used to inform policies regarding professional development and continued support for rural public high school teachers.

Keywords: **inquiry-based instruction, chemistry education, next generation science, social cognitive theory, rural education**

The discussion, practice, and development of curricular standards is a relatively new phenomenon that has gained traction in the past fifty years (The National Commission on Excellence in Education [NCEE], 1983). As of 2023, all 50 states have science standards; six developed their own, 20 adopted NGSS, and 24 created standards based on NGSS (NSTA, 2014). The Next Generation Science Standards (NGSS) are the most recent push toward STEM education that shifted from content-heavy standards to inquiry-based standards. In this study, inquiry is defined, based on the description throughout the *Framework* (National Resource Council [NRC], 2012), as instruction and activities that include students planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; and proposing answers, explanations, and predictions. This curricular shift requires designing and implementing laboratory experiences that include inquiry as stressed within the NGSS.

Statement of the Problem:

The shift toward inquiry requires professional development (PD), monetary resources, and planning time. Rural life has its own set of challenges (Corbett & Gereluk, 2020): lower education levels of parents of rural children when compared with nonrural parents (Byun et al., 2015); fewer high-paying careers in rural areas (Thiede et al., 2018); brain drain, or a departure of talented youth leaving rural areas for more opportunities in metropolitan ones (Carr & Kefalas, 2009); and higher rates of overall poverty, concentrated poverty, and poverty that persists through generations (Brown & Schafft, 2011; Schaefer et al., 2016). Teaching a course that is resource-heavy in a school that is small, rural, or a combination of the two can be particularly challenging due to less funding available to schools in rural areas than non-rural ones (Lichter et al., 2012). Additional issues that rural public chemistry educators face, especially at smaller schools, are loss of dedicated planning time due to multiple course preparations (Goodpaster, et al., 2012), isolation from others with specific content matter expertise and experience (Burton et al., 2013; Flinders, 1988; Hanushek, et al., 2005; Rockoff, 2004;), and inequitable funding due to the majority of rural areas that are socioeconomically depressed (Showalter et al., 2023). A lack of planning time, feeling of professional isolation, and inadequate funding would be particularly detrimental to a teacher of a course, such as chemistry, that requires resources, equipment, or time to adequately teach. The present study aims to highlight the voices of chemistry teachers who are implementing inquiry-based science teaching within their rural public high school classrooms to determine whether the issues of loss of planning time, professional isolation, and inequitable funding are pervasive or benign.

Literature Review

Application of NGSS to High School Chemistry

This study focuses on the laboratory practices within the NGSS in a high school chemistry class, which can be grouped into the categories as shown in Table 1 (McNeill et al., 2015; NRC, 2012, p. 42). The Science Georgia Standards of Excellence (GSE), include three practices embedded within 14 of 36 elements of the six main standards for high school chemistry: investigating, sensemaking, and critiquing (Georgia Department of Education [GaDOE], 2016). Even though Georgia was one of the lead partners in developing the NGSS (NGSS Lead States, 2013), it is one of many states that chose to develop its own set of standards rather than to implement the NGSS (NSTA, 2014). Both the NGSS and the GSE are officially based on and informed by the *Benchmarks for Science Literacy* and the *Framework* (GaDOE, 2016).

Table 1

NGSS Science Practices

	Science Practices	
Investigating Practices	Sensemaking Practices	Critiquing Practices
Asking questions	Developing and using models	Engaging in an argument from evidence
Planning and carrying out investigations (PCOI)	Analyzing and interpreting data	Obtaining, evaluating, and communicating information
Using mathematical and computational thinking	Constructing explanations	

The science practice emphasized in this study will be "planning and carrying out investigations" (PCOI). PCOI is the crux of performing laboratory experiments, as anything less is simply following a set of prescribed instructions and getting an expected outcome. Students involved in genuine inquiry in the form of PCOI will employ the autonomy and analysis that could move to a higher level in Bloom's Taxonomy. Therefore, as students will be planning and carrying out investigations, resources and inquiry-based learning (IBL) are required. The Instructional Leadership for Science Practices (ISLP) has a rubric for evaluating teachers that contains the eight practices; the portion containing PCOI is shown in Table 2 (McNeill et al., 2015).

Table 2

Science Practices Continuum – Students' Performance

	NGSS Practice
Level	Planning and Carrying Out Investigations (PCOI)
1	Students do not design or conduct investigations
2	Students conduct investigations, but these opportunities are typically teacher-driven. Students do not make decisions about experimental variables or investigational methods (e.g., number of trials).
3	Students design or conduct investigations to gather data. Students make decisions about experimental variables or investigational method (e.g., number of trials)

4	Students design and conduct investigations to gather data. Students make decisions about experimental variables or investigational method (e.g., number of trials)

Note: Only the Investigative Practices listed for PCOI are included in this table

Considerations with changing standards

In Georgia, many of the demands of having students' PCOI were not required as part of the previous standards, the Georgia Performance Standards (GPS), which were developed in 2006 on the heels of the 2002 legislation, No Child Left Behind (NCLB), and focused almost exclusively on content readily tested. NCLB increased federal oversight in holding schools accountable primarily using test scores, while high schools also included graduation rate; each state retained control of its own testing, with science testing mandated in 2007 (Moore, 2005). NCLB also required schools to have “highly qualified” teachers in place; a demand that small, under-resourced rural schools had difficulty meeting (Eppley, 2009; Tieken, 2014; Tieken & San Antonio, 2016). The shift from GPS to GSE meant that teachers were to have students involved in actually *doing* science through PCOI (GaDOE, 2018). While IBL, such as PCOI, has been documented to be one of the best methods for teaching science to students, there may be teachers who have spent years developing practices with little attention to IBL (NRC, 2012). A continuum may be the best way to view IBL in the classroom to show that there are multiple methods of implementation in the classroom (Capps et al., 2012; Cullen, 2015).

Table 3

Inquiry Continuum

Essential Feature	More ß-------------Amount of Learner Self-Direction --------------> Less Less ß----Amount of Direction: Teacher or Material Variations-->More			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source

2. Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner give data and told how to analyze
3. Learner formulates explanation(s) from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence and how to use evidence to formulate explanation
4. Learner connects explanation(s) to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	Learner given all connections*
5. Learner communicates and justifies explanation(s)	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use to sharpen communication	Learner given steps and procedures for communication

**Statement not in original document. Adapted from page 29 of NRC (2000).*

Types of Inquiry

The inquiry continuum includes five essential features within variations of student autonomy, as shown in Table 3. The most self-directed version has the learner communicating and justifying explanations as opposed to the teacher giving the learner steps and procedures for communication (NRC, 2000, p. 29). Banchi and Bell (2008) agree and identified four levels of inquiry: confirmation, structured, guided, and open. Students become more self-directed the closer they get to open inquiry. While students are responsible for research, the teacher acts as the facilitator, asking probing questions to spark curiosity among the learners.

Facilitating Inquiry

This curiosity can be fostered in students using virtual representations or models, thus facilitating inquiry (Davenport et al., 2018; Donnelly et al., 2013; Winberg & Berg, 2007; Yaron et al., 2010). Students have been shown to increase learning through inquiry and problem solving, as well as PCOI, in most computer simulations, but must work within the confines of the programming (Davenport et al., 2018). Virtual presentation of inquiry activities requires technology, which may be a barrier to some schools, particularly in a rural context. There are several reasons why virtual labs could be beneficial to rural schools: lack of resources/funding creates the need to find alternatives, simulations allow for less resource-intensive labs, can perform more dangerous labs virtually, and virtual labs allow for more trial and error. Even cheaper, less resource-heavy labs take time to purchase, set up, and break down. The benefits of virtual lab simulation do not matter if the technology is not in place or updated to be able to make use of these opportunities: computers, bandwidth/Internet, and possibly subscription services for the simulation. In this way, funding is needed for both resources for labs as well as for technology for virtual labs.

