2024

Teachers' Conceptions of Students' Data Literacy in Life Science and Physical Science Classes

Bridget Nicole Smith

Teachers' Conceptions of Students' Data Literacy in Life Science and Physical Science Classes

by
Bridget Nicole Smith

A Dissertation
Submitted in Partial Fulfillment of the Requirements for
The Degree of Doctor of Education
In Curriculum and Leadership
(Curriculum and Instruction)

Key words: teacher conception, science data literacy, data literacy strategies, life science, physical science, high school

Columbus State University
Columbus, GA

Deniz Peker, Ph. D., Committee Chair, Department Chair, Department of Teacher Education, Leadership, and Counseling
Richard Rogers, Ed. D., Assistant Professor, Methodologist, Department of Teacher Education, Leadership, and Counseling
Lauren Neal, Ph. D., Assistant Professor, Third Member, Department of Teacher Education, Leadership, and Counseling

Dedication

This study is dedicated to my parents and professors who have been a source of inspiration and guidance and to my sons, Jack and Jett, who sacrificed much of their time to make this possible.

Acknowledgements

The completion of this study could not have been possible without the expertise and guidance of Dr. Deniz Peker, Dr. Richard Rogers, and Dr. Lauren Neal. I would like to express my sincere gratitude to my committee chair, Dr. Deniz Peker, for his patience, guidance, and expertise knowledge in this process. I would also like to thank Hatton Lovejoy Scholarship, PAGE Foundation Scholarship, Woodrow Wilson Teacher Grant, and Columbus State University Alumni Scholarship for aiding in the funding of this program.

VITA

Bridget N. Smith
802 Salem Road, LaGrange GA, 30241
706-616-5972|smithbridget5972@gmail.com

SUMMARY STATEMENT

Ambitious science teacher with approximately 8 years of experience working in a variety of secondary and college science classes. Experienced in teaching face-to-face and online college labs and courses. Skilled in developing real-life phenomenon engaging lessons, differentiating lessons based on the students' needs, time management, classroom management and utilizing positive reinforcement methods. Skilled and certified in secondary sciences, gifted education, and curriculum and instruction.

EDUCATION

Columbus State University, Columbus, Georgia

- Doctorate in Education, Leadership and Curriculum |January 2024|
- GPA 4.0

Columbus State University, Columbus, Georgia

- Tier 1 Leadership Certification |December, 2022|

LaGrange College, LaGrange, Georgia

- Education Specialist, Curriculum and Instruction |July 2020|
- GPA 4.0

Columbus State University, Columbus, Georgia

- Master of Arts in Teaching, Biology |August 2018|
- Masters of Science, Biology |January 2018|
- Bachelor of Science, Biology |May 2015|

Chattahoochee Valley Community College, Phenix City, Alabama

- Associate of Science, General Science |December 2020|
- GPA: 4.0

Research

- Published research in the Georgia Journal of Science, 2021, Title: Effect of Estrogen Pretreatment on Glial-Like Cell Viability Following Stress Response Hormone Treatment

Honors

- Teacher of the Year at Troup High School, 2022-2023 school year
- Professional Association of Georgia Educators, 2022
- Hatton LoveJoy Scholarship Recipient, 2021-2023
- Columbus State University Alumni Scholarship Recipient, 2021-2022, 2022-2023
- Hatton Lovejoy Scholarship Recipient, 2019-2020
- Woodrow Wilson Fellow Recipient, 2017-2018
- Dean's List, Spring 2013
- Tri-Beta, Awarded graduation ropes and certification, Spring 2014
- Hope Scholarship, Recipient, 2011-2015
- Magna Cum Laude, Spring 2015
- Scholastic Honors Recipient, 2023

Certifications

- Secondary Science (grades 6-12)
- Biology (grades 6-12)
- Broad Field Science (Grades 6-12)
- Gifted certification
- AP Biology certification
- AP Environmental Science certification
- T-6 Curriculum and Instruction certification
- Tier 1 Leadership
- Office Pro Certification (Excel, PowerPoint, Microsoft word)
- First Aid
- BLS
- CNA/Medication Aid
- CPT

RELEVANT WORK EXPERIENCE

Chattahoochee Valley Community College, Phenix City, AL | August 2023-Present

- Teach Principles of Biology courses using different teaching skills to effectively interact with students.
- Use a variety of instructional strategies to support and motivate adult learners.

Eastern Gateway Community College, Steubenville, OH | March 2021-July 2023

- Teach online science courses using different teaching skills to effectively interact with students.
- Answer students' inquiries via an online portal.
- Use a variety of instructional strategies to support and motivate adult learners.

Science Teacher (6-12)

Science Teacher |Troup High School, LaGrange GA | August 2018-present

- Develop engaging lessons that are differentiated and challenge students at an appropriate level
- Teach various classes with a diverse group of students and learning abilities
- Assess and grade various items and provide effective feedback

Woodrow Wilson Fellow

Student Teaching |Troup High School, LaGrange GA | August 2017-2018

- Develop engaging lessons that are differentiated and challenge students at an appropriate level
- Teach various classes with a diverse group of students and learning abilities
- Assess and grade various items

Graduate Assistant |Columbus State University, Columbus GA |August 2015-May 2017

- Taught Principles of Biology labs, graded papers, assisted in proctoring exams, held office hours, assisted students with worksheets in lectures

RESEARCH

- Publication: Effect of estrogen pretreatment on glial-like cell viability following stress response hormone treatment, Georgia Journal of Science (2021)

COMMUNITY SERVICE

- American Red Cross, Columbus GA
- Dash Services, LaGrange, GA

- Habitat for Humanity, Columbus, GA
- Magnolia Manor Nursing Home, Columbus, GA
- Mentored a high school student and an undergraduate in research
- CSU activities
- PBIS Chair, LaGrange, GA

Abstract

Data literacy in science is an evolving field of study as students need to be able to collect, analyze, interpret, and make inferences from different sources of data. Much research centers on teachers' use of data to improve instructional practices, but less focus on teachers' conceptions of student data literacy and strategies used to foster data literacy in life and physical science high school classes. Thus, there is a need to address this area as recent Georgia assessments reveal that over 50% of students are performing below proficiency level in science. Consequently, this research sought to understand teachers' conceptions of science data literacy and strategies used to foster data literacy in science. Moreover, the study aimed at identifying specific data literacy knowledge and skills teachers expect their students to possess, teachers' conceptions of how students work through different concepts related to data literacy, and how these instructional strategies and conceptions of data literacy differ between life science and physical science teachers will be addressed. The present research employed the transformative learning theory, which suggests that conceptions are cultivated from beliefs, experiences, expectations, and purposes. Teacher conceptions were explored through the lens of the transformative learning theory. Purposeful sampling was used to select participants. Using a qualitative interpretivist paradigm and an exploratory case study design, interviews, observations, and document analyses were conducted to obtain data, which employed open, axial, and thematic analysis to develop themes. Major findings indicated teachers lacked confidence and needed additional training. Moreover, teachers believed that students' past experiences impacted conceptions, expectations, and strategies used to foster data literacy. Visuals and models were a common way to represent data. Information gathered provided insight on science curriculums and designing professional development centered on data literacy.

Table of Contents

List of Tables

List of Figures

Chapter I: Introduction

Science Literacy

The need to provide quality content literacy strategies and resources in science is evident across state achievement scores. Numerous schools in Georgia fall below the national average science scores. For example, 27 states outperformed Georgia in 8th grade science based on the most recent available report (National Assessment of Education Progress [NAEP], 2023). Similarly, based on the NAEP report card for students in 12th grade science, only 27% of physical science students were able to use science concepts in an inquiry setting and explain science concepts related to electron configuration. Moreover, less than 50% of students were able to use sources of evidence in an explanation on metals' physical properties (NAEP, 2022). These results indicate that adjustments need to be made in the science curriculum to improve student achievement.

Literacy skills are needed in many areas of life as students need to master such skills to academically succeed, and high schools have a vital role in preparing students to be competent and effective citizens in an innovative society. Science literacy includes being able to read, write, comprehend, critically think, and solve complex problems with no apparent answers. Consequently, teachers are responsible for implementing instructional support to improve content literacy in science. Moreover, schools are charged with preparing students for post-secondary education and careers, which requires proficient science literacy skills, especially in the twenty-first century workforce and modern society to progress the world in science and technology (Adnan et al., 2021; Byee & Fuch, 2006; Dani, 2009; Schmoker, 2011; Yasar, 2020). Employers often look for potential employees that are proficient in collecting data and using data to make decisions in an innovative society. Therefore, there is a need to adjust the science curriculum to ensure students are literate in science to prepare them for post-secondary careers and education (Erwin, 2017).

A curriculum centered on science literacy is essential to achieving critical thinking through use of real-world situations and scientific conceptualization. Although common standards are established, curricula vary across the state, district, and schools making it challenging to determine effective data literacy resources in science. Nonetheless, the Science Georgia Standards of Excellence is centered on science literacy where students analyze information, construct arguments using evidence, develop models, and learn content in an inquiry setting. Proficiency in scientific literacy includes scientific knowledge, reasoning, critical thinking, and decision making based on sources of data. These components promote communication of concepts and make inferences of the natural world through argumentation and social problems. Achieving science literacy and being able to think scientifically and critically is the targeted goal of science education, which centers on knowledge, identifying questions, developing conclusions based on evidence, data, reasoning, and applying scientific concepts to real-life situations. Moreover, mastering science literacy allows individuals to apply scientific knowledge to real-life social issues to make positive changes. To be competent in science literacy, students should be able to interpret and evaluate scientific concepts and data and use scientific evidence to develop claims and draw conclusions (Adnan et al., 2021; Dani, 2009; Holbrook & Rannikmae, 2009; Lederman et al., 2013; Llewellyn, 2013).

The United States reformed much of the science curriculum to make learning centered on achieving a deeper understanding of science literacy and applying concepts to real-world issues, which was based on the adoption of the Next Generation Science Standards (NGSS) (Celik, 2014). Moreover, reforms, such as The No Child Left Behind act of 2002 and Every Student

Succeed Act of 2015 were implemented to address inequalities in learning and enforce accountability (United States Department of Education, 2021; Washington Office of Superintendent of Public Instruction, 2021). Yet, many curriculum reform ideas are not successfully implemented, which is indicated by state standardized assessments and NAEP report cards (Georgia Department of Education, 2022; NAEP, 2022). Holbrook and Rannikmae (2009) state that science literacy must have an impact on students' lives and motivate students to be change agents in a technology and science driven age. Thus, science education must be connected to relevant context situations to form a connection with students. To do this, student conceptions of science topics must be addressed. However, science teachers often have different conceptions towards what students should learn in secondary classes. For example, some emphasize data collection as an important part of inquiry science, while others emphasize communication of data sources to make scientific decisions (Gibson & Mourad, 2018; Lotter et al., 2007; Sund, 2016). Nonetheless, most agree that literacy in science is needed to ensure students can apply scientific knowledge to real-life situations (Adnan et al., 2021; Holbrook & Rannikmae, 2009) and use data connected to science concepts to solve real-life problems (Erwin, 2015; Filderman et al., 2021; Gibson & Mourad, 2018; Kjelvin & Schultheis, 2019). This research focused on a component of science literacy, which included data literacy.

Data Literacy

Data literacy refers to "the ability to collect, understand, manipulate, and use data" and is related to "the ability to collect, filter, select, analyze, interpret, critique, visualize, and communicate data (Suryadi et al., 2021, p. 1). Bowler et al. (2019, p. 2) describes being data literate as "a data-literate teen will have the skills, knowledge, and disposition needed to understand data in their personal life as well as in the contexts of data collection in the world in which they live." This description centers on the belief that data literacy is needed to engage in reasoning and problem solving based on real-life situations, which aligns to other research (Erwin, 2015; Suryadi et al., 2021). Data literacy is a cross-cutting theme in science, technology, engineering, and mathematics (STEM) education, which centers on computational thinking and the ability to interpret data to make informed decisions (Bodzin & Shive, 2003; Byee & Fuchs, 2006; Cezar & Maçada, 2021). For example, the importance of data literacy in science aligns the Georgia Standards of Excellence and the Next Generation Science Standards (NGSS), which emphasize formulating questions, collecting data to answer the questions formed, analyzing, interpreting, and making decisions based on the data provided and gathered.

Collecting, analyzing, and communicating data sources fosters conceptual understanding. During the collection process, students learn what counts as data, work with a variety of data sources, and identify necessary data to answer research questions. In the analysis process, students should be able to analyze data to identify patterns, consider ways to present data on different platforms, notice variation across data sources, and critically analyze information through conceptual thinking of different data sources. Students need to be able to distinguish data from evidence and coordinate multiple sources of evidence to construct scientific arguments (Forster et al., 2018; Greer & Curty, 2022; Suryadi et al., 2021).

Achieving data literacy improves one's ability to communicate data, use data as evidence, guide learning in an inquiry setting, and lessen one's likelihood of being susceptible to misleading information (Wolff et al., 2016). Communication of data results can take place in a variety of ways, such as constructed responses aligned to the claim, evidence, and reasoning science template, graphs, posters, data tables, and many other visual representations. Teachers are encouraged to provide students with multiple forms of visual data and ask questions that promote thinking, such as “What do you notice?” “What would you like to know?” “What trends or patterns can you identify in this data source to develop inferences on a particular topic being studied?” Moreover, in an inquiry science class, students should be encouraged to develop their own questions and locate relevant information and data sources to answer their questions that are relevant to their local context and community (Lotter et al., 2007). Since assessments have an important role in effective instruction, teachers can utilize a variety of science data literacy activities to identify students' knowledge and conceptualization of concepts being learned in class (Conn et al., 2020; Filderman et al., 2021).