Another barrier to some rural chemistry classrooms is that textbooks are too old, or, more specifically, laboratory activities provided within those textbooks do not use IBL. One school’s chemistry textbook, copyrighted in 2002, contained labs and hands-on activities, but only one lab had any element of PCOI or inquiry in it (Davis, 2002). The remainder of them were “cookbook” labs: laboratory activities with very prescribed procedures where all students should get the same results by properly following the procedure. Students completing the same procedures and getting the same results takes away any semblance of inquiry or autonomy students may have in constructing their understanding of the phenomena. A survey of 571 teachers found that 55% taught at least three inquiry labs per semester where students designed the procedure (Deters, 2006). Even that does not fully satisfy having at least a minimum amount of inquiry or PCOI required for the standards and elements in NGSS or GSE, since seven elements within the GSE explicitly state that students are to PCOI. In Georgia, chemistry is not a required course and, therefore, does not have a state-wide assessment; assessments administered in chemistry are at the district or school level, and most do not require inquiry. Courses that are not required are usually accompanied by a lack of guidance. While this does allow for teacher autonomy, it also means that the way the courses are taught, regarding inquiry and PCOI, can vary widely. Incorporating IBL into chemistry curricula could reduce the variance in how the course is taught, but it requires time outside of the classroom, even for experienced teachers. Leaders in education must respect this and make sure that teachers know how the program or innovation will fulfill the tasks they are trying to accomplish (Arnett, 2018).

Rurality

The National Center for Education Statistics (NCES) breaks down the “rural” designation down into the following three categories for funding under the Rural Education Achievement Program (REAP): 41 – Rural, Fringe, 42 – Rural, Distant, and 43 – Rural, Remote. These categories are defined by their distance from urban areas (Geverdt, 2015). Schools that are farther away from urban areas have trouble finding teachers, which is exasperated by a trend in gifted education to try to set the sights of motivated students toward getting out of the rural area they grew up in and to pursue careers elsewhere, or “brain drain” (Howley, 2009; Howley et al., 2009; Lawrence, 2009). Additional research has shown that rural students are at a distinct disadvantage because of the lack of proximity to corporations and large events that attract talent. Combine this with the brain drain (Carr & Kefalas, 2009) and the documented results that show teachers in rural areas teach more course preparations (Zost, 2010), have less specialized education (Cady & Rearden, 2009), and earn less money that their urban or suburban counterparts, and what remains may be a recipe for a diminished education on the part of the rural student (Deck, 2001; Rakes et al., 2006). Schafft (2016, p. 150) states that it is “unclear how effectively schools are educating students.” This is supported by rural students who do continue to higher education being more likely to experience discontinuous enrollment or delay entry than non-rural students (Byun et al., 2015).

Assets of Rurality

While the present study does bring to light many issues associated with teaching in rural areas, it is important to keep in mind that many teachers have taught in rural areas for several years and may continue to do so. This may be in large part due to the rural cultural wealth (Crumb et al., 2023) present in many of these communities. Classifying rural areas as a homogenous mixture would be an overreach and does not do justice to the similarities and differences between communities and cultures in those areas (Flora et al., 2018). Showalter (2019) estimates that almost one in five students in America attends a rural school. When compared with urban students, rural students graduate from high school at higher rates (Dahill-Brown & Jochim, 2018). Teachers in rural areas can leverage this rural cultural wealth by building upon the social and cultural capital available, which can lead to student improvement in both educational achievement and attainment (Chambers & Crumb, 2020; Means et al.,2016).

Theoretical Framework

Constructivist theory holds that knowledge is not transmitted from the teacher to the learner in the same form but is constructed through active learning by the learner (Wheatley, 1991). As far as it relates to the cognitive capacity to learn and pedagogy, constructivism has its foundation in the works of Piaget, Bruner, von Glaserfeld, Dewey, Stanley, Gesell, and Vygotsky (Stone, 1996; Vanderstraeten, 2002). Piaget (1972), regarding abstract thought or mental capacity, described how learners would pass through various stages in their lives; this is especially applicable when looking at children actively involved in science education (Shayer & Adey, 1981). Vygotsky (1929) emphasized the social aspect when constructing knowledge and implied that there was a connection between the psychological processes and the environment inhabited by humans. These tenets of constructivism can be found throughout the NGSS and *Framework* (Bell, et al., 1995; Railean, et al., 2016; Taber, 2010).

As a result of the IBL explicit in the GSE, this research espouses a social constructivist understanding of knowledge formation upon which the methodology and data analysis of this study is built. Teachers are charged with helping facilitate learning and understanding within and between their students. Content must be learned and constructed through experiences such as inquiry and laboratory activities in the classroom: actively engaging, building, observing, and sharing information, which allows students to construct the knowledge. This is even more effective when students have taken ownership of a concept or activity, whether alone or in a group.

Ownership does not come from simply engaging in an activity; rather, it is synthesized through students engaging in real-world experiences and existing knowledge, hypothesizing and testing those hypotheses, and then drawing conclusions from their findings. Jonassen (1994, p.35) describes the learning outcomes as not predictable and that "instruction should foster, not control, the processing of the learner." Learning occurs when students tap into their curiosity about the world; they try to understand how it works (Olusegun, 2015). Curiosity is also piqued through reflection, which allows for self-regulation and abstraction (von Glasersfeld. 1995). Critical thinking is part of knowledge construction and interpretation within a community of learners (Confrey, 1995). This community of learners is built around the ways in which scientists use language, behave, and conduct investigations (Shotter, 1995). Driver (1994, p.5) stated that in order for students to learn science, they needed to be "initiated into the culture of science." To do this, a student must value the same kinds of discourses as the classroom teacher, or the student may feel especially disenfranchised (Moje, 1997).

Conceptual Framework

This study is viewed through an equity lens, which the National Science Foundation (NSF) defines as the "reduction in attainment differences between those traditionally underserved and their peers" (Zucker et al., 1998, p. 37). The focus on rural education is not to exclude urban and suburban populations from any inequity that occurs within those areas, but to bring attention to a lack of equity or a need for social justice in rural areas (Eppley, 2017). While extensive research has been done looking at equity as it relates to gender (Campbell et al., 2000; Grigg et al., 2006; Haslanger, 2000; Maehr & Steinkamp, 1983; Scantlebury, 1994), ethnicity (Aikenhead, 1997; Chapin, 2006; Grigg et al., 2006; Peng & Hill, 1995; Rakow, 1985; Rodriguez, 1998), and poverty (Arambula-Greenfield, 1999; Hewson et al., 2001; Lynch, 2000; O'Sullivan et al., 2003; Rodriguez, 1998), one area that remains less charted is the equity of place.

There is a failure to recognize spatial inequity, or equity of place, as a distinct disadvantage (Roberts & Green, 2013). "Simple", "redneck", or "backwoods" are terms used by the media to stereotype rural people. With former U.S. President Obama commenting about rural citizens being "bitter" about the loss of jobs and economic stimulus in their areas, it is no wonder that the stereotypes of rural people exist and are pervasive in today's society (Seelye & Zeleny, 2008). Students in rural areas have worth and require the just distribution of education resources, which includes teacher PD related to standards-based teaching, especially, for this study, as it relates to the teaching of chemistry standards in rural public high schools (Eppley, 2017).

Unlike some urban schools, rural schools have not typically been popular recipients of philanthropy (Beeson & Strange, 2000; Howley et al., 2009; Martin, 2010; Sherburne, 2016). A lack of philanthropy combined with the cuts that have occurred in the past two decades and a serious problem in the rural American education system is visible (Ansalone, 2004). NCLB did very little to advance and help rural districts and schools (Jimerson, 2005). The Every Student Succeeds Act (ESSA) has made significant strides in ensuring that states incorporate rural funding initiatives, studies, and formulas into their plans; however, much more needs to be done, as the equity gap has existed for a long time (Brenner, 2016).

There is a vital need to look at whether the required standards are inequitable (Roberts & Green, 2013). It could also be that teachers are misinterpreting the standards. Eppley (2015) describes an instance where teachers attempting to implement Common Core State Standards exhibited what Pearson (2013, p.55) describes as a "fundamental misunderstanding of the comprehension process." While the standards being described are ELA ones, a comparison can still be made with those in science as misunderstandings of the comprehension could happen in any subject. Students who would be taught chemistry from teachers with these misconceptions may test lower on assessments and have an overall skewed view of science, in general. If teachers have a misconception in how the standards should be implemented and assessed, then this could be overcome through PD or collaboration with other teachers of the same course at the school or nearby schools. Regarding collaboration, rural schools are often small or located a distance from other schools by the very nature of being rural. Also, PD is often lacking in quantity or quality in these rural districts because of a lack of money to pay for substitutes, ability to attract people who really grab attention, or those working on cutting-edge pedagogy or technology (Dunac & Demir, 2017; Reese & Miller, 2017). More research is needed to determine teacher views of the standards themselves, along with what they feel is necessary to teach those standards, particularly from a rural public high school viewpoint in a specific field like chemistry.

Purpose and Research Question

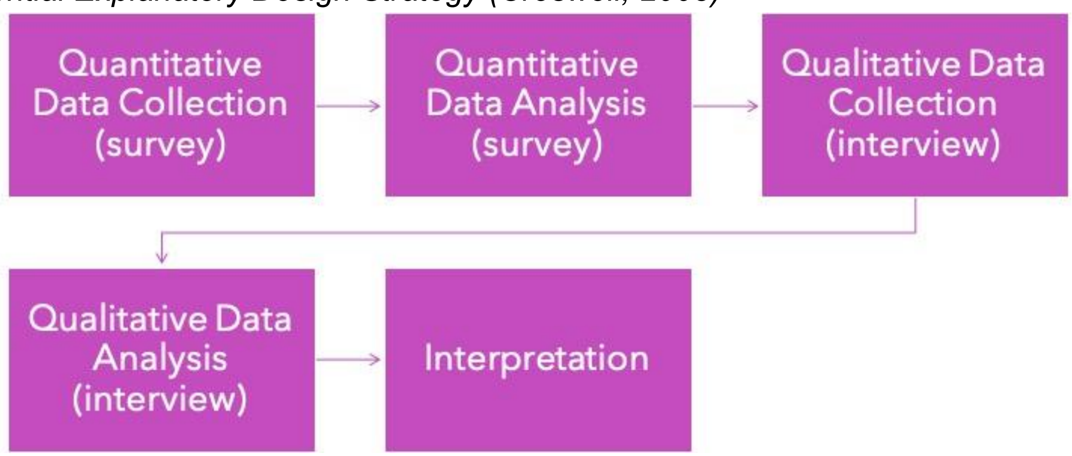
The purpose of this research is to give a voice to rural high school chemistry teachers using a curriculum with PCOI standards embedded throughout. It also to determine whether IBL, as described in the NGSS and earlier documents, is being utilized in rural public high school chemistry classrooms. The research question guiding this study is: *What are the views of rural Georgia public high school chemistry teachers regarding the feasibility of teaching GSE High School Chemistry through inquiry?*

Methodology

The ultimate goal of this study is to accurately understand and voice the views of the participants. A mixed-method design was utilized for this study for a more complete analysis of the phenomenon (Creswell, 2005; Tashakkori & Teddlie, 2003). Neither approach was dominant; both provided equal contributions in the present study. A semi-concurrent implementation of a sequential explanatory design strategy was utilized, as shown in Figure 1 (Creswell, 2003).

Figure 1

Sequential Explanatory Design Strategy (Creswell, 2003)



The design allowed the interview guide to become dynamic in response to changes in data from the survey, resulting in more in-depth analysis and questioning based on the closed-ended survey responses. Interviews expanded the breadth and depth of the survey (Towns, 2008). Surveys are best used if the data cannot be observed directly or is not available in previous research literature, and are most effective in investigating opinions and emotions, or human phenomena (Artino et al., 2014; Jann & Hinz, 2016, p. 105; Phillips, 2017). A cross-sectional design was used for the clearly defined population of rural public high school chemistry teachers in Georgia and only occurred once at a specific point in time, and the design allowed the researcher to explore potential causal relationships, which could not be done if a descriptive design was used (Jann & Hinz, 2016, p. 112-113).

Face-to-face interviews are considered to be the most flexible in terms of complexity of the questionnaire, coverage, and even assistance of the interviewer (Leeuw & Berzelak, 2016, p. 144). A mixed-methods approach, with most data being qualitative from the interviews, interspersed with quantitative data from the survey, helped answer the research question appropriately, particularly for participants in rural schools throughout Georgia.

Survey Instrument

Several of Ladd's (2011) 5-point Likert-style questions were selected for the survey instrument to probe teacher perceptions of their resources, support, and access to resources. Questions were added regarding the use of a constructivist mindset in the participants' classroom and lab supplies. The entire survey by Ladd was not used, particularly the questions relating to teacher job satisfaction with retention. The research question was addressed using questions taken and modified or condensed from the survey *Inquiry Beliefs and Practices* used by Jeanpierre (2006), which was modeled after Burry-Stock's (1999) expert science teaching educational evaluation model (ESTEEM) survey.

Questions were used to determine the degree to which the participants utilized inquiry labs and labs in general. Those who reported not completing labs on a regular basis were asked to discuss this during the interview phase. Participants who utilized a large percentage of inquiry labs were also sought after to discuss the topic during interviews. Basic demographic information was collected during the survey to determine eligibility based on the requirements for participation. Other questions involved the schedule of classes, perceived location of school (rural, suburban, or urban), courses taught by the participant, and years taught, with the level of education. The perceived location of the school was checked after the survey to determine whether the school truly was rural, and was added to determine if there was a difference in participant response based on the perception.

Data collection of surveys was completed using Qualtrics, and quantitative data analysis using SPSS. A link, or QR code, was provided to educators via business card, photo, social media post, or email. The cards were distributed at the Annual Conference for the Georgia Science Teachers Association (GSTA). Regional Educational Service Agency (RESA) representatives in the various areas in Georgia were asked to distribute to rural schools in their areas. All information involved the adult participant(s) and their views of teaching the chemistry standards, which meant that IRB approval for each individual district was not necessary.

Context of Study & Participants

The sample for this study consisted of rural public high school chemistry teachers in Georgia who were currently teaching, or had taught, high school chemistry within three years from the date of the survey, allowing for schools with a high turnover in rural areas the ability to participate (Ansalone, 2004; Deck, 2001; Monk, 2007). The time window of three years also means teachers may have taught under the previous GPS standards before the state began rolling over to the GSE. The participants varied in terms of gender, race, and years of experience, but all were at least 18 years old to legally consent to participate in the study and held a valid teaching license from the State of Georgia. All rural schools in Georgia were invited to participate in hopes that themes of shared rural experiences might be evident. The school's demographics were checked using the NCES database of schools in Georgia (NCES, 2018). While the most used definition of rural within rural education research comes from the NCES (Thier et al., 2021), for the purposes of this study, town and rural areas were grouped together as they face similar challenges.