With the emphasis on incorporating data literacy in science and an era centered on use, analysis, and manipulation of data, there is a need for students to be proficient in data literacy, which will positively impact student performance in secondary science and prepare students to be effective members of society (Gibson & Mourad, 2018; Mamedova et al., 2021). To prepare students for post-secondary education and careers in science, teachers must identify effective teaching strategies that target data literacy as every citizen must be able to analyze and synthesize data to make informed decisions in the world and prepare for the future (Conn et al., 2020; Filderman et al., 2022; Raffaghelli & Stewart, 2020; Wolff et al. 2016). Therefore, proficiency in data literacy is needed in the workforce and technology driven age (Magana, 2017). Through an emphasis on data rich classrooms, teachers can use lessons that center on engaging, exploring, elaborating, extending, and evaluating data to incorporate data literacy in their science classes (Ellwein et al., 2014; Harris et al., 2012).

However, many STEM areas have yet to effectively integrate data in the curricula to improve students’ learning in their ability to analyze, interpret, and make decisions based on real-world data and issues (Ellwein et al., 2014; Lestari & Rosana, 2020). Moreover, NAEP scores indicate learning deficiencies among students, which can partially be attributed to the COVID-19 pandemic. A recent conference report of NAEP scores cited a directional focus on increasing student engagement in STEM learning, use of data-driven classrooms with an emphasis on preparing students' skills needed to work with data, and supporting teachers to use effective instructional approaches in the learning process (Baker et al., 2022). Nonetheless, many teachers have indicated a lack of confidence in teaching data literacy, which suggests that professional learning centered on how to teach data literacy would be beneficial in advancing students' data literacy (Miller et al., 2021; Shernoff et al., 2017; Yang, 2022; Zucker et al., 2014).

Therefore, supporting teachers' integration of data literacy in science classes would help bring authentic data learning experiences to students and expand data literacy understanding in K-12 education to support STEM learning. This will help prepare students for STEM careers that require problem solving and critical thinking through use of all types of data (Gould, et al., 2014). Ensuring students are advanced in STEM subjects enforces global competitiveness, which is closely connected to global economics (Meyer 2016; Ornstein & Hunkins, 2018). This reiterates the need to support critical thinking skills and promote students to make connections within the curriculum and within other disciplines to develop further understandings in context areas. By fostering data literacy in secondary schools, students will be able to make better informed decisions and solve problems related to schooling, society, and in their personal lives (Gould et al., 2014). Hammett and Dorsey (2020) suggest that students need to use data in exploration activities centered on phenomenon-based learning, and messy data is an effective source to use during this learning process. Messy data allows students to engage in the NGSS concepts through use of authentic data and explorative investigations, where students analyze data and develop argumentation through use of sources of evidence. Authentic data aligned to real-world problems is suggested to engage students in learning and complex thinking. Models have been found to be useful to facilitate visualization and promote students to interpret complex data sets. Authentic data also engages students in focusing on data results and considering bias sources, which promotes students to think like scientists (Gould et al., 2014).

In addition to using data as evidence to support inquiry STEM learning, data literacy can be used to advance cross-curricular approaches, decision making, and inclusion through meaningful, intentional approaches and improve equity in schools. For example, Gibson and Mourad (2018) describes data literacy as knowing the tool to use based on quantitative data, understanding how to apply the tool in a scientific context, understanding how to interpret data related to questions or formulated hypotheses, and being able to effectively communicate results based on data and scientific concepts. Data literacy can also be used as an interdisciplinary approach, which has been linked to improved student outcomes. For example, van 't Hooft et al. (2012) and Vahey et al. (2012) used a project called “Thinking with Data” to address cross-curricular approaches centered on data literacy. The findings indicated that this interdisciplinary approach improved science, social studies, and mathematical achievement among students.

Moreover, data literacy has improved decision making in previous studies. For example, Dunlap and Piro (2016) found that explicit instruction and collaborative data literacy learning improved pre-service teachers’ decision making. Similarly, Lestari and Rosana (2020) found that rising 9th grade students were deficient in using data to make decisions therefore suggesting that additional data literacy support was needed that center on decision making to prepare students for careers and advance education. Consequently, expanding data literacy requires a collaborative approach among stakeholders to positively impact informed decision making that affects today's society and the future world (Conn et al., 2020; Filderman et al., 2021).

Collaborative approaches nurture an environment conducive to supporting teachers, which is essential in advancing students' data literacy as teachers must know data literacy and understand how to develop data literacy in the context of their classrooms. To be effective, teachers should collect, analyze, and interpret data to make informed decisions in their instructional practices using academic and non-academic data, such as attendance and behavioral data (Conn et al., 2020). However, many teachers do not use data strategically to make informed daily decisions. Consequently, it is unclear if pre-service teachers are adequately prepared in data literacy in their classrooms. Nonetheless, evidence-based recommendations have been made to support novice teachers in data literacy. These include teaching foundational data literacy early in preparation programs that include multidimensional data use from academic and non-academic sources. After foundational knowledge is established, learning opportunities that center on data literacy should be embedded throughout the preparation program (Mandinach & Gummer, 2016).

A focus on teachers' data literacy and its impact on students' learning is a relatively new field of study. Much research is situated on teachers' use of classroom data to make instructional decisions (Dunlap & Piro, 2016; Henderson & Corry, 2020; Kennedy-Clark et al., 2020; Raak et al., 2021), but less research centers on teachers' conceptions and use of authentic data to advance students' data literacy. Once teachers become confident and proficient in data literacy, they will be able to incorporate data literacy activities in science, which will allow teachers to gain a deeper understanding of students' abilities to synthesize information and make inferences based on data sources presented (Miller et al., 2021; Shernoff et al., 2017). These understandings are aligned with much of the Georgia high school standards and therefore an essential learning skill that students need to master in life science and physical science classes. Consequently, intentional implementation of data literacy activities in K-12 education is needed to promote understanding. For example, students need to understand the objective of collecting data through use of research-based strategies (Medova et al., 2022). Therefore, teachers need to clearly communicate the purpose of data collection, analysis, and interpretation.

In preparing data literacy lessons, a variety of instructional strategies and resources that provide diverse opportunities should be considered when designing data literacy activities. For instance, collaborative learning should be emphasized, which is supported by Vygotsky's social learning theory, to expand students' data literacy knowledge (Ofori-Attah, 2021). Teachers should allocate time for students to develop data literacy skills through use of meaningful data connected to real-world context (Celik, 2014; Jordan et al., 2015; Vahey et al., 2012). Furthermore, teachers should stay current with use of different instructional resources, such as technology to develop visuals of data, to allow students to submerge themselves in data analysis using technologies to develop graphs and other visuals (Gibson & Mourad, 2018; Whitman & Kellher, 2016).

Effective instructional approaches are needed to foster data literacy in science, which includes a variety of learning components, such as knowing how to collect, find, analyze, and interpret sources of data. Yet, many lack the ability to work effectively with data in these elements (Jordan et al., 2019; Sugiarti et al., 2021). D'Ignazio (2017) cites five tactics of incorporating creative data literacy in learning, which includes utilizing community-centered data, using data to make data biographies, making data messy, utilizing learner-centered tools, and community-centered outputs to foster engagement in data literacy. Similarly, Gibson and

Mourad (2018) found that participants of a data literacy conference recommended teachers identify specific skills related to data collection and data analysis and then combine these areas into a content specific course. To identify appropriate data instructional approaches, reaching out to other instructors other than biology teachers to identify how they implement data literacy strategies in their departments and classrooms was a proposed recommendation, which mirrors the present research design.

In addition to research based instructional approaches, teachers' conceptualization of data literacy is essential to help individual learners' needs and improve learning outcomes in data literacy (Henderson & Corry, 2020; Yang, 2022). To be data literate, students must first understand sources of data, how data is collected, and the value of data in making inferences. For example, the NGSS state students should be able to decipher between qualitative and quantitative data sources, which can be displayed in visuals to identify patterns and investigate phenomena (NGSS Lead States, 2013). Likewise, students need to understand the benefits and limitations of different data sources, such as discrete, continuous, raw, nominal, ordinal, archive, and real-time data. Therefore, teachers' conceptualization of data literacy is essential in supporting students' understanding in these areas (Hunter-Thomson, 2019).

Identifying teachers' conceptualization is an intricate process, which requires an understanding of a complex set of events or ideas and is limited in the data collection process as there is an interplay between the conceptual process and an actual observation process (Sequeira, 2015). Nonetheless, identifying teachers' conceptions gives insight into teachers' forms of ideas and will be useful in regards to the focus of the present research study. Lotter et al. (2007) suggest that teachers' beliefs about students' abilities impact instructional decisions.

Moreover, teachers' professional knowledge of teaching in a particular area is known as pedagogical content knowledge, which has been linked to instructional effectiveness (Cannon, 2022; Cui & Zhang, 2022). However, conceptions of effective instruction vary (Lotter et al., 2007). Pedagogical content knowledge influences the way teachers engage students in learning based on their content knowledge and knowledge of teaching. Data use and data practice is under conceptualized, which suggest that teachers have pedagogical content knowledge deficiencies in this area (Spillane, 2012). Henderson and Corry (2021) found that teachers were underdeveloped in data literacy suggesting that teachers' data literacy needs should be identified so that professional development could be implemented to improve instructional practices and students' learning.

Miller et al. (2021) situated their study on data literacy in secondary sciences and found that professional development had positive implications for supporting teachers' use of incorporating data literacy strategies. However, the study was limited as it did not consider teachers' conceptions of data literacy knowledge and skills students needed to possess, nor did it address teachers' conceptions of how students perform on data literacy concepts, teachers' conception of strategies to foster data literacy among students, and differences between life science and physical science conception. Therefore, addressing these data literacy areas is needed to improve data literacy among science students. By improving data literacy, students are able to engage in data literate discourse and scientific problem solving.

Improving data literacy would affect many stakeholders including teachers, families, students, administrators, businesses, school leaders, and curriculum developers. For example, students will benefit from the present research as it will shine light on strategies that are currently being used to foster data literacy and teachers' belief of what students need to know to be data literate, which will help develop curricula and trainings centered on best instructional practices to promote student learning. Teachers and curriculum developers will benefit from the present research as conceptions and strategies used will be revealed that will help teachers implement effective lessons and strategies that are instructionally sound to advance students' learning. Improving data literacy will thus positively impact teachers' instructional effectiveness as their roles as educators. Similarly, administrators and school leaders will benefit from the present research as it will provide areas where they can serve as support roles and implement professional learning based on the needs identified. By improving data literacy, student data literacy will positively impact student performance and further prepare students for career and college readiness, which will affect performance ratings for teachers, administrators, and schools. Likewise, since data literacy is needed in many of the careers offered in today's society, local businesses will benefit in this area as future employee candidates will be ready to work in jobs that require data literacy skills and understanding. Therefore, improving data literacy will be beneficial to families as it will help ensure students are competent in data literacy and ready for the competitive world that centers on use and understanding of data. Consequently, improving data literacy offers valuable implications for stakeholders in the community, and collaborative partnerships could be emphasized to further improve data literacy among secondary students (Conn et al., 2020; Filderman et al., 2021).

The present research took place in the researcher's rural school district, which has a large number of students below proficiency level in science based on biology EOC data. For example, 59.81% of students scored below proficient on the EOC biology and physical science assessments in 2019. Moreover, in comparison to the state's average score, this rural high school scored below in science by 7.54% (Georgia Department of Education, 2020). Additionally, upon speaking with teachers and discussing teacher and common district assessments, it is evident that students lack proficiency in data literacy as many struggle with visualizing, analyzing, and interpreting data sources in science.

Statement of the Problem

Underdeveloped data literacy among students in science has been identified in the school district where the researcher works. Currently, teachers have different views towards data literacy and thus use different instructional approaches to support data literacy in their science classes. These different ideas of data literacy are poorly communicated among teachers. Moreover, little collaboration takes place between life science and physical science teachers to discuss and identify best instructional practices to improve data literacy. As a result, this leads to ambiguous ideas of best instructional strategies to improve data literacy. This problem impacts student performance in science because many science standards require students to obtain and use data sources to analyze, interpret, and communicate scientific topics. Many possible factors contribute to this problem, including teachers having a poor understanding of data literacy (Dunlap & Piro, 2016; Kippers et al., 2018; Yang 2022), poor student conceptual understanding of data literacy (Dichev & Dicheva, 2017; Vahey et al., 2012; van 't Hooft et al., 2012), and lack of understanding how to obtain and apply authentic data (Farrell et al., 2021; Vahey et al., 2012; Wolff et al., 2019). The present study contributed to the body of knowledge needed to address this problem by identifying teachers' conceptualization of data literacy, teachers' expectations of data literacy, teachers' instructional strategies used to promote data literacy in science classes, and differences in conceptualization and strategies among life science and physical science high school teachers.

Much research focuses on teachers' use of data to improve their own instructional practices (Dunlap & Piro, 2016; Henderson & Corry, 2020; Miller et al., 2021; Stephenson & Patti, 2007; Yang, 2022), but few studies address teachers' conceptions of student data literacy in high school science classes. Additionally limited research addresses teachers' conceptions of how students work through different concepts related to data literacy in science classes, and few studies address teachers' conceptions of students' skills and knowledge needed to be data literate and strategies used to foster data literacy varied in the literature. Moreover, limited studies were available in the databases that addressed the differences between life science and physical science teachers' conceptions of students' data literacy and strategies used to improve data literacy.