Survey Sample

A total of 171 participants began the survey instrument, of which only *N*=153 were deemed as eligible participants and completed the survey. One hundred twenty-eight unique rural public high schools were represented out of the 202 total that fit the research parameters in Georgia. From this population, eight participants consented to an interview during the survey portion of the study and gave pertinent contact information to accompany their response. All participants' identities remained confidential, and pseudonyms were given to each to avoid identification and possible fear of retribution for their comments.

The education level of the participants varied, as shown in Table 4, with 47.7% of survey participants holding a master's degree compared to 44% of teachers in the state of Georgia (GOSA, 2020, p. 2). Even though only 12.4% of participants indicated a doctorate or equivalent degree, 83.0% had a degree beyond a four-year bachelor's degree.

Table 4

Education Level of Survey Participants

Factor	Total Sample	Percent
Education		
n	153	n/a
Bachelor's degree	26	17.0
Master's degree	73	47.7
Specialist degree	35	22.9
Doctorate degree	19	12.4

Total	**153**	**100**

A bit more information about the survey participants that helps to add to the context is the years of chemistry teaching experience due to teaching chemistry under both the GPS and GSE. Table 5 lists the frequency and percentages of the groupings of experience.

Table 5

Survey Participants Years of Chemistry Experience

Years of Experience	Frequency	Percent
1 – 5 Years	60	39.2
6 – 10 Years	40	26.1
11 – 20 Years	33	21.6
More than 20 Years	20	13.1
Total	**153**	**100**

Most survey participants, 65.3% (*N*=100), were in their first 10 years of chemistry teaching experience, and 86.9% (*N*=133) of participants had 20 years or less of chemistry teaching experience. While the percentages of participants in their first 10 years of chemistry teaching experience is close to the percentage who held a bachelor's or master's degree, 65.3% and 64.7%, respectively, they cannot be assumed as being the same individuals; for example, one of the interview participants, Eleanor, had more than 20 years of experience while holding a bachelor's degree as her highest level of education.

Participant Selection

Purposeful sampling was used to select participants. As a result, the participants were chosen in order to maximize the variety of answers and to highlight teacher voices as to whether inquiry was taught, the percentage of labs that were inquiry, and the number of labs in general, with regard to high school chemistry. The interviewed population is described in Table 6. The survey did not measure gender as part of the demographic information, but gender determination by names traditionally associated with gender showed that less than 20% of participants had a traditionally male name, which is contrary to data that shows that 75% of STEM teachers identified as male (National Science Board, 2018). Greater gender diversity in the interview participants was desired, but attempts to bring in more male participants were not successful.

Table 6

Interview Participant Information

Pseudonym	**Gender**	**Reason for Selection**

Alice	Female	Expressed interest in helping, smaller rural school, low lab number, 10% inquiry
Bridgette	Female	Low labs; lots of commentary; pros and cons
Cathryn	Female	90% inquiry; only 4 labs
Daisy	Female	Block schedule, interesting clarification statements, low lab numbers, 20% inquiry, struggled with low-income multiple preps
Eleanor	Female	Disagrees with the way the State is mandating PLCs and how district and school are implementing them.
Felicia	Female	Rural; 80% inquiry; trouble with students planning investigations.
Gladys	Female	Low lab numbers; poor school; isolation
Hugh	Male	Male; no other chemistry teachers; new teacher; second career; low inquiry on survey; no PCOI

Participant Context

The interview participants had an average of 9.6 years of experience, with three having 15 years or more and one having more than 25 years. Comparatively, three participants only had either one or two years of experience, and five out of the eight had between one and ten years.

Four participants held a bachelor's degree, two held a master's degree, and two reported holding a specialist degree. Only one of the participants went to college intending to teach and held the only bachelor's degree in education. The other seven participants held at least a Bachelor of Science in a scientific discipline.

The interviews were recorded using Zoom Pro and then transcribed and coded using Atlas.ti (Barry, 1998). Due to the shelter-in-place order during the 2020 COVID-19 pandemic, in-person interviews were not possible (Exec. Order No. 04.01.20.01, 2020). However, Zoom interviews have been shown to yield similar results as in-person (Handgraaf, et al., 2012). The combination of teachers already being comfortable with video conferencing, along with the amount of time they spent checking email and being available online, led to a greater willingness to participate in both the survey and interviews.

The survey included an optional incentive drawing for one of ten $25 Amazon gift certificates for completing. An online random number generator was used to determine the ten winners. In addition, each interview participant was given a $25 Amazon gift certificate as compensation for their valuable time.

Data Analysis

Analyzing the data involved using open, axial, and selective coding. Codes were assigned while analysis was being done, which aimed at answering questions regarding the underlying issues, main actors involved, and roles being played, context of place, intention or purpose, and how the phenomenon occurs in the first place. After these codes were identified, axial coding was used to group them together into larger groups. Finally, selective coding was used to gather the themes and data synthesis.

Quantitative survey data was analyzed using descriptive statistics. Frequencies of participants' answers for each question were combined and analyzed using the 5-point Likert-style questions. For analysis purposes, the answers to the Likert scale questions were combined into three main categories: agree, disagree, or neutral. These ordinal data that resulted from the answers on the survey required non-parametric tests (Cooper & Johnson, 2016). A Chi-Square Test was used to analyze the quantitative data and determine the likelihood of the data resulting from chance. The majority of the quantitative data was used to determine frequencies that impacted and influenced the larger qualitative interview instrument and analysis.

Informed Consent

Informed consent for the survey was obtained digitally; it was electronically signed and dated. The survey through Qualtrics was programmed with skip logic to ensure that only those providing informed consent were able to take the survey (Swanson et al., 2014). To ensure trust and freedom to speak the truth about their workplaces, all teachers were given a pseudonym from a random name generator easily accessible online. Identifiable information such as district and school were not provided in the results of this study.

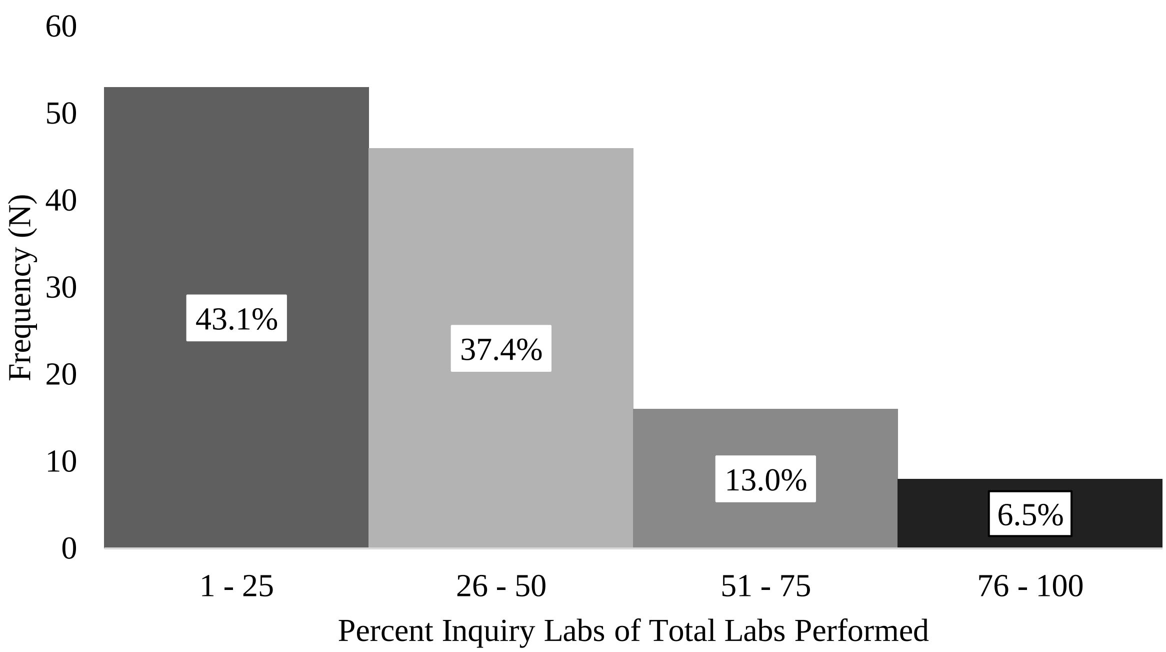
Findings

The question driving the research was as follows: *What are the views of rural Georgia public high school chemistry teachers regarding the feasibility of teaching GSE High School Chemistry through inquiry?* 80.4% (*N*=123) of participants indicated using inquiry labs in their general chemistry classroom, as opposed to AP or Honors. However, one participant stated, "I love the idea/concept of inquiry but find it's neither practical nor safe in my reality…We have limited lab facilities, lab equipment, and lab consumables, and the third-person method of requesting supplies really slows down the materials pipeline…[inquiry] requires planning weeks ahead of time, and that just doesn't happen."

Data revealed that inquiry labs, in some form, are being utilized in the rural public high school chemistry classroom, but are perceived to make up less than half of the overall labs in the majority of participants' classrooms. Answers ranged from a minimum of 3% to a maximum of 90%, and Figure 2 shows that 43.1% (*N*=53) of participants use inquiry for between 1-25% of their labs, while 37.4% (*N*=46) of participants utilize inquiry as part of 26-50% of their overall labs. This indicates that of the participants who admitted to using inquiry in the general chemistry classroom, 80.5% (*N*=99) of those used it in half of their labs or less. Moreover, a very small percentage of teachers, 6.5% (*N*=8), indicated utilizing inquiry labs in some form in over 75% of their labs performed for the chemistry course.

Figure 2

Inquiry Labs as a Percentage of Total Labs Performed



Some participants chose to comment regarding IBL indicating that they used it most often in AP courses or honors courses, while others stated that "student to teacher ratio makes inquiry difficult." Several participants also cited lack of time as a reason why they did not engage students in as much inquiry in that "52 minutes a class is an extremely short period of time to get full lab experiences in" or that "my biggest barrier is the time constraint of grading in a timely way" and "there just isn't the kind of time I would want for more fully or even semi-fully inquiry-based labs." These quotes imply that teachers want to use IBL in chemistry, but some feel that they cannot do so within the bounds of their classroom environments.

Number of Labs Performed Per Semester

Participants were asked about the number of student labs performed during a semester. Table 7 lays out the entire data set of participants as well as splits them up into inquiry or no inquiry based on their answer to a previous question on the survey instrument. On average, teachers implemented 13.6 labs with a minimum of 2 and a maximum of 30 (Table 7).

Table 7

Number of Student Labs Performed Per Semester

Factor	Frequency	Mean	Standard Deviation	Minimum	Maximum	Mode
No Inquiry	30	11.3	6.67	3	27	4 (*N*=6)
Inquiry	123	13.6	6.29	2	30	20 (*N*=16)
Total	153	13.6	6.29	2	30	20 (*N*=17)

There was also a difference in the mean number of labs performed per semester in those who performed inquiry (13.6) and those who did not (11.3). Even though comments mentioned not having enough time to complete IBL labs, the teachers utilizing IBL labs performed, on average, 2.3 more labs per semester than those who did not utilize it. The time issue was further examined through a comparison of the schedules implemented at each school and the use of IBL labs.

School Schedules

Data concerning school schedules versus use of inquiry labs, as reported by the participants on the survey instrument, is detailed in Table 8. The majority of teachers (*N*=92) reported being on a semester long block schedule, followed by those on a traditional schedule (*N*=46).

Table 8

School Schedule vs. Use of Inquiry Labs

Schedule	Self-Reported Use of Inquiry Labs					
	Frequency			Percent		
	No	Yes	Total	No	Yes	Total
Traditional (Period)	10	36	46	21.74%	78.26	100
Block (Full Year)	1	6	7	14.29%	85.71%	100

Block (Semester)	19	73	92	20.65%	79.35%	100
Hybrid	0	8	8	0%	100%	100
All Block	20	79	99	20.20%	79.80%	100
All Non-Traditional	20	87	107	18.69%	81.31%	100

Inquiry labs were reported in 78.26% of participants on traditional schedules versus 79.35% of on a block semester schedule, revealing very little difference in inquiry usage between these two subgroups. Those on a hybrid schedule reported a 100% inquiry usage, although the sample size of *N*=8 is not large enough to make an overall conclusion, and 85.71% of participants on a year-long block schedule (*N*=8) reported using inquiry. Schedule, combined with the number of different or unique course preparations (preps), was cited by participants as a hindrance in completing laboratory experiments.

School schedules were mentioned during the interviews as possibly impacting the types and number of labs performed by students in a high school chemistry course. Alice had the following to say about inquiry labs and scheduling:

> *I have them for one semester, which is 18 weeks. And even if I were to teach, you know, give every substandard a week, it's not going to work out. So, a lot of times what we do with those "plan and carry outs [standards]' is I find a PhET, because then…they have those limitations already set.*

Eleanor stated that she did not complete inquiry labs but did complete 14 labs with her students in some form per semester. She also explained that her school recently underwent a change in schedule from traditional to block due to the vision of a new superintendent. When asked whether she noticed a difference between the two schedules in the number of labs she was able to do, she stated the following:

> *[The] only positive is lab time. And again, when the state went through such financial hardships, one of the things our county did was ask for a variance so that we could have larger classes. This past semester, I had 32 students in a gifted class and 34 in a regular chemistry class. And it would, it would give me heart palpitations, to think about lighting Bunsen burners. And, you know, having them do acid-base titrations because it's almost impossible to stand guard over 34 kids in a classroom. So, block was good, only that sometimes I could divide the labs up where half the class was doing the lab. The other half was doing something else. But then it just, you know, it dragged out forever.*

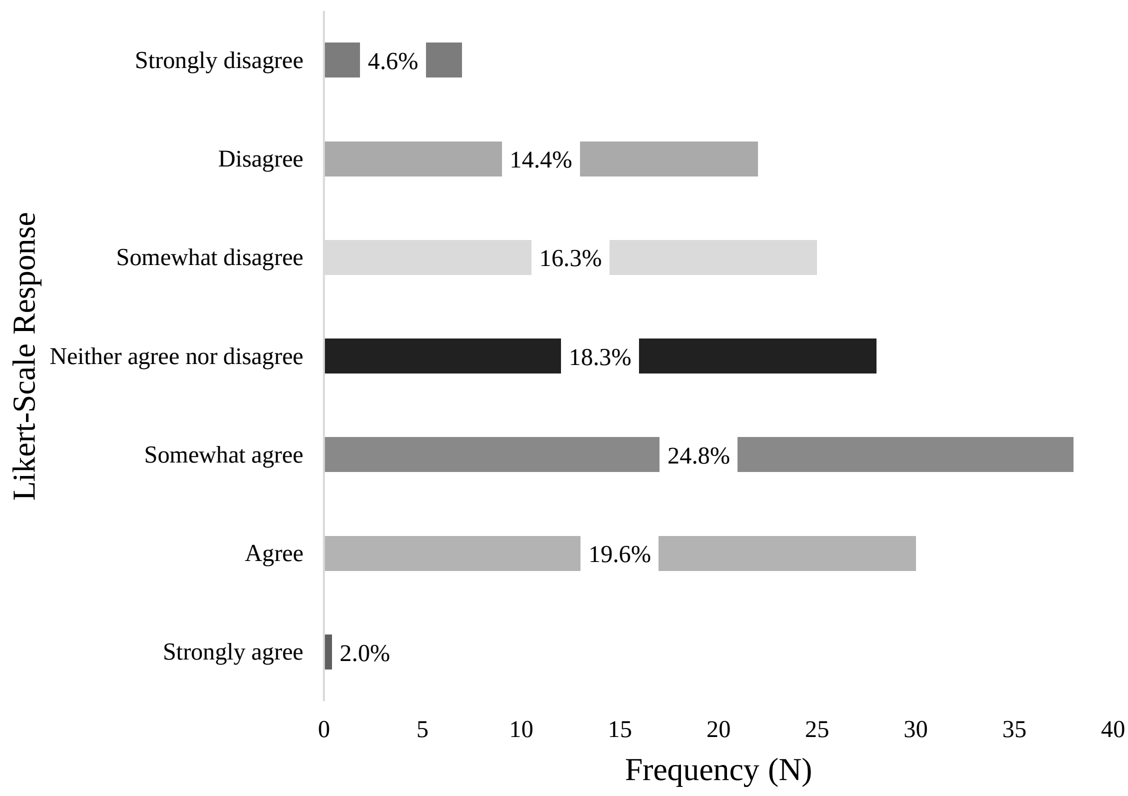
She recalled how an increased class size, combined with a changing schedule, resulted in increased teacher anxiety and stress. Her "heart palpitations" when thinking about that number of students in lab, "lighting Bunsen burners," or "standing guard over 34 kids in a classroom" involved in labs with a significant risk, as in acid-base titrations, indicate that inquiry can be stressful. Modifications were made regarding lab instruction, but these changes were not without extra work on the teacher to overcome challenges faced regarding schedules and the number of students.