Purpose of the Study

Understanding teachers' conceptions of student data literacy and strategies and approaches used to improve data literacy in science is an area that has limited research. Nonetheless, addressing this area is useful to many areas in secondary science classes, which center on data analysis and using data for decision making (Cavalluzzo et al., 2013). Therefore, the purpose of the present study was to use a qualitative research design to discover the conceptions high school life and physical science teachers have toward student data literacy and strategies used to improve life science and physical science education in a school district located in west-central Georgia. Teacher conceptualization is defined as ideas and understandings teachers have toward data literacy among life science and physical science students.

Specifically, this study focused on discovering the conceptions teachers have related to data literacy to reveal teachers' understanding concerning the meaning of data literacy. The research also sought to discover specific data literacy knowledge and skills teachers expect their students to possess, and teachers' conceptions of how students work through data literacy concepts. Lastly, the research investigated specific instructional strategies teachers use to foster data literacy and compare differences, if any, between life science and physical science teachers.

Research Questions

1. What are secondary science teachers' conceptions of data literacy?
2. What specific data literacy knowledge and skills do teachers expect their students to possess?
3. What are teachers' conceptions of how students perform or work through different concepts related to data literacy?
4. What specific instructional strategies do teachers use to scaffold and foster data literacy, and how do these instructional strategies and conceptions of data literacy differ between life science and physical science teachers?

Overview of Theoretical and Conceptual Frameworks

The present study aimed to investigate teachers' conceptualization of student data literacy and their experiences with different data literacy strategies. The current research employs the transformative learning theory (Mezirow, 2009), which states that learning involves making meaning of one's experiences and consists of change to meaning structures, which includes schemes and perspectives (Tikka & Oinas-Kukkonen, 2019). The transformative learning theory maintains that people must make their own interpretation through change in schemes and critical reflection to lead to perspective transformation (Dirkx, 1998). Meaning schemes are an important component of the transformative learning theory, which refers to the concepts, beliefs, and feelings that shape one's interpretation of knowledge and information.

The rationale for using this learning theory came from the idea that learning takes place through self-examination and meaning structures, which addresses how one makes meaning of a stimulus and is shaped by past experiences, feelings, and thoughts. The transformative learning theory suggests that conceptions are cultivated from beliefs, expectations, experiences, and purposes (Bush et al., 2020). The current research sought to examine teachers' conceptions of student data literacy and strategies to improve data literacy, which will be addressed through open and reflective discussions to prompt self-examination among participants, which is a critical component of the transformative learning theory (Mezirow, 2009; Strange & Gibson, 2017). Document analyses allowed evaluation of data literacy assignments in science classes. This helped provide an overview of the curriculum used to teach data literacy in science classes. The documents obtained were reviewed for learning processes and competencies needed to advance data literacy. Teachers were asked to provide explanations for the documents they supplied as this helped the researcher understand the teacher's interpretation of their experiences, which aligns to the transformative learning theory as meaning structures are formed.

Through semi-structured interviews and documents (Merriam & Tisdell, 2016), teachers were asked to critically reflect on their experiences with data literacy among high school students, which aligns to the transformative learning theory by enhancing self-awareness through reflecting on experiences. Similarly, observations provided information on how teachers make sense of data literacy through their own instructional practices (King et al., 2019; Perry, 2021). The results of this research provides insight in understanding one's self, revise one's belief system, and make behavioral changes through implementation of strategies to improve data literacy, which aligns to the transformative learning theory.

In addition to the overarching transformative learning theory framework, the present study is situated on the concept of proficiency in data literacy as a component of science literacy needed to be successful secondary classes and prepare students for postsecondary education, careers, and citizenship. The conceptual framework centers on the facets of data literacy obtained from Gibson and Mourad (2018), which include collecting, recording, analyzing, interpreting, communicating, and using data for decision making. These facets of data literacy include a matrix of competencies associated with different levels of understanding, which includes basic intermediate, and advanced understanding of data literacy.

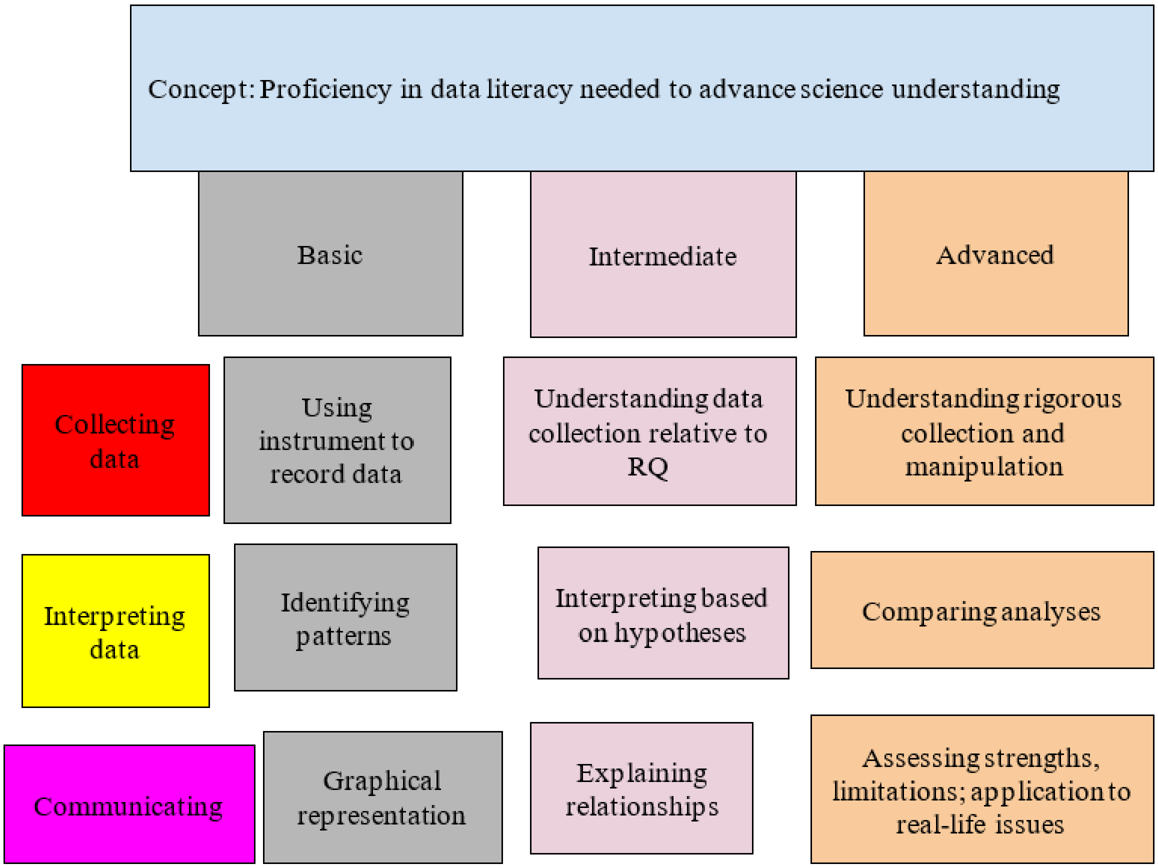
For example, a basic understanding of collecting and recording data would require knowledge in using an instrument to obtain and record data; whereas, intermediate data literacy understanding of data collection would include the ability to identify data and collect relative to a scientific question as well as knowledge in how to enter data into a spreadsheet or database. To progress in competency of understanding and reach the advanced data literacy level of data collection, understanding how to incorporate rigorous data collection and understanding how to store, manage, and manipulate different types of data is required (Gibson & Mourad, 2018). Moreover, Spillane (2012) suggested organization in data should be considered in the conceptual framework of data literacy research as it allows identification of patterns and relationships.

A basic, intermediate, and advanced understanding of analyzing and interpreting data is also considered in the present research. For example, a basic understanding of analyzing and interpreting data requires students to know how to describe data and identify patterns of data; whereas, an intermediate level of understanding for analyzing and interpreting data would require students to know how to analyze and interpret data and be able to interpret results based on hypotheses and research questions. Additionally, an advanced level of understanding would require understanding how to incorporate data analysis when selecting experimental design and being able to compare results among analyses (Gibson & Mourad, 2018).

Similarly, communicating data can be separated into three understanding levels. For example, a basic understanding of commuting data requires knowing how to construct visuals and being able to describe graphical representations of data; whereas, an intermediate level of understanding requires being able to explain the relationships among data and understanding how to use data sources as evidence in argumentation. Taking understanding to a deeper level and an advanced level would require being able to assess strengths and limitations of data and understanding relationships of data and how it relates to issues in society. Figure 1 displays the data competency matrices (Gibson & Mourad, 2018).

Figure 1

Matrix of data literacy competencies



In addition to the levels of understanding and data literacy competencies described, the present study embraces the belief that data literacy requires an ability to understand and evaluate sources of authentic data, use mathematical reasoning to solve real-life problems, select and explore sources of authentic data to answer research questions or support argumentation, and use a variety of visuals to display sources of data. These concepts are presented in Table 1 below, which is an adapted conceptual illustration from Kjelvik and Schultheis (2019).

Table 1

A comparative diagram illustrating the overlap of quantitative reasoning and data literacy

Mathematical Reasoning	Mathematical Reasoning and Data Literacy	Data Literacy
Applying theory to mathematical models and functions.	Applying mathematical principles to real-world problems through use of data and critical thinking.	Selecting and exploring data to develop questions and evaluate information.
Using computational thinking to identify patterns in data, curate data, and visualize a variety of data.	Understanding and evaluating information from data.	Developing an understanding of content knowledge through use of data.

Thus, the present study's conceptual and theoretical framework centers on the belief that concepts are formed from experiences, data literacy involves critical understanding of collecting, analyzing, interpreting, and communicating data, and authentic data should be used to guide and answer scientific research questions.

Methodology Overview

Research Design

The present research followed a qualitative, interpretivist paradigm (Kivunja & Kuyini, 2017). The use of a qualitative research design is appropriate when there is a limited understanding of the research phenomenon and when capturing participants' voices is essential to gain a deeper understanding of the research problem. Qualitative research allows one to gather qualitative data that is then decoded to identify themes and subthemes. The interpretivist paradigm was chosen as it situates on human experiences, which the present research sought to address from participants' data literacy strategies. Moreover, the interpretivist paradigm seeks to understand the individual and their interpretations of concepts, which aligns to the present research phenomenon of teachers' conceptualization of data literacy. Additionally, the present research sought to analyze human behavior through observations and gain an understanding of teachers' interpretation of data literacy, which centers on the interpretivist paradigm (Kivunja &

Kuyini, 2017; Stahl & King, 2020). This paradigm connects to meaning-making, which relates to one's views of realities based on previous knowledge and experiences. Through the present research, participants' meaning-making of data literacy and strategies used to foster data literacy were addressed (Krauss, 2005). Table 2 displays the researcher's lens by situating the research on the interpretivist paradigm.

Table 2

Paradigm lens of researcher

Process	Lens
Paradigm	Interpretivist: Conceptions are formed from beliefs, experiences, expectations, and purposes (Kivunja & Kuyini, 2017; Pulla & Carter, 2018)
Approach	Qualitative approach with a focus on context and human experiences (Kivunja & Kuyini, 2017; Pulla & Carter, 2018).
Constructing Meaning	Meaning-making is a process in which one interprets experiences based on previous knowledge and past encounters.

An exploratory case study design (Baxter & Jack, 2008) was used as this design allows the researcher to conduct an in-depth exploration that focuses on a person, group of people, or phenomenon and is valuable in focusing on a particular area of a research problem by extensively studying participants. Due to the limited literature that addresses teachers' conceptions of students' data literacy in science classes and strategies used to foster data literacy, an exploratory case study design was used in the present study. This design aligns to the present study's research goal, which sought to analyze a complex issue in a real-life setting by focusing on a group of physical science and life science teachers in a local school district. Specifically, semi-structured interviews, observations, and documents were used as data collection methods to obtain qualitative data as participants respond to different prompts related to their conceptions of students' data literacy and strategies used to improve data literacy in science (Merriam & Tisdell, 2016; Rashid et al., 2019; Wiens et al., 2019).

Population Characteristics and Sampling Procedures

The population included science teachers with different levels of education and experiences. Non-random purposeful sampling (Suri, 2011) procedures were used in this study. The participants included teachers from two rural, high-needs high schools located in the same district in west-central Georgia. A total of 3,859 high school students were enrolled in the school district, which included the following demographics: 44.1% Black students, 42% White students, 7.4 %, Hispanic students, 4.5% multi-racial students, 1.7% Asian/Pacific Islander students, and 0.2% American Indian. Additionally, 56.1% were economically disadvantaged, 10.7% were students with disabilities, and 3% were English language learners (Georgia Department of Education, 2023).

Seven of the participants were from where the researcher worked, which consisted of approximately 1,400 students and included the following demographics: 56.2% White students, 33.6% Black students, 4.6% Hispanic students, 4.5% multi-racial students, and 1.2% Asian/Pacific Islander students. Additionally, 55% of the student body were economically disadvantaged, and 9.1% are students with special needs (Georgia Department of Education, 2023).