Teacher Views of Inquiry

Because the GSE explicitly states that students are to PCOI without explaining how this could be done or what this might look like in a classroom, the first portion of this section investigates participants' views on whether students designing their own laboratory investigations is a critical component in the high school chemistry course. The views are especially critical when examining schools with a single chemistry teacher. The data for this is presented in Figure 3.

Figure 3

Students Designing Labs as Critical to the Course



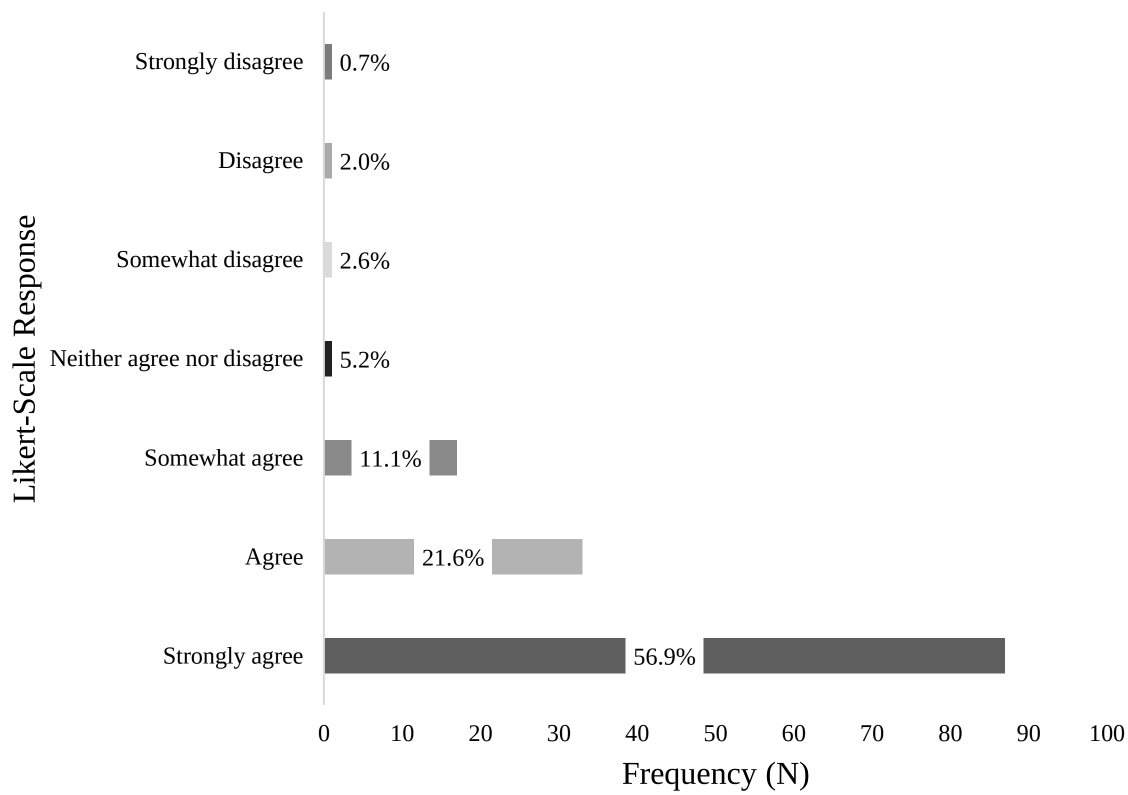
Note: The figure presents the data associated with participants' answers to the Likert-style question that began with "Please use the rating which best describes your inquiry teaching and learning beliefs for the following statements…"

46.4% (*N*=71) of participants agreed that students designing their own investigations is critical to the general chemistry course. Of note is that even though the data were grouped into three main subgroups, the extremes of "strongly agree" and "strongly disagree" did not gather many responses, with 2.0% (*N*=3) and 4.6% (*N*=7). respectively. Essentially, participants were relatively split on the importance of students devising their own laboratory investigations, with just over 10% more on the affirmative side than the negative side.

According to Figure 4, 89.6% (*N*=137) of the participants agree that student investigations are critical to chemistry. Unlike Figure 3, which shows that students coming up with their own labs had no extremes, Figure 4 reveals that 56.9% (*N*=87) strongly agreed that students carrying out investigations were critical to chemistry. Teachers in the study agree that students should carry out investigations, but have mixed opinions as to how much of the experiment students should plan.

Figure 4

Student Investigations as Critical to the Course

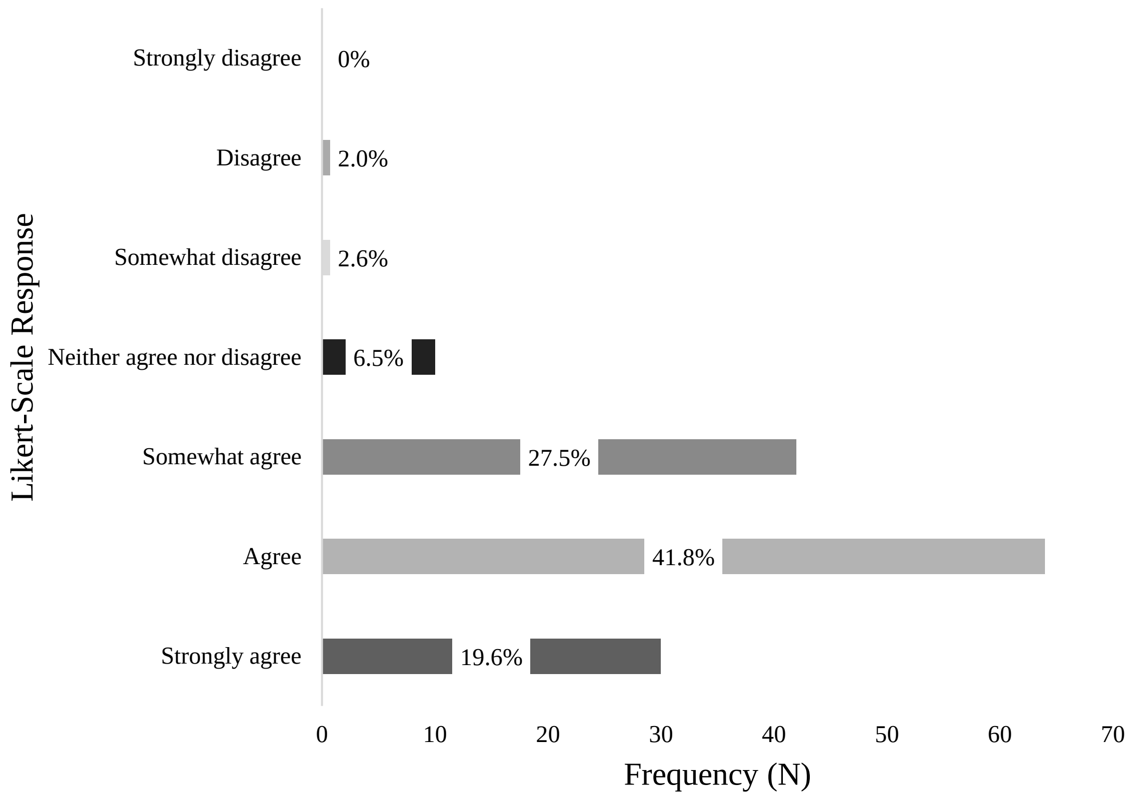


Note: The figure presents the data associated with participants' answers to the Likert-style question that began with "Please use the rating which best describes your inquiry teaching and learning beliefs for the following statements…"

Participants were asked about the time required for labs. One participant stated that students conducting their own labs took more time, but did not necessarily have to take more money if a teacher is creative. Figure 5 reveals that 88.9% (*N*=136) of participants believe that students conducting their own labs require more time and resources than regular labs.

Figure 5

Time and Resources for Inquiry vs. Regular Labs



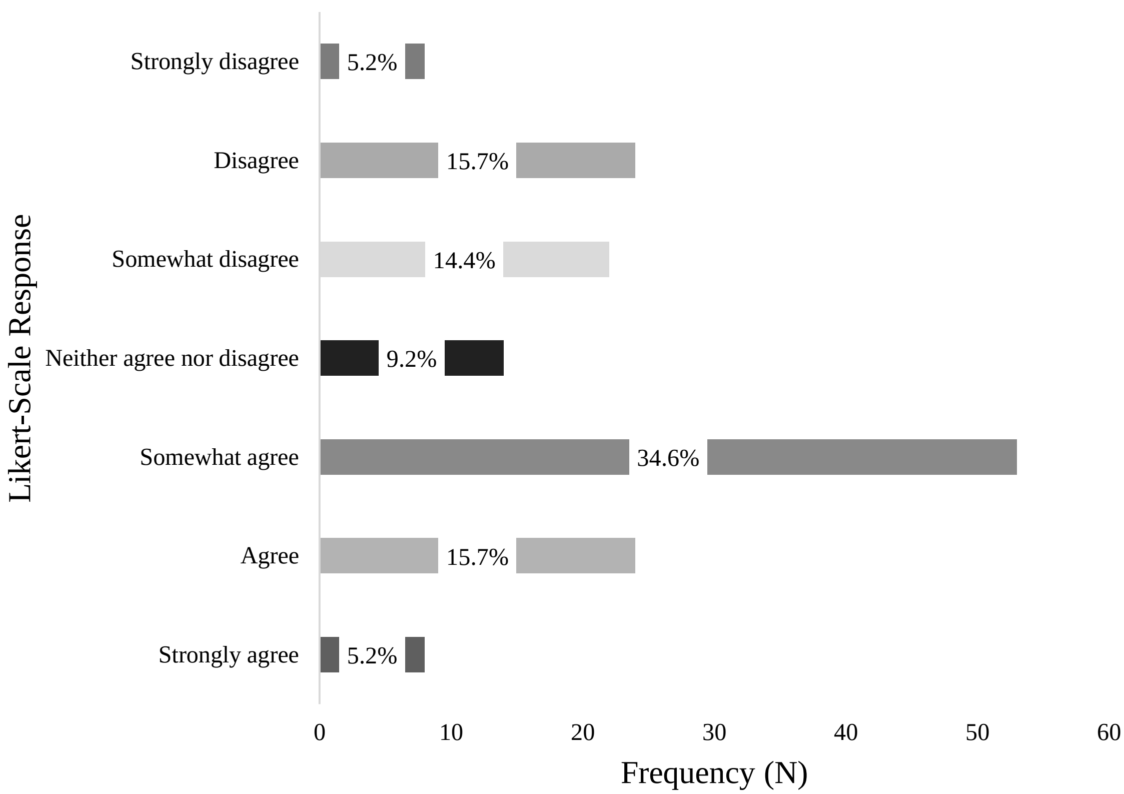
Note: The figure presents the data associated with participants' answers to the Likert-style question that began with "Please use the rating which best describes your inquiry teaching and learning beliefs for the following statements…"

Most teacher participants believe labs are a critical component in the course, and that students conducting their own experiments require more time and resources than regular labs. Thus, the question that must be asked is whether students coming up with their own labs or learning through IBL is too time-consuming for the course? Responses were compiled in Figure 6, with 55.5% (*N*=85) participants agreeing that inquiry labs were too time-consuming for the course, while 35.3% (*N*=54) disagreed. Based on the comments after this section, participants interpreted "inquiry" in the question prompt as open inquiry, or the type that has the greatest amount of student autonomy and the lowest amount of teacher guidance on the continuum in Table 3. One participant stated that the time constraint of teaching requires labs to "be more teacher-led" and that the teacher must "stay on task" to complete labs within the time allotted. This was echoed as another participant thought that "inquiry labs take more time and more resources," but that the "time is better spent with more of a guided inquiry experience."

Comments on the feasibility of teaching GSE High School Chemistry through inquiry included concerns over various issues, such as lack of time, supplies, equipment, time to grade, planning or preparation time, and student apathy. Even though these hindrances were brought up, comments also included that students are involved in some guided inquiry. One participant added that "I do a lab almost every week…for on-level" chemistry courses. Adding these comments to the quantitative data from the survey shows that most participants viewed teaching the GSE High School Chemistry through an inquiry-based approach as at least feasible.

Figure 6

Perspectives on Inquiry Labs Being Too Time-Consuming for the Constraints of the Course



Note: The figure presents the data associated with participants' answers to the Likert-style question that began with "Please use the rating which best describes your inquiry teaching and learning beliefs for the following statements…"

Even with the time constraints, Alice reported completing 12 labs per semester, of which 10% she classified as inquiry labs, which indicated an assumption that inquiry labs must be wet labs, or labs requiring chemicals within the classroom. The language of the standard does not indicate that the labs should be wet labs. Cathryn, who had the highest inquiry percentage of labs at 90% and reported having completed four inquiry labs per semester, agreed that inquiry labs were time-consuming and had the following to say when asked how long they took:

> *Well, one, what if it takes a week? One of them takes, and that's five days at one and a half hours apiece. By the time they get in there and they get their head around, it takes some [time] for them to get their head around the question.*

She described how strongly she felt about making her students think and struggle with problems and then find solutions to them, indicating that though the inquiry process is time-consuming, it leads to critical thinking and problem-solving.

Synopsis

The research question asked about Georgia rural public high school chemistry teachers' views of the feasibility of teaching GSE High School Chemistry through inquiry. The survey data show that 79.49% of participants used inquiry in their labs. However, this did not measure the frequency of the inquiry alone, and it also did not measure this against the seven PCOI standards/elements. Those who answered yes on the survey to using inquiry in their courses reported an average of 35.94% of their labs as involving inquiry. Interviews further explored the use of inquiry labs, and participant responses revealed that while each of the eight participants admitted to commonly implementing guided inquiry during their lab instruction of the seven PCOI standards/elements, only one participant utilized PCOI during chemistry labs. Even that one participant only used PCOI during four out of the seven incidents of PCOI in the GSE.