Similar to the student population demographics, teacher demographics varied across the school. For example, approximately 60% were White, 38% were Black, and 2% were Hispanic. Nonetheless, diversity among teachers varied less compared to the student population. Additionally, approximately 60% of the teachers are females and 40% of the teachers are males. Of the teachers in the school district, there was a wide range of experience and education. For the purpose of this study, experience was defined by years of service as an educator, and education was defined by highest degree obtained. Some participants were in the induction phase of teaching (less than 3 years of teaching experience), while others had over 30 years of experience. Similarly, the level of education ranges from a bachelor's degree to a doctorate degree. Most educators were teaching within their certified field. The average level of education was a master's degree. Given the diversity of the student body and certified personnel, the present research included a rich variety of educators of different ethnicities and educational backgrounds to ensure cases are true representatives of the sample (Borup, 2016). Prior to selecting participants for the study, school district permission, participant informed consent, and an IRB approval application was obtained to ensure all research protocols were satisfied. Participants' willingness to participate was confirmed via email, and participants were informed of the purpose of the present study and the confidentiality of their participation in the study. The criteria for selecting the participants were that each participant was an active employee teaching high school science classes in the school system.

Physical science participants included the following: One White male with three years of educational experience who had a master's degree. A White female with 16 years of educational experience and had a doctorate degree. Additionally, another White female was included. She was in her first year of teaching and held a Juris doctorate degree. Lastly, one Black female with two years of experience and a master's degree was included in the physical science teacher category. Similarly, life science teachers included the following: A White female with one year of experience and a specialist degree, a bi-racial female with six years of experience and a master's degree, a white female with less than one year of experience and a bachelor's degree, and a Black female who was in her first year of teaching and held a master's degree.

Eight participants were included in the present study to try and ensure rich data were obtained, especially since many of the participants had limited years of experience. The researcher attempted to recruit teachers with more years of experience; however, response rate was low as many did not respond to the several emails sent. Nonetheless, the researcher anticipated this to be challenging and thus offered each participant a $25 Visa gift card at completion of the data collection process for their time and willingness to participate in the study.

Data Collection Tools/ Instruments

Interviews

Prior to conducting the interview, the interviewer minimized bias by reflecting and setting aside individual beliefs related to the topic so that the results of the interview were not constrained. All interviews were semi-structured in nature, and follow-up questions were used for some of the interview questions. Nonetheless, the interview was focused on guided questions to obtain teachers' conceptions, expectations, and strategies used to foster data literacy. The interviews were conducted in-person and recorded using an app on the researcher's phone. Prior to conducting the interviews, background information from participants was retrieved, which include level of education, years of teaching, current position, race, and gender. This information was retrieved through a short questionnaire, which was sent after obtaining each participant's consent form. During the interviews, notes were taken to record participants' responses, which included non-verbal data, such as body language. Following transcription, data were analyzed using open coding, axial coding, and thematic analysis to identify recurring and emerging themes related to teachers' conceptions, expectations, and strategies used to improve data literacy (Bezen, et al., 2016; Merriam & Tisdell, 2016).

Observations

Observations were conducted in-person and lasted 45 minutes. Each participant was observed once. These observations took place during the school day when participants were providing instruction. The researcher began the observation for each teacher at the beginning of the block to ensure consistency. Moreover, the researcher was a passive participant (Ergler, 2017) while conducting observations. This was because the researcher was noticeable in the room when conducting classroom observations but did not interact with the participants or students. Thus, the researcher sat in an area away from others and took notes using an observation guide and research journal. Therefore, the degree of involvement was low, which aligns to the passive participant. Highly descriptive field notes of the setting, participants, activities, and conversations were documented and converted to a narrative format (Merriam & Tisdell, 2016).

Documents

Each participant was asked to supply a data literacy activity and evaluation document that they had used in their science classes. These sources helped capture the curriculum in place. Documents were only obtained from participants included in the study to ensure confidentiality and participants' willingness to share materials. The authenticity and accuracy of each document was verified (Merriam & Tisdell, 2016). However, much of the documents supplied were premade.

Although steps were taken to lessen bias in the research, some ethical concerns were still considered, such as teachers knowing the researcher. Therefore, the personal and professional relationship the researcher had with the selected participants may have caused the participants to act in socially desirable ways to impress the researcher and may not reflect the true conceptions of data literacy and instructional strategies and resources being used in physical science and life science classes. Nonetheless, the researcher strived at maintaining a professional relationship with all participants throughout the duration of the study. Additionally, the researcher had an equal role as participants in the study as all work as teachers in the same school district. Thus, a superior leadership position was not a bias factor in the present research (Merriam & Tisdell, 2016).

Data Analysis Procedures

Based on participants' availability to fulfill their role in the present research, data was simultaneously collected and analyzed for interviews and observations, which were followed by document analyses. The qualitative data that was obtained from the interviews, observations, and documents was categorized and coded. Data were systematically categorized as it was collected, and open-coding was initially used in the analysis process (Merriam & Tisdell, 2016). Axial coding was used to find connections in the datasets, and thematic analysis was used to identify patterns. Data were organized using analytic questions and visual devices, such as tables created in Microsoft Word. Once main themes were identified, the study narrowed in data supporting subthemes. Moreover, data were organized based on the present study's purpose and the comparative analysis method was used to narrow categories. All data were compiled into one file for each RQ for data from the interviews to allow comparisons among participants' responses (LeCompte, 2000).

Each interview was transcribed and analyzed, which followed with member-checking to improve validity in the present study (Stahl & King, 2020). Data from all three instruments were read multiple times, and noted impressions were recorded during this process. Preconceived themes were set aside to allow in-depth exploration of the data. The research questions were referred to regularly as data were analyzed based on individual responses and research questions. Comments and highlighters in Microsoft Word were used to group data, which was categorized using codes, and codes were used to identify themes and subthemes in the dataset.

Another researcher was asked to code a portion of the data. This helped establish validity as an inter-coder agreement rating was used to establish themes that are consistently identified from the codes identified by the two coders (Kennedy-Clark et al., 2020). A comparison of themes was made between life science and physical science teachers (Bezen et al., 2016; Merriam & Tisdell, 2016).

The discovered themes helped answer the research questions. Thus, through the data analysis process, themes addressing concepts teachers have related to data literacy and teachers' understanding of the meaning of data literacy in science was revealed. Additionally, coding lead to identification of themes and subthemes, which were created based on the present study's research question that centered on teachers' conceptions, expectations, strategies used to foster data literacy and differences, if any, between life science and physical science teachers' conceptions of data literacy (Bezen, et al., 2016; Merriam & Tisdell, 2016).

Cypress (2017) suggested that rigorous qualitative research compares to the concepts of reliability and validity, which are both necessary for trustworthy outcomes. Validity in qualitative research relates to how well the results of a study illustrate the true findings among participants alike; whereas reliability in qualitative research refers to the consistency of the measure being used. The present study was carefully designed with validity and reliability in place by identifying the research paradigm alignment, triangulating data, member checking, use of an inter-coder, and reflective practices of the researcher (Stahl & King, 2020).

Limitations/Delimitations

Limitations

Purposeful sampling was used to select participants based on their willingness to participate in the study, and all science teachers in the district were not included. Therefore, the study consisted of a small sample that was a representative of the teacher population in the school district. Consequently, a small sample size can cause findings to be limited as the study site only included one geographical region in two schools, thus limiting the representation of the present research and narrowing the perspectives collected. Since the sample size was small, the results obtained were limited on generalizability. Nonetheless, the rich description that was included helped address this area (Merriam & Tisdell, 2016). Moreover, although only a small sample was included, the sample consisted of the majority of teachers in the researcher's science department and thus illuminated conceptions and strategies being used to address data literacy, which will be useful for future development of professional learning and science curricula. Nonetheless, the lack of diverse ethnicities and genders among the participants can be attributed as a limitation of the present study. Lastly, confounding variables (covariates) were not addressed in the present research, which may impact teachers' conceptions.

Delimitations

The selected topic was chosen as the area of focus to allow the researcher to explore data literacy conceptions, expectations, and strategies used among teachers, which findings can be used to adjust science curriculums and develop professional learning targeted to improving instructional effectiveness to increase student achievement. The research questions helped identify teachers' conceptions, expectations, and experiences of student data literacy in science classes. Moreover, the selected population was targeted to ensure teachers' responses directly addressed the research questions. Participants were easily accessible since they were all in the same district as the researcher. Positive, professional relationships established with many of the selected participants likely permitted participants to feel comfortable and allowed them to provide a thorough synopsis of their conceptions and experiences related to data literacy in science. The rapport the researcher had among the chosen population likely increased participants' willingness to participate in the study. Since the population was from only one school district, meeting with participants and conducting observations was feasible. Additionally, participants were diverse in education background, experience, and science subjects they taught to help obtain teacher conceptions from different backgrounds and perspectives. Multiple sources of data were gathered to triangulate the study. Moreover, the use of a qualitative paradigm and triangulation of data collection methods aided in establishing validity and reliability in the present study.

Definition of Terms

- Authentic data: Data that is relevant to students' lives and obtained from real-world issues (Kjelvin & Schultheis, 2019).
- Competence: A set of skills, knowledge, and attitudes that are possessed or needed to be acquired to perform an activity within a specific context, whereas, performance may range from the basic level of proficiency to the highest levels of excellence (Sampson & Fytros, 2008).
- Concept: Refers to an idea that is formed from observations and/or experiences (Sequeira, 2014).
- Conceptions: Involves the formations of ideas (Sequeira, 2014).

- Conceptualization: Involves specifying exactly what one interprets through words or a complex set of ideas (Sequeira, 2014).
- Contextualization: The process by which connecting knowledge with real-life situations (Rogayan & Macanas, 2020).
- Data Literacy (in the context of science learning): Data literacy is the ability to collect, manage, evaluate, and apply data, in a critical manner (Ridsdale et al., 2022). This includes the abilities to select, clean, analyze, visualize, critique, and interpret data, as well as to communicate stories from data and to use data as part of a design process (Wolff et al., 2019).
- Educational Data Literacy: "The ability to collect, manage, analyze, comprehend, interpret, and apply educational data in an ethical, meaningful, and critical manner" (Papamitsiou et al., 2021, p.10).
- Experienced teacher: An educator with greater than 3 years of experience.
- In experienced/induction teacher: An educator with 3 or less years of experience.
- Life science classes: Includes the following high school courses in the researcher's school district: Biology, anatomy, and environmental science.
- Life science teacher: An educator who teaches primarily science that centers on living organisms.
- Physical science classes: Includes the following high school courses in the researcher's school district: Physical science, chemistry, and forensics.
- Physical science teacher: An educator who teaches primary sciences that center on concepts that are non-living.

Implications and Significance of Study

Lack of proficiency in science data literacy negatively affects students' performances. Students in the local school are underperforming in science, which is evident in EOC scores as over 50% of students in the district scored below proficiency in science based on physical science and biology scores in 2019, 2022, and 2023 (Georgia Department of Education, 2023). As a result, students' overall performance is low, which negatively impacts students' grades. The effects of low proficiency in science extends beyond the school. For example, state administered assessments scores are used to assess the effectiveness of schools and districts, which is reported in the College and Career Ready Performance Index (CCRPI) score. These scores are used to enforce accountability, and low scores can negatively impact schools from receiving federal funding and create a negative perception. Based on the most recent CCRPI report available, the school's overall score is 73.5 for the 2019 school year, which is below the system's and state's average of 73.5 and 78.8, respectively (Georgia Department of Education, 2023). Therefore, there is a need to identify teachers' conceptions of data literacy and strategies used to foster student data literacy to improve student achievement in science classes.

Despite the federal accountability efforts in place to improve students' learning in a data driven society, many students struggle in reaching data literacy proficiency suggesting training centered on data literacy should be revised (Henderson & Corry, 2021). Although research has been conducted to address the effectiveness of literacy resources in improving students' performance and scores in science classes (DiCecco & Gleason, 2002; Kaldenberg, et al., 2015; Reed et al., 2017), less has been done on teachers' conceptions of students' science data literacy, teacher expectation of specific data literacy knowledge and skills students need, and scaffolded strategies and resources used to foster student data literacy. Additionally, limited research was available in the databases used that addressed teachers' conceptions of students' data literacy among life science and physical science classes in a high needs school. Therefore, to fill this gap and address local needs, the present study was situated in a rural area and focused on teachers' conceptions at two high schools in the district.

The present study provided knowledge to the developing literature of data literacy approaches in science education by conducting interviews, observations, and document analyses in a rural school district consisting of two high needs high schools and focused on teachers' conception, expectations, strategies used to foster data literacy, and differences, if any, between life science and physical science teachers. For the purpose of this study, a high needs school is defined as a school that has a student population that consists of 30% or more qualifying for free or reduced lunches according to the free and reduced guidelines from the Georgia Department of Education.

Many stakeholders have the potential to benefit from the present research, which shines light on conceptions, experiences, and expectations teachers have towards data literacy in science. The findings can be used to positively impact teachers, leaders, and students in the school district. Since the researcher serves as a science teacher in the district where the research was conducted, the present study will increase her knowledge of conceptions and strategies used to foster data literacy so that she can provide effective data literacy instruction in her science classes. Moreover, the results of this study can be used for leaders in the district to allocate funding for resources and professional development that centers data literacy in science (Kennedy-Clark et al., 2020). School level faculty have the potential to also benefit from this study as it provides an understanding of teachers' conceptions of data literacy to identify areas of improvements, which results can be used to revise science curricula across the school and district.

Often, preservice and newly in-service teachers struggle with identifying effective strategies to improve science data literacy, and much research suggests that there is a lack of effective training centered on data literacy (Mensah, 2011). Therefore, addressing the present study's research questions added to the available body of research of effective strategies in science to improve data literacy and limited research on teachers' conceptions of student data literacy.

The present study offers an in-depth understanding of the targeted participants' conceptions of student data literacy in life science and physical science high school classes. Through the information gathered from teachers' conceptions and instructional data literacy practices, science curricula can be revised to promote change in science instructional approaches and resources to improve student learning. The implications of this study can be used to develop professional learning and curriculum aligned to best instructional data literacy practices and strategies for in-service and preservice teachers to improve science learning and prepare students for a 21st century workforce (Henderson & Corry, 2021). Consequently, the present study provides knowledge to the developing literature of data literacy approaches and resources in science education to improve high school student data literacy and thus student achievement. Considering the present research will only focus on teachers' experiences and conceptions, future research can be replicated that addresses students as participants in a larger research scale that includes more than one school or district and across Georgia or the United States.

Summary

Literacy in science relates to students' abilities to read, write, comprehend, critically think, and solve complex problems with no apparent answers. The present research focuses on data literacy, which is a component of science literacy. Data literacy is an evolving field that centers on collecting, manipulating, critiquing, analyzing, interpreting, and communicating sources of data, which is emphasized in by the NGSS and Georgia Standards of Excellence. These standards center on inquiry learning, constructing argumentation, and using and interpreting sources of evidence, which can include a variety of authentic data sources. With the evident need of improving the local high school science education, the present study adds to the limited studies available that address teachers' conceptions of student data literacy and offer information on instructional strategies and resources used to promote data literacy in science. The findings aid in identifying differences and similarities between life science and physical science high school teachers in regard to conceptions of student data literacy and strategies used to foster data literacy in science, so that changes can be made to improve student achievement in science. The research employs the transformative learning theory, which suggests that conceptions are cultivated from beliefs, experiences, expectations, and purposes. Moreover, the research centers on the conceptual framework that data literacy includes a matrix of competencies and data facets, which requires an overlap of quantitative reasoning. Participants were purposefully selected from two schools in the same district, and data were collected through semi-structured interviews, observations, and document analyses. Data were coded to develop themes. Although the study had several delimitations, such as selecting participants that would likely aid in supplying rich data and including participants from diverse backgrounds, several limitations must be considered. These include the researcher's established relationship with the selected participants, a small sample size, and limited generalizability. Nonetheless, the present study offers valuable information to curriculum specialists and program developers in designing resources and strategies to improve data literacy in science. Moreover, the differences identified between life science and physical science education can be used to promote cross curricular collaboration. The results of the study can also be used to design on-going professional development that centered on supporting students' data literacy abilities in science. The following chapter includes an in-depth literature analysis aligned to the research topic.

Chapter II: Review of Literature

The present research situated on the problem of students' data literacy being underdeveloped affecting students' learning in their high school science classes. Since data literacy conceptions and strategies implemented among life science and physical science teachers are not clearly defined, the present research addressed teachers' conceptions, expectations, and strategies used to foster data literacy. Likewise, analysis of similarities and differences between the two groups of science teachers were addressed. Thus, addressing this problem helped identify current conceptions, expectations and practices implemented so the science curriculum can be revised, and professional learning can be designed to improve teachers' data literacy instruction.

The researcher used an educational database journal located in Galileo as a primary source for obtaining sources for the present study. Key words and phrases used in the search included the following: data literacy, physical science, life science, teachers' conceptions, students' data literacy, teachers' data literacy expectations, and data literacy strategies. Moreover, data was obtained from the Georgia Department of Education and Governor's Office of Student Achievement.

Theoretical and Conceptual Frameworks

The present research theoretical framework is situated on the lens of the transformative learning theory, which includes humanists' assumptions. The transformative learning theory is based on the belief that one interprets their own experiences based on perceptions (Meesuaisinta et al., 2014). The construct of interest includes teacher conceptions of data literacy, teachers' conceptions of student data literacy, data literacy knowledge and skills teachers expect their students to possess, specific instructional strategies used to scaffold data literacy, and differences in life science and physical science teachers' strategies and conceptions. The transformative learning theory aligns to the primary focus and constructs of the present research, which suggests that conceptions are cultivated from beliefs, expectations, and purposes (Bush et al., 2020). For example, with a focus on teacher conceptions the research was conducted through the lens of the transformative learning theory that centers on self-evaluation and interpretation of ideas teachers have formed related to data literacy. Moreover, since learning requires one to form new ideas, the transformative learning theory is aligned to the present research and constructs that seeks to identify teachers' strategies used to positively transform student data literacy in science.

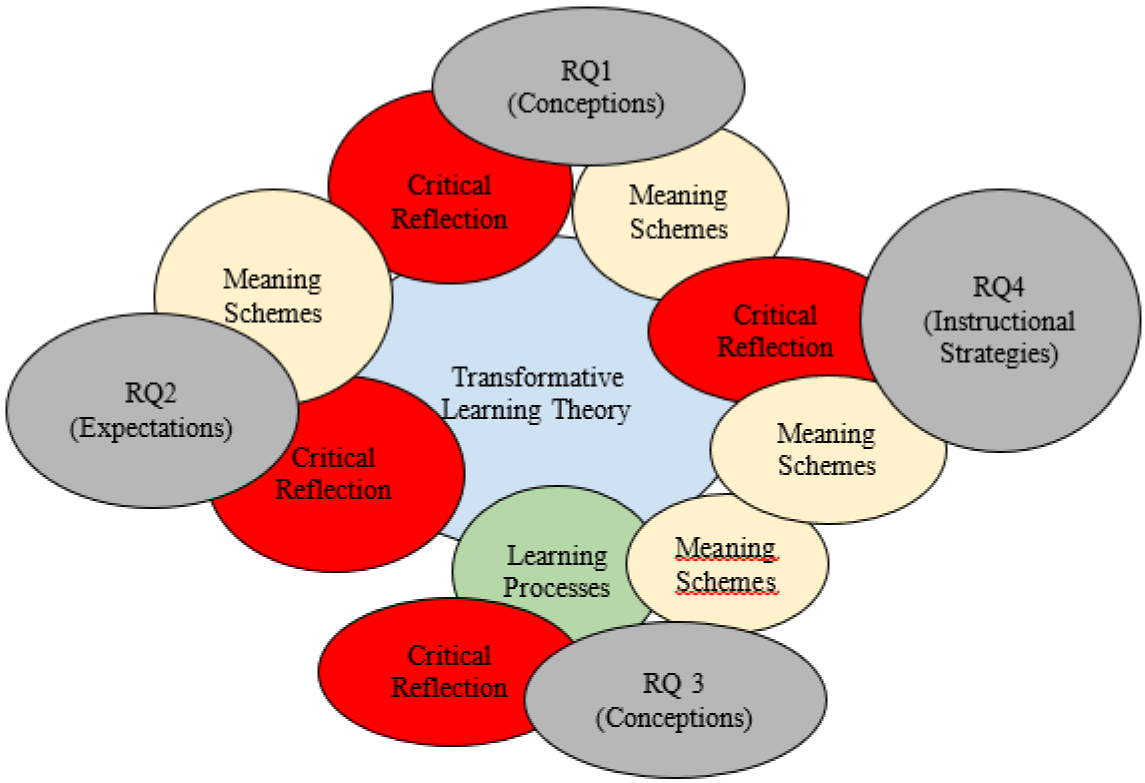
The purpose of the study was to develop an understanding of teachers' conceptions of data literacy, teachers' expectations of student data literacy, and strategies teachers have used based on their experiences to improve student data literacy in science. Therefore, the purpose of the present research study aligns to the transformative learning theory, which centers on adults and emphasizes the idea that learning involves making meaning of one's experiences and consists of change to meaning structures, which includes schemes and perspectives (Tikka & Oinas-Kukkonen, 2019). Since learning takes place through meaning structures and meaning structures are shaped from experiences, this theory aligns to the research purpose, which sought to identify teachers' conceptions of data literacy and experiences with strategies associated with teaching data literacy in science.

Moreover, the present study's four research questions were aligned to the transformative learning theory in similar ways. For example, the first research question seeks to identify teachers' conceptions of data literacy. This question requires participants to reflect on their own beliefs, experiences, and formation of ideas, which is known as the self-examination phase of the transformative learning theory. Similarly, the second research question addresses teachers' expectations of specific data literacy knowledge and skills that they expect their students to possess. This research question connects to several facets of the transformational learning theory such as critical reflection, habits of mind, and meaning schemes. The third research question seeks to examine teachers' conceptions of how students work through data literacy concepts, which connects to the transformative learning theory as it centers on learning process and meaning structures, which are shaped by past experiences and conceptions are shaped by beliefs, expectations, and purposes. Similarly, the fourth research question focuses on specific strategies teachers use to foster data literacy and differences between science teachers, which is aligned to the transformative learning theory as this question seeks to have participants critically reflect on their practices and meaning structures that are created from past experiences. Figure 2 illustrates connections between the research questions and the transformative learning theory.

Additionally, the transformative learning theory centers on self-understanding, which is addressed in the present research questions as teachers are asked about their conceptions, expectations, and experiences with data literacy and strategies used to improve data literacy in science (Tikka & Oinas-Kukkonen, 2019)

Figure 2

Transformative Learning Theory Alignment



In addition to the theoretical framework described, the present research is situated on a conceptual framework that centers on the belief that data literacy is a component of science literacy, and proficiency in data literacy is needed to prepare students for postsecondary education and careers. The conceptual framework centers on a matrix of competencies using different facets of data literacy including use of authentic data literacy. This framework aligns to the research questions, constructs, and purpose, which seeks to examine teachers' conceptions of data literacy and strategies used to foster data literacy among students in science classes. When carrying out the proposed research by conducting observations and interviews, the facets of data literacy including a matrix of competencies associated with different levels of understanding, will be addressed through interviews and observations. Therefore, research questions 1 and 3 address conceptual competencies as described in the conceptual framework.

The following sections includes an in-depth literature review of the research topic, which will address history of data literacy, how data is conceptually defined, student conceptualization of data literacy, students' data literacy in physical science, students' data literacy in life science, interventions to improve students' data literacy, teacher conceptualization of data literacy, pedagogical content knowledge, and need for data literacy training.

History of Data Literacy

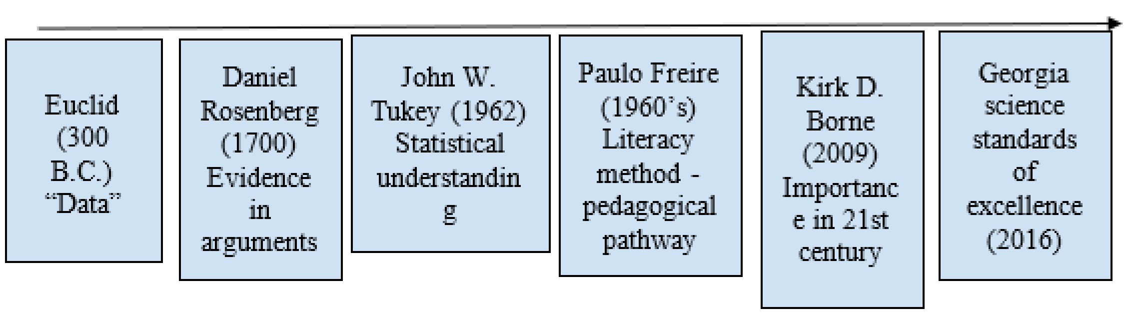
The concept of data literacy as a component of teacher education programs is relatively new but becoming increasingly popular as there has been an interest in incorporating data literacy in secondary science classes to improve student learning in recent years. This has become an important aspect of preparing students for post-secondary education and careers as data literate citizens need to be able to use data and analyze data associated with real-world problems and develop solutions to lessen issues (Lee & Wilkerson, 2018; Miller et al., 2021).

The word data was first developed by Euclid who was a Greek mathematician in 300 B.C. and wrote a book that centered on geometrical axioms and was titled *Data.* Nonetheless, data evolved as Daniel Rosenberg suggested that data was often associated with arguments used to support principles or evidence used to support facts in experiences and experiments during the 1700s. In the 1900s, the meaning of data literacy evolved to include mathematical and statistical information used by computers. Taking a different approach to the meaning of data literacy, John W. Tukey suggested that data literacy required an understanding of statistical data rather than an emphasis on using equations in *The Future of Data Analysis* written in 1962. Similarly, Paulo Freire developed a literacy method in the 1960's that centered on three stages, which included an inquiry stage, thematic stage, and problematization stage. This literacy method provided pedagogical pathways for data literacy years later (Tygel & Kirsch, 2015).

Extending on an understanding of data literacy, Peter Naur emphasized using data to represent facts or ideas in his 1974 book titled *Concise Survey of Computer Methods*. Naur promoted the idea of making data accessible to others and understanding data processing. Expanding on this idea, Jacob Zahavi emphasized utilizing effective tools for data mining and highlighted the importance of models and charts to display results and understand data in an article titled *Mining Data for Nuggets of Knowledge* in 1999. Similarly, Kirk D. Borne emphasized the importance of being data literate in the 21st century workforce in a paper titled *The Revolution in Astronomy Education: Data Science for the Masses* that was published in 2009. Additionally, Georgia standards of excellence in science were created in 2016, which emphasize advanced data literacy understandings. Figure 3 displays the timeline of major involvement in the meaning of data. Therefore, data literacy has progressed over many years, which has formed into a connection with science to develop complex thinking and visualization for interpretation of data sources (Foote, 2021).

Figure 3

Timeline of evolution in the meaning of data

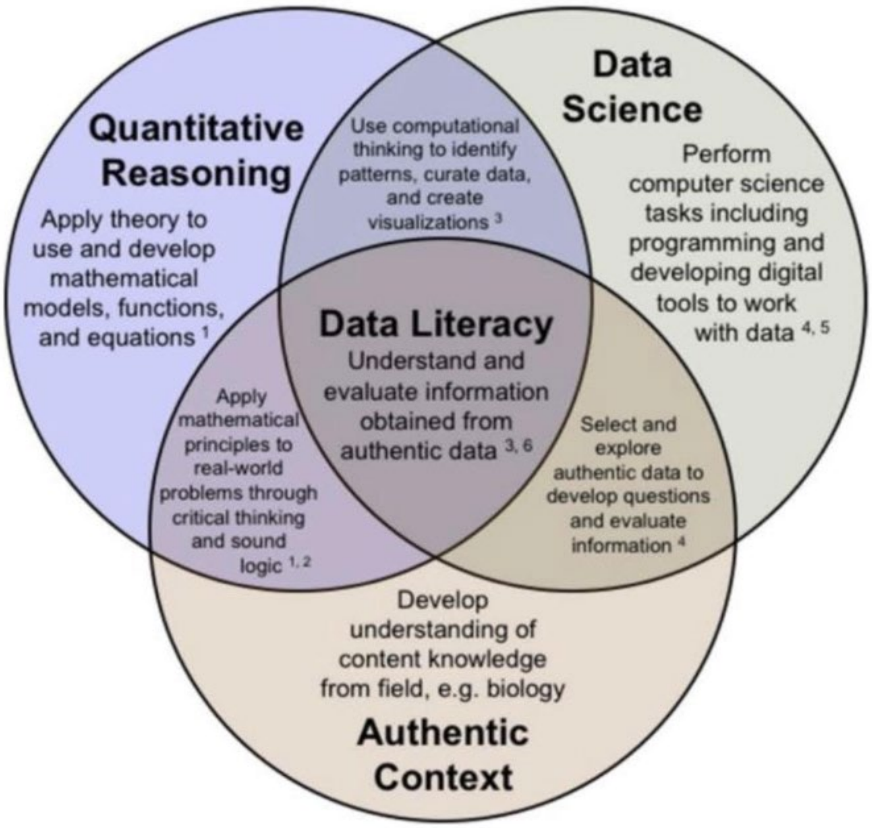


How Data is Conceptually Defined

Wolff et al. (2016) describes data literacy as a “set of abilities around the use of data as part of everyday thinking and reasoning for solving real-world problems” (p.1). There are many pedagogical implications that suggest students benefit from working with data when implementing an inquiry design. Nonetheless, many science teachers have underdeveloped skills and little support in implementing pedagogical content knowledge related to data literacy. Data literacy is known as the ability to collect, analyze, interpret, and develop inferences from sources of data and connect such analysis to real-world situations and concepts. As part of being data literate, students need to understand how data are measured, sampled, impact of variability in datasets (characteristics of data), how to use data visuals and representations, and develop inferences from sources of data. Data literacy is a cross-curricular concept as it can be incorporated into all core classes. Kjelvik and Schultheis (2019) defined data literacy as an overlap in quantitative reasoning and data science through use of authentic context (see Figure 4). Quantitative reasoning includes the ability to use mathematics to solve real-world problems and may include computational thinking and application of mathematical models; whereas data science requires the ability to use computers to work with sources of data. However, both include computational thinking and the ability to understand, evaluate, and interpret sources of data (Ceccucci et al., 2015; Dichev & Dicheva, 2017; Harris et al., 2012; Kjelvik & Schultheis, 2019). Although there is an overlap of data literacy in many STEM areas, it is especially important in the science classroom. Students should be able to connect data to scientific concepts, consider datasets as aggregates, use different representations when communicating data, connect data sources to other content areas and situations, and understand multivariate dataset relationships (Lee & Wilkerson, 2018).

Figure 4

Data literacy application to other fields of study (Kjelvik & Schultheis, 2019)



Although a relatively new concept, many recommendations have been proposed to improve data literacy in science, which includes implementing data-base inquiry learning, teaching specific data literacy skills, providing students with case study examples, and embedding technology in data literacy instruction. Moreover, Miller et al. (2021) found that professional development improved teachers' confidence in implementing data literacy in secondary science classes, which suggests resources should be invested in this area. Nonetheless, ongoing support is needed to foster skills and confidence in using data literacy instructional approaches in secondary science classrooms. Use of formal and informal learning should be incorporated to promote data literacy that center on tangible data use and using tools to visualize data to prompt students to make inferences from data and consider additional questions that can be answered in an inquiry learning setting. Additionally, data literacy involves using sources as data as evidence to support claims and argumentation. Table 3, located at the end of chapter II, presents a concept analysis chart, which summarizes research centered on data literacy. Each research is addressed in detail in the text.

Data literacy involves critical thinking and communication, which are competencies needed for post-secondary careers and education. The ability to use data to analyze, solve, and communicate problems and propose potential resolutions is becoming increasingly popular in today's society. Nonetheless, many curricula need to be addressed to advance such data literacy competencies. Khan and Mason (2021) examined the practicality of data literacy using a science, technology, engineering, and mathematics (STEM) paradigm. The researchers conducted a review that centered on data literacy for question-based pedagogy and problem solving skills. A curriculum review was administered in Australia. The science curriculum emphasized understanding science, human endeavor, and science as a part of inquiry learning. A proposed revision to the science curriculum suggests that critical thinking, reasoning, and reflecting should be embedded to promote problem solving and critical thinking as it relates to use of data in science. The authors recommended that data literacy needed to be further addressed in STEM subjects with emphasis on mathematical thinking and essential skills needed to be data literate in the 21st century. Moreover, emphasis was placed on being able to identify patterns in data sources to solve problems. The review indicated that developing a better understanding of what data literacy is and competencies needed to be data literate will help design a framework directed toward a curriculum that centers on data literacy in science classes. The present research utilized these implications to frame a study that addressed in-depth analysis of teachers' understanding of student data literacy and pedagogical approaches used to improve data literacy in science classes.

Student Conceptualization of Data Literacy

There is much need for data literacy in today's society. Unfortunately, data literacy is often not emphasized enough in secondary education. Nonetheless, with focus on NGSS, positive changes are being made through use of interdisciplinary, real-life data approaches. van 't Hooft et al. (2012) situated their research in determining the effectiveness of the Thinking with Data (TWD) Project materials to improve data literacy. The research was conducted to determine differences in middle school students' gains in cross disciplinary data literacy using a TWD curriculum, compare gains between content areas, and to determine if preparation for future learning pedagogical approach had an effect on student learning of data literacy. Modules within this project were interdisciplinary. The study consisted of 576 seventh graders from two schools of which 114 were included in the control group and 462 were included in the treatment group. The treatment groups were administered TWD materials, whereas, the control group received traditional instruction. Additionally, teachers in the treatment group received training prior to implementing this study. A pretest/posttest study design was used to determine the effectiveness of the TWD materials in improving data literacy among students. Sources of data in the study included notes from professional development sessions, lesson plans, pretest/posttest data literacy assessment, content assessment in math and science, student artifacts, class observations, and interviews. The pretest/posttest design allowed data literacy and comparison groups. A multivariate analysis of variance (MANOVA) was used to analyze this data and determine gain scores from the pretest and posttest. The MANOVA results were statistically significant $F(16, 841.2)=6.172$; $p<0.001$, which indicated that the assumption of equal variance was not met, and thus the groups had significantly different variances. Moreover, 31% of the total gains can be explained by the TWD intervention, which was indicated by n2=.308. Moreover, the results indicated that students in science that received the TWD intervention had significant gains $t(84)12.665$, $p < .001$, $d = 1.36$ (very large effect) for School 1. Moreover, the statistical analyses indicated the following significant results for school 2: $t(27) = 4.441$, $p < .001$, $d = .83$ (large effect). Additionally, the estimated marginal of means increased by 25.83 between the pretest and posttest data literacy assessments. Overall, the findings indicated that significant gains were made in science and mathematics. Moreover, data literacy improved when the project was implemented with real-life, recognizable problems. These findings suggest that students' knowledge and literacy skills increased when real-life content and connections were made in the curriculum with use of the TWD interventions, and future research should consider interventions that use interdisciplinary approaches and emphasize specific data literacy interventions. The recommendations of interventions used to improve data literacy were included in the present research as teachers were asked for specific strategies they have used and resources that they find effective to foster data literacy in science.

Living in a data driven world, students need to be able to conceptually understand how to collect, process, manipulate, analyze, and communicate sources of data. Bowler et al. (2019) used an exploratory research approach to determine what teens understand about data literacy and to determine what concepts, models, and competencies should guide training to support teen data literacy. A total of 13 teens were interviewed. The results indicated that participants believed data referred to numeracy values, while a few defined data as a collection process. Nonetheless, limited responses viewed data as a resource. Yet, one participant suggested that in order to define data literacy, the context must be properly defined. Participants believed that facilitating conversation about data can improve data literacy. Many participants did not view data as a system. Overall, the findings indicated that much ambiguities centered on defining data and data literacy. The results also suggest using a holistic approach to data to ensure students advance data literacy in complex situations. These implications offered valuable insight to the present research in the development of effective interview questions that address teachers' conceptions of what data literacy is, approaches to teaching and discussing data literacy, and conceptions of student data literacy in science classes.

Extending on integrated approaches, Dichev and Dicheva (2017) argued that data science should be taught interdisciplinary in other curricula. The authors described the implementation of a science data literacy course centered on utilizing real-world data to teach collecting, processing, analyzing, and using data. The guiding questions that were used to design the course centered on data science literacy in a data-driven world, concepts and skills students should be taught to be prepared in a data driven world, and how data literacy should be embraced in a university curriculum. The course was offered in a middle size southern liberal arts university, and participants included 18 undergraduates attending this university in two general education courses. The course goals and objectives centered on computational analytic data analysis abilities. The course structure included an introduction of computational data structure, data collection, data processing, data modeling, statistical analyses, and visual communication of data sources. Five weeks were allocated toward programming and using data to think structurally. To improve student motivation, hands-on, student-centered activities, such as labs, were implemented. Knowledge and skills gained from the course was measured using a pretest/posttest. Additionally, data related to changes in students' attitudes toward data science was also obtained using this data collection method. The results were used to determine the effectiveness of the course design. Descriptive statistics and a t-test were performed. The students' pretest mean was 56.062; whereas, the posttest mean was 71.625. Therefore, the difference in the averages of the pretest and posttest results was 15.57, and the results were significant (t=3.9; p<0.05). The implications of implementing this data science centered course suggest that data literacy embedded in courses improved students' science data literacy and thus should be considered in future curricula designs.

Expanding on the concept of thinking with data (TWD) and cross-curricular approaches, Vahey et al. (2012) situated their research using this project to improve data literacy through use of cross disciplinary approaches. The research sought to determine if students engaged in TWD materials had increased understanding of cross curricular data literacy, if TWD increased students' understanding of mathematics, determine how teachers used the preparation for future learning framework, how cross disciplinary links were implemented across the curriculum in different content areas, and how the results can be used to implement a large program centered on data literacy. An exploratory research design was used that was grounded in mathematics, which emphasized using appropriate data to make inferences and predictions. Modules that included four 2-week sessions were included, and the project was implemented among 7th graders from two Ohio middle schools in social studies, mathematics, science, and English. The research sought to determine if students' understanding of cross disciplinary data literacy improved when TWD was used and if understanding of required mathematical concepts improved when using the TWD. One hundred and fourteen students were in the treatment group and completed the TWD, while 462 were in the control group to allow a comparison. The beginning of the research focused on students using data to construct arguments, and students considered different variables as sources of evidence to support or oppose arguments. The TWD project required students to use real-life data related to water sources in three countries. The modules within this project utilized a framework that was called the preparation for future learning, which required students to investigate problems, reflect, and apply mathematical concepts. Data were collected using a data literacy assessment, a pretest/posttest math assessment, observations of teachers, and teacher interviews. Overall, students in the TWD group significantly outperformed students in the control group (t= (156.273)10.750, p<.001). Moreover, students in the TWD group had significant mathematical gains t(24)04.899, p<.001, d=0.56). Moreover, based on teacher observations, the TWD design allowed teachers to incorporate collaborative discussions, and teacher interviews revealed positive perspectives of using this design to embed data literacy across curriculums. These results suggest that using sources of evidence and constructing argumentation improved student data literacy. However, the study had several limitations, which included a small sample size (only two math teachers were included) and differences in instruction. Nonetheless, the research offered valuable insights in constructing an observation guide for the present study to include using evidence to support argumentative collaborative learning through use of data literacy strategies.

With the emphasis on argumentation in the common core standards, students need to know how to engage in this scientific discourse. Llewellyn (2013) states that in order for students to engage in scientific literacy, they must be able to formulate questions, connect prior knowledge to new information, state claims, and support statements with sources of evidence. Moreover, students need to be able to understand counterclaims and communicate sources of information. Students need to be able to discern between deceptive claims and substantial claims supported by sources of evidence. The author breaks down the difference between traditional labs and argument based labs, which emphasize phenomenon, investigation, data analysis, and explanations supported by sources of evidence. Therefore, teachers need to foster reasoning through argumentation and sources of evidence in science classes. Moreover, students need to be able to make inferences from observation data, analyze statements for substantial evidence, test other claims, and make their own claims with supporting scientific evidence. These implications are helpful when developing questions that address how teachers foster data reasoning and advance their students in using sources of data in scientific investigation, communication, and argumentation.

Understanding how teachers support students in conceptual understanding of data literacy requires addressing interventions used to foster learning, which is a focus in Rahmawati et al. (2020) research that also used a pretest/posttest design like van't Hooft et al. (2012) to evaluate STEM approaches to improving data literacy with the use of technology and how to increase data literacy with such approaches. The researchers used a quasi-experimental research design, and 26 students were included from Yogyakarta. All participants attended the same class, and thus only an experimental group was included in this study. The research was conducted for approximately a month and a half in 2019 using a pretest, treatment, and then posttest design. The pretest/posttest assessment centered on aspects of data analysis and reading data. Moreover, the intervention focused on integration of a discovery learning model with the use of a simple spring vibration technology to emphasize analyzing and reading data. Descriptive statistics and normalized gain (N-gain) were used to analyze and compare the pretest data with the posttest data. Standard gain values were calculated by subtracting the posttest from the pretest and dividing the difference between the maximum score and pretest score and multiplying the findings by 100%. Gains on the posttest were calculated and categorized based on the following standard gain ranges: Greater than 70= high, 30-70=medium, and less than 30=low. The average score for the pretest and posttest was 22.63 and 79.58, respectively. Fifty-four percent scored in the high criteria category for improved data literacy, and 42% scored in the moderate category for data literacy. Therefore, the results indicated that students' data literacy increased when technology use was embedded in the STEM approaches. This provides implications for STEM teachers to utilize when teaching data literacy and further suggests that educational practices should align to scientific context to prepare students for a data driven world.

Ensuring students understand objectives of data literacy lessons through use of graphical representations is essential in the learning process. Roberts and Brugar (2017) situated their research based on the semiotic, transactional, and emergent literacy theories to describe and explain students' understanding of graphical devices in social studies. Eighty-one students were randomly selected from three elementary schools, which included at least two students from each school but no more than six. Differences in urban and rural schools were analyzed. The Visual Literacy Assessment was used to determine students' ability to identify, interpret, and interact using graphic organizer devices. Interviews were also conducted. Mann Whitney U-test revealed that all effect sizes were significant, $p<0.05$. Many had limited knowledge on visuals, such as graphs, and 75% of third grade students could not name tables correctly. Similarly, many students struggled in explaining the purpose of tables connected to data use. For example, only 7.14% of third graders, 16% of fourth graders, and 25% of fifth graders were able to demonstrate complete understanding of the purpose of data tables. The findings indicated that students' graphics literacy rate was not on target with the readings and comprehension assigned in lower elementary schools. These results suggest teachers should be aware of how graphical representation positively impacts students' reading comprehension, and that proper instruction of the graphical deception is needed to allow students to find data in the text that will be used in the graphic representation. Nonetheless, the study was limited in student demographic data, empirical testing, consideration of other instructional variables, and small sample size. However, the research offered insight on addressing how teachers foster visualization of data literacy in the present research.

Taking the argument in a different direction, Eshun and Graft-Johnson (2012) conducted a quantitative study using a field study questionnaire to determine student perceptions of assessments when creative project-based learning was implemented. The study consisted of 247 undergraduate students from the Department of Communication Design of Science and Technology students as participants. Moreover, the research questions focused on student perceptions of creativity using graphic designs, students' perceptions of using creativity as a learning tool, how assessments impacted student learning, and areas for improvement in the assessment process. Descriptive statistics were performed to assess students' perceptions of creativity and assessment design. Approximately 98% of the students suggested that creativity had a significant impact on learning. Moreover, 56% of participants suggested that low scores on formative assessments could motivate students to make adjustments in their learning. Additionally, 87% of the participants agreed that students should have a role in the assessment process. These findings suggest that teachers should incorporate students in a variety of assessment processes, and these results are valuable in means of constructing assessment to monitor students' data literacy understandings.

Working with authentic data can provide extensive learning opportunities in an inquiry-based science setting that emphasizes preparing scientists and citizens and is a focus in the NGSS (Gould et al., 2014). Kjelvin and Schultheis (2019) suggest authentic literacy should be used to improve data literacy. This also supports the NGSS, which centers on computational thinking and using data as evidence to support argumentation. Using authentic data promotes critical thinking and engagement, which will improve student learning. Utilizing authentic data establishes meaning and a context of real-world learning. Thus, establishing relevance in learning is essential. Furthermore, Kjelvin and Schultheis (2019) recommends allowing students to engage in data complexity improved learning as it increases students' ability to identify patterns and make predictions using raw, complex data. Additionally, data selection is another criteria of data literacy, which involves selecting the appropriate data sources to develop inferences. The selection process will differ depending on the data sources. Curation is another component of data literacy, which involves tidying and preparing data to be evaluated. Organization has an important role in the curation process, and the size of the data will impact its complexity in data analysis. Likewise, authentic data is often complex in terms of including outliers, missing values, and unexpected trends. Therefore, these areas promote critical thinking and encourage the learner to strategically plan how they will use and evaluate data with high variability. Although authentic data is highly useful in engaging and promoting critical thinking, data complexity is often challenging and thus scaffolding is likely needed for data intensive activities. Nonetheless, for authentic data to be used, teachers need resources and adequate training to ensure confidence and best instructional practices are used when implementing data literacy learning.

Use of authentic data promotes genuine science learning. Jordan et al. (2019) research situated on using authentic science to engage and motivate students in climate change. The research cited a need to conduct this study to identify best instructional design and methods to address the deficiency in students' conceptualization of data literacy. A participatory modeling method was used, and the study utilized an argumentative research design where students stated claims, found authentic evidence, and developed explanations through application practice of different datasets to explain climate change. Emphasis was placed on students being able to identify patterns in data sources, linking social and natural sources to datasets, ability to formulate inferences based on data, ability to analyze and interpret different data sources connected to climate change, logically making predictions based on available data, using models to explain evidence connected to risks and benefits of different energy sources connected to climate change. The results suggested that model-based reasoning was an effective instructional design to promote use of authentic data aligned to authentic learning in science connected with interdisciplinary methods. Moreover, the research cited the importance of future research focusing on the relationship between engagement and trust in scientific data sources. This shined light and was an area of exploration when teachers' conceptions of data literacy were addressed in the present research.

Drawing on the topic of utilizing real data, Erwin (2015) suggested that authentic data literacy should be embedded in an inquiry, student-centered learning environment that promotes project-based learning and investigation aligned to common core state standards. In these activities, students use guiding questions and work with a variety of data by organizing, analyzing, interpreting, and reporting findings. These activities encourage students to critically think about scientific concepts through use of real, authentic data. Moreover, use of authentic data has been linked to increased student motivation. Teachers can use authentic data in many ways to increase students' depth of knowledge. These implications were considered in the present research as teachers were asked to provide examples of data literacy learning activities through documents, which were analyzed for sources of data and how the data is connected to scientific concepts being learned.

Extending on an emphasis in an inquiry setting, Wolff et al. (2019) situated their research on six principles, which emphasized inquiry data collection and analysis, starting with small samples and expanding datasets, real, contextual data related to students' lives, a focus on competencies rather than skills, an emphasis on collaborative activities that are creative, and used of authentic data collected by the students themselves. An ethnographic research design was employed. The research sought to determine the impacts of an inquiry setting on data literacy. The participants included three teachers that were purposefully selected. Four field studies were implemented, which included 67 students. Moreover, data were collected from students ages 10-14 attending primary and secondary schools. Lessons were developed, and participants selected lessons and activities based on the needs of their classes. Data were collected through observations and photographs. The results indicated that students that were encouraged to develop their own research question in an inquiry setting were more likely to critically reflect on data quality and data sources. The findings indicated that younger students needed scaffolded support in formulating questions designed to inquiry lessons, and students benefited from collecting their own data as it promotes students to critically consider the quality of data sources. The implication of this study suggests that teachers should consider designing lessons that incorporate open data opportunities that promote cross-curricular learning and critical thinking to improve data literacy. These findings were connected in the present research as cross-curricular approaches were included in the observation guide and considered in the analyses of responses to interview questions that addressed strategies and pedagogical approaches used to foster data literacy.

Bodzin and Shive (2003) presented a paper at the National Science Teachers Association Annual Meeting, which focused on using authentic data to promote inquiry learning in science education. The goal of the study was to have students use authentic data and connect such data to scientific topics through use of inquiry learning. The researchers suggested that inquiry learning with use of authentic data allowed the learners to engage in interdisciplinary methods and contextualize content being learned to real-world problems. The research utilized a web-based resource as students gathered authentic data related to watershed. Collaborative meetings were implemented to ensure inquiry activities aligned to instructional goals in the curriculum. Web-based resources were created to aid students in collecting and analyzing data. The website resources also included interdisciplinary connections to the topic, watershed, being addressed. Students conducted their own sampling to collect authentic data related to watershed. Web-based resources and databases were used to help students identify trends and patterns in the data sources and an activity that allowed learners to develop relationships between different factors that contribute to watershed. The implications of this research suggest that teachers should present a motivating context when first engaging students in similar authentic data literacy activities, select a sampling site, consider different data collection tools, and engage students in different data analyses to advance data literacy where students can effectively communicate authentic data. These findings offer an understanding of using data in classroom activities. Therefore, these results were embedded into the research design and addressed as data were obtained related to use of data sources and context of data used during instructional practices.

Extending on the emphasis of using authentic data to promote inquiry learning, Hume and Coll (2010) presented findings of students engaging in an authentic science inquiry curriculum, which utilized an interpretivist paradigm and a multiple case study qualitative research design. The research was also situated on the constructivist framework, which sought to answer what, why, and how questions related to student learning. Specifically, the research sought to determine what students were learning from science scientific inquiry, why students were learning, and how students were learning. Data were collected through semi-structured interviews, observations, and document analyses. Overall, the findings indicated that students could explain what they were doing but had difficulty explaining why they were doing it. Moreover, teachers determined content that was being taught in the inquiry settings based on context within their local community in an attempt to connect learning to real-world issues. The findings indicated that the learning process emphasized route, skills, and supervised learning rather than a deep conceptual understanding. Consequently, the results also indicated that such learning that emphasized procedural skills and rules in scientific investigation did not improve conceptual understanding or skills in argumentation in science. Additionally, the results suggest that teachers should adjust their instruction from being dispensers of knowledge to providing students with real-life experiences that can derive their own understanding. This style of teaching enables the student to be the active participant and the teacher to serve more as a facilitator for learning. The implications of the study suggest that authentic science learning should be used to promote higher order thinking and such a style of learning can be integrated with authentic data. These inferences were addressed when observations are conducted.

In summary, the research presented suggest that students' conceptualization of data literacy improved when interdisciplinary methods, inquiry learning, and real-world data were used to advance students' ability to make connections when learning components of data literacy (Dichev & Dicheva, 2017; Vahey et al., 2012; van 't Hooft et al., 2012). Use of real-world, authentic data improved students' understanding as it allowed students to explore relevant topics and use evidence to solve real-world problems (Bodzin & Shive, 2003; Dichev & Dicheva, 2017; Hume & Coll, 2010; van 't Hooft et al., 2012; Wolff et al, 2019). Additionally, teachers eluded that use of real-world data was also suggested to be useful in students' conceptual understanding of using as evidence in argumentation (Jordan et al., 2019; Llewellyn, 2013; Vahey et al., 2012). Similarly, use of technology was found to improve students' conceptual understanding of data literacy (Rahmawati et al., 2020), and teachers need to identify a variety of literacy abilities, such as graphical understanding, which is an important part of interpretation of data (Roberts & Brugar, 2017). Moreover, when evaluating students' data literacy, it is important to use a variety of assessments to allow students to make adjustments on the area of data literacy being learned (Eshun & Graft-Johnson, 2012). Emphasizing a focus on competencies rather than skills provided a better avenue for supporting students' understandings of data literacy (Wolff et al., 2019). These results suggest an avenue of areas to look for that include use of authentic data, inquiry learning, technology embedded instruction, a focus on competencies, and use of cross-disciplinary methods when conducting observations and document analyses in the present research.

Student Data Literacy in Physical Science

The physical science high school course requires students to engage in a variety of data literacy learning. For example, students must be able to obtain, evaluate, and communicate sources of data in chemistry, forensics, physical science, and physics classes. Moreover, use of mathematical thinking and development of models using sources of data is emphasized in the state standards. For example, standard SFS2 in forensics requires students to analyze and interpret sources of data related to digital evidence, and standard SFS3 requires students to analyze and interpret sources of data related to drugs in the body. Similarly, standard SP1 in physics requires students to analyze and interpret sources of data velocity and acceleration. The emphasis on using sources of data to analyze, interpret, developing mathematical models, and planning and carrying out scientific investigations are prominent among all Georgia State standards for high school science classes. Consequently, proficiency in these courses require competencies in data literacy.

A variety of interventions have been researched to improve data literacy in physical science classes. For example, Suryadi et al. (2021) conducted research to assess students' ability to obtain, analyze, and interpret data in a high school physics class. Students' data literacy skills and abilities were assessed using an essay written 6-item test. Sixty students from five high schools in Indonesia were included. The study focused on students' ability to collect, analyze, interpret, implement, and evaluate data. Students' scores from the written 6 item test included three categories: 1 for no response or incorrect response, 2 for answering correctly with an incomplete explanation, and 3 for answering with a complete explanation. Once students' tests were scored, data were recorded and descriptive statistics were performed. Students' scores were compared among the five high schools. Results from the test indicated that students' data literacy understandings were below satisfactory. The highest achievement in one school was 78 out of 100 and the lowest achievement in four out of five of the schools was 33 out of 100. Moreover, students' ability to evaluate, interpret, and assess were lower compared to collecting data. These findings suggest that the issue of students underperforming in data literacy in science classes is not in isolation to the research's local setting. Consequently, there is a widespread need to identify effective learning strategies and resources to improve student data literacy in physical science classes.

Expanding on research that addresses students' understanding of data literacy physical science, Zucker et al. (2014) utilized smartgraphs, which is a web-based software to facilitate student learning in data literacy, data visualization, and identification of misconceptions associated with graphic representation of data in eighth and ninth grade physical science classes. This software promotes student interactive learning and provides scaffolded activities based on students' individual needs. This research was conducted for two years using an experimental study design. The participants were from 26 schools and included 29 teachers, 72 sections of physical science, and 1,700 students. Participants were randomly assigned to control and treatment groups. Each group received instruction on the same content, but the experimental group utilized smartgraphs to supplement graphing instruction. After completion of the first year of the study, students in the treatment group made significant improvements based on a comparison between pretest and posttest. However, the effect size was small. Moreover, teacher logs indicated positive perspectives to using smartgraphs after completion of the first year. Similarly, significant student gains were found at the completion of the second year. Teachers indicated that their comfort and confidence increased when using smartgraphs activities. Moreover, teachers preferred to use multi-sensor sources in small groups rather than a single source for whole group instruction on data graphing. Nonetheless, a surprising finding of this study found that teachers preferred generic scaffolding over scaffolding provided in the software. However, the research provided implications for use of research-based software tools that help students conceptualize information through graphing data aligned to NGSS practices of science.

Taking the argument in a different direction, Sugiarti et al. (2021) employed a quantitative descriptive research design. One hundred and eighty-one students from three schools were randomly selected. A survey that scientific literacy knowledge and competence of scientific literacy was used to obtain data. Data were analyzed using descriptive statistics and inferential statistics. The results indicated that students had the highest indicator achievement (74.4%) on knowledge of atoms and molecules. Yet, the indicator for organizing, analyzing, and interpreting scientific data and information was the lowest (60.5%). These findings suggest that students' abilities to make connections with scientific concepts using data sources was overall deficient. The implications of this study suggest involving work of scientists in the classroom through use of real-life situations and data sources, which requires the teacher to be competent in the domain of connecting content through authentic learning that relates to students' personal lives. This research provides insight on examining how teaching uses data literacy to advance students' conceptual understanding in science classes.

Medova et al. (2022) sought to examine students' performance and attitudes towards use of research projects to advance statistical and science literacy. The research questions focused on identifying key design features of interdisciplinary activities that centered on advancing students' learning in science and statistical reasoning and challenges that students encounter when engaging in statistical reasoning-based activities. Seven primary students were placed in three groups that rotated throughout the design of the lesson. The research setting took place in a primary classroom. The overarching topic of the lesson design and activities centered on properties of water. Students used data sources to investigate the water cycle, and fish eggs were used as a material to engage students in investigating water density. Data were collected from a research journal, which described students' behaviors while engaging in the lesson and an audio recording of the classroom. The results indicated that setting learning goals, providing scaffolded, differentiated support, implementing reflective formative assessments, and providing students with autonomy to take ownership of their learning were key features in activities that advance students' statistical reasoning and science learning. Moreover, lack of essential vocabulary, knowledge of physical quantities, and misconceptions of densities negatively impacted students' performance. The researchers cited that requiring students to collect their own data was likely an advantage and helped instill purpose by promoting students to engage in analyzing and interpreting the data. These findings connect to Sugiarti et al. (2021) suggestions of establishing relevance when teaching data literacy in physical science classes.

In summary, identifying effective strategies and resources is needed to improve data literacy in physical science. Students' ability to evaluate, interpret, and assess were lower compared to their ability to collect data (Suryadi et al., 2021). Similarly, students were able to remember scientific concepts but had low indicators in analyzing and interpreting sources of data connected to physical science concepts (Sugiarti et al., 2021; Suryadi et al., 2021). Nonetheless, Zucker et al. (2014) found that smartgraphs were effective in improving students' data literacy, which offers valuable insight in addressing the deficiencies of data interpretation and evaluation as identified in Suryadi et al. (2021). Therefore, data visualization and data literacy relevance were considered in the data collection procedures of the present study when teachers were asked to provide insight on strategies they use to scaffold and foster data literacy in science.

Student Data Literacy in Life Science

Similar to the Georgia state standards of high school physical science courses, life science courses are also centered on mathematical thinking and students' ability to obtain, evaluate, and communicate sources of data related to scientific topics. For example, standard SB6.d in biology requires students to "use mathematical models to support explanations of how undirected genetic changes in natural selection and genetic drift have led to changes in populations of organisms" (Georgia Department of Education, 2023, p. 4). Similarly, the high school environmental curriculum emphasizes data literacy through the use of analyzing information and using data to predict changes. For example, standard SEV2.b requires students to "analyze and interpret data to determine how changes in atmospheric chemistry (carbon dioxide and methane) impact the greenhouse effect" and "analyze and interpret data related to short-term and long-term natural cyclic fluctuations associated with climate change" (Georgia Department of Education, 2023, p. 2).

Extending on students' data literacy conceptions in terms of data visualization and using data to make predictions, Chin et al. (2016) addressed the impacts of choice-based game assessments in improving data literacy and visualization in a 10th grade biology class. The research sought to determine if student choices in the game predicted their learning from the game and if the curriculum taught the students to choose more effectively with respect to data visualization. The researchers hypothesized that data visualization curriculum would guide students towards patterns of behaviors and learning compared to the control group. The participants included N=93 10th grade biology students from schools in California. The curriculum centered on two main principles of data visualization, which included simplicity and truthfulness. Data visuals were compared and contrasted, and a choicelet game, called Storylet, was used, which emphasized telling stories about the data used. Each story centered on three main data visualizations, which allowed students to explore concepts. The Storylet was administered for two weeks after the last day of instruction. Students were administered assessments to examine what they learned. The results indicated that time spent reading was a significant predictor of science content learning: $F\text{-}change(1,84) = 5.2$, $p = .025$, $R2$-change = .06; final model, $F(2,84) = 4.79$, $p = .011$, $R2 = .10$. Moreover, the findings indicated that total story time spent predicted factual and message learning ($F(1,84) = 11.1$, $p = .001$ and $F(1,84) = 8.4$, $p = .005$, respectively). Comparing the intervention with a control, the findings suggested that student achievement improved when choices were incorporated that included data visualization. Moreover, student choices within the game impacted students' learning. The researchers suggested that future research should consider a mixed method design to include addressing students' learning and perceptions through in-depth interviews. These findings were considered in the present study's observation guide, which addressed data sources used in connection with scientific concepts to facilitate data literacy.

Identification of effective interventions is necessary to advance data literacy and meet individual leaner's needs. Lestari and Rosana (2020) conducted a quantitative descriptive study, which consisted of 235 students in 8th grade to determine students' data literacy profile in Ciamis when using a data literacy intervention called the local potential during the 2019/2020 school year. Four schools were included in the study and differences among these schools were analyzed. This intervention was implemented while students were learning concepts related to interactions of living things and their environment. The participants had an average ability score and were the same age. Exploring data, selecting data, converting data, and using data for decision making was analyzed when students were learning about interactions between living things in an environment in an 8th grade science classroom. These areas were scored using a 0-4 range. Percentage score was calculated by dividing the score obtained by the maximum score and multiplying by 100%. Scores were classified based on the following percentage range: 80-100% very good, 60-80% good, 40-60% sufficient, 20-40% poor, and 0-20% very poor. Overall, students scored higher in exploring data compared to using data to make decisions. For example, the scores for exploring data were 41.02, 43.45, 30.34, and 42.45 for schools 1, 2, 3, and 4, respectively. In contrast, the scores for using data to make decisions were 28.63, 19.03, 36.28, and 29.47 for schools 1, 2, 3, and 4, respectively. The findings indicated that students were more literate in exploring data and deficient in using data for decision making. Specifically, the average percentage score was 39.32% (poor category) compared to 29.47% (poor category) for making decisions. Nonetheless, all four categories scored below the sufficient category for the percentage average. Consequently, these results suggest that teachers need to utilize data literacy activities regularly to prepare students for careers and advanced education. The findings provide implications in the present research on constructing interview questions that target what and how teachers provide scaffolded support to advance student data literacy from being able to explore and collect data to being able to interpret and use data to make decisions.

Expanding on the topic of scaffolding, Belland and Kim (2021) conducted a quantitative research study that sought to determine if time spent in each scaffolding stage, which included individual work and working collaboratively, predicted argument quality among high school environmental science students. The researchers used computer-based problem-based scaffolding learning literacy, collaboration, and argumentation among 24 10th and 11th grade students. Log files and a pretest/posttest informational literacy assessment were used. Time spent in the individual and collaborative stages were measured in hours. Essays were utilized to measure each student's argumentation skills, including two scores and a common rubric. The results indicated that significant positive predictors of argumentation included literacy scores and individual time spent working. Although indirectly related to data literacy, these results offer valuable consideration as it relates to determining the time each teacher spends on data literacy within their classes.

Citizen science is an area of science that allows teachers to engage students in learning through connection of real-life issues (Jordan et al., 2015; Vahey et al., 2012). The use of authentic data to embed citizen science in learning is becoming a popular topic as it allows a connection between community-level outcomes. Research design centered on citizen science allows the learner to discover socio-scientific outcomes based upon authentic data collected. This type of design also allows the learner to take an active role in the process of asking and answering authentic questions (Jordan et al., 2015). Farrell et al. (2021) conducted a study, which involved students collecting authentic real-life data related to potable water and use of online software to analyze and interpret the data sources. The purpose of the research was to determine perspectives of using real-life data to improve students' ability to collect, analyze, and interpret data. The research was grounded in analyzing arsenic water pollution in Maine, which should be below 10 ppb. However, pollution results indicate that much water in Maine read above this measurement making this study relevant to students in the area, which positively impacts student data literacy. This research project included several components, such as training teachers in data literacy workshops, implementing citizen science, collecting data, making visuals with data, and implementing community outreach programs based on the analyses of the data. Moreover, the lessons within this project centered on developing questions and choosing graph types, simplifying data based on a focused question, comparing datasets, using different sources to visualize data, and making conclusions based on data analyses. Fourteen teachers were included in this project, which was implemented during the Covid-19 pandemic. A survey was administered to teachers at the end of the year, which discovered 70% of teachers found the data literacy modules helpful. Moreover, eight teachers indicated that story mapping was helpful, and 13 participants expressed that the data to action component of the project, which included using data to make improvements in their communities, was a useful tool in improving data literacy. These results suggest that data literacy can be taught through collaborative work between teachers and scientists with use of authentic data to solve real-life problems to improve students' local communities. These implications were addressed in the present study when sources of data were used in classroom observations and documents were examined. Moreover, teachers were asked if and how they embed the local community's needs to engage students in authentic data literacy learning.

Similarly, Harris et al. (2012) suggest that activities that incorporate quantitative reasoning improve student motivation, engagement, and knowledge in ecology. Specifically, Harris et al. (2012) focused on an ecology context, environmental salt pollution, of a science curriculum that centered on data literacy. To teach this unit, lesson plans, assessments, websites for visuals, and land-use data related to the Hudson River were utilized. At the beginning of the unit, students were engaged in sources of water passed around the room as they were asked to consider potable water. Afterwards, students explored conductivity in water areas outside, which served as the data collection process. Afterwards, students explained their data and made predictions. Students then explored toxicity bioassay, which was then followed by extension activity that required students to calculate sodium concentrations in aquatic areas. The authors suggested that this lesson design encouraged students to use real data to solve real-world problems.

Working with real-life, authentic data is often messy, which challenges students to organize data and determine sources and use of complex data that are not ideal generally in an inquiry setting (Gould et al., 2014). Moreover, Ellwein et al. (2014) centered their research on student-centered activities using a project focused on climate change within modules. The participants included 10 instructors and 243 undergraduate students from schools across the nation. Approximately 20%-30% of the students had no experience with working with authentic science data. A digital biology laboratory was used in this project, which consisted of different learning modules. The biology of climate exchange module focused on data sets, scientific literature related to datasets, contextual information, different assignments centered on exploring, analyzing, and evaluating sources of data. Scientists were consulted in the design of this module. The constructivist 5E design model was used to create this module, which included inquiry-based learning centered on engagement, exploration, explanation, elaboration, and evaluation components. The goals within the module's activities were to have students interpret graphical and statistical data, understand statistical significance, use technology to plot and describe data, be able to describe data orally, and develop an argumentation using sources of data. Surveys were administered to participants, which were different for instructors and students. When the modules were implemented, 60% of instructors indicated that students were able to recognize scientific principles; whereas, 100% of instructors indicated that students were more likely to analyze situations in terms of variables after completing the modules. Moreover, 80% of the instructors indicated that students were able to interpret sources of information related to scientific principles. Additionally, most instructors indicated that students were engaged in the modules and the quality of contextual information was appropriate. Furthermore, most instructors (9/10) indicated the project was user friendly and cost efficient. Overall, most of the students indicated that they enjoyed working with authentic data and learned from the challenges associated with messy data collection. Students expressed appreciation of the design that allowed them to engage in self-directed activities and use of authentic data to explore concepts. Additionally, students showed appreciation for use of interactive data and using tools to visualize data. The results indicated that authentic data exploration allowed students to engage collaboratively to solve real-life problems. Moreover, this model demonstrated reasonable implications toward collaboration with scientists and using authentic data through personalized experience to solve real-world problems. The design of the course implemented in this research aligns to mind, brain, and educational research, which suggest students should engage in a variety of modalities of learning that prompt deeper understandings (Whitman & Kellher, 2016).

In summary, similar to the findings for physical science classes, student choices and data literacy varied, but much of the research suggests students are still struggling in reaching advanced competencies levels