Conclusion

Data from the survey and interviews revealed that teachers are somewhat divided on whether IBL of the GSE is feasible. 80.4% of survey participants stated that they used inquiry in their classrooms, indicating that IBL in high school chemistry using the GSE is feasible. Interestingly, when the answers were cross-referenced to participants' scheduling, there was very little difference in inquiry percentages between traditional schedules and block schedules.

Several participants stated that they use Physics Education Technology (PhET) simulations to teach the standards, but the teachers also stated that students are not planning investigations, even though these online simulations can be set up in a way that students must PCOI. However, creating the assignment and rubric for grading takes planning time before and after the activity, and adequate planning time is a resource that 46.4% of participants reported not having. This indicates that though teachers may be willing to implement PCOI more, they do not feel they have the time to do so.

Further, responses indicated that while teachers do not have adequate planning, they also do not feel they have adequate training for implementing true inquiry in their chemistry classrooms. One participant stated that the planning time was taken up by general school-mandated PD that was not content-specific. The participant's frustration with losing time for PD that was not seen as being relevant highlights an additional need for teacher autonomy in PD choice. Only 23.5% of participants received PD that they chose and for which the district paid. This is not because teachers do not want to be involved, as 90.2% of participants reported being involved or a member of a professional or teacher organization. Ultimately, PD, planning time, and autonomy in PD may all be seen as equity issues or a lack of access.

The overwhelming majority of participants indicated that they used inquiry, as defined on the survey instrument and in the *Frameworks*, within their classrooms, and they believed that students need to PCOI to get the most out of the course and to address the standards. A need to address all PCOI standards was expressed, but most teachers cited lack of time as a reason why inquiry was not completed in all the standards or elements within the GSE. An overabundance of preps can lead to less time per course, which is often found at smaller rural schools where there are fewer sections of courses to be taught, so teachers find themselves teaching multiple preps. Other factors that participants stated played a role in the lack of inquiry or students involved with PCOI included money or resources, equipment, and student apathy. While these factors can also be present in large urban schools and would not be rural-specific, rural schools were described by participants as having a number of these issues all at once. Any teacher at a small school will have to deal with multiple preps, but the lack of resources and colleagues to bounce ideas off of is compounded by the distance between schools in a rural area.

Limitations

Instrument Limitations

Using only a portion of the original survey instrument is a limitation in the study as it draws into question the integrity of the modified instrument. This could be remedied in the future by either establishing a more reliable instrument upon which multiple quantitative analysis techniques could be performed or by using an already established instrument. However, the use of in-depth narratives from participants adds reliability and validity to the current study's findings.

Definition of Inquiry as a Limitation

While the survey instrument included a definition of inquiry from *A Framework for K-12 Science Education* (NRC, 2012), there were no further questions that determined participants' own definitions of inquiry. The interview guide did not include questions regarding participant or researcher definitions of inquiry. The lack of presenting or asking for a common definition as a point of symmetry in both instruments is a point of limitation within the current study. Without the common definition being stated or asked for, the questions involving inquiry could have been interpreted in various ways regarding the survey.

Implications

Findings from this study indicate that most public high school chemistry teachers in rural Georgia report using IBL, especially when it comes to laboratory investigations. Interview responses indicate that many teachers interpret PCOI as something implemented only during wet labs. Though wet labs are one method of implementing inquiry via PCOI, they are not the only type of laboratory investigations or inquiry activities available to teachers. Online simulations are available and allow students an element of PCOI. However, even these can be as teacher-directed as a cookbook lab. The instructor is responsible for determining the desired level of inquiry using the inquiry continuum (Table 3) and can turn any cookbook lab into an inquiry lab to some degree with the appropriate amount of editing.

Scheduling and education do not have a significant influence on the use of inquiry in the classroom or for labs. Additionally, 83% of participants earned a degree greater than a four-year degree, which shows that education regarding degrees conferred upon instructors is not a limitation in the incorporation of IBL by chemistry teachers in rural areas. However, education level does not necessarily equate to dedicated PD in chemistry pedagogy. One major finding of the study is that the majority of teachers, 80.4%, report using inquiry labs in the general chemistry classroom. The issue is that there are still approximately 20% of chemistry classrooms that are not using inquiry labs, even though inquiry is written into the Science Georgia Standards of Excellence. The present study cannot say for sure in each case whether it is a lack of understanding into what inquiry is or a deficit in how to prepare labs using inquiry; either of these can be solved utilizing PD, but the PD plan must diagnose whether the issue is one or both of the deficiencies causing the lack of teachers' utilization of PCOI within the chemistry classroom.

Professional Development

PD was the focus of several survey questions to understand its impact on the implementation of inquiry in rural high school chemistry classrooms; participants in the interviews also expressed a desire to have chemistry-specific PD. Specifically, teachers want PD to be centered around laboratory experiments that are cost-effective as well as efficient to allow students to construct their knowledge of the concepts. One potential option is for the state to provide content-specific training free of charge, made available through a virtual format; this would also allow teachers in rural areas to participate, which is something that 15.7% of survey participants and 100% of interview participants indicated they wish for. The lack of general PD, chemistry-specific PD, as well as the lack of funding all contribute to the low number of teachers who are in self-reported compliance with the PCOI wording within the standards/elements of the GSE. Changing standards without proper implementation through PD of the teachers who will be using those standards has led to the problems highlighted within the current study.

Funding

This study also revealed that schools and districts are not doing enough to provide teachers with resources for implementing chemistry-specific lab activities, as almost one-third of participants felt that outside sources of funding were required to have enough lab supplies to adequately teach the class. One participant remarked that a resourceful teacher can make it work with less, but the participant only knew this from years of experience working in a school where teachers worked together to formulate a plan for implementing more labs with fewer resources. At least two participants described fund-raising efforts through optional lab fees, while another detailed an elaborate science department candy fundraiser that stocked the labs with updated equipment and chemicals, which removes that as a barrier to inquiry.

Future Work

The current study investigated the perceptions of public high school chemistry teachers from rural areas in the state of Georgia. Participants expressed a desire to have more chemistry-specific PD on the topic of facilitating laboratory investigations, particularly for students' PCOI. These teachers would also benefit from chemistry-specific pedagogy in the areas of inquiry and facilitating students' PCOI. PD needs to be enacted in Georgia to provide these rural public high school chemistry teachers with the training that the data showed is needed for effective implementation of the GSE.

This study could be replicated throughout the United States to determine the perceptions of rural teachers from around the country; rural chemistry education could be better informed by examining possible commonalities and differences from all states in a study such as this. Future research could also include private, urban, and suburban schools in different states. Additional studies into teachers' definitions of inquiry and what is required for students to PCOI would be beneficial to those looking to provide reliable and effective PD. NGSS and states incorporating NGSS-like standards would also benefit from determining teacher perceptions of inquiry. The researcher did not look at degree level or education when considering whether to interview survey participants, but it would be interesting to see how background or degrees impact the teaching of chemistry and other laboratory sciences.

Data from the current study shows that over 80% of participants using inquiry in the classroom is encouraging, but that excitement must be tempered when thinking about how that leaves almost 20% of participants who are not using inquiry in their classrooms. In addition, the 80% using inquiry may have different definitions of inquiry, even though a definition was provided in the survey. Discovering how teachers define inquiry would be a pivotal finding for future research. Without a standardized test in chemistry in Georgia, studies, like the present one, are needed to check in on the teachers and to give them a voice. Understanding what is truly being done in the classroom through the words of the teachers themselves is important, and identifying the needs of teachers in rural areas is part of the overall mission of providing equitable and adequate education to all students in the United States.

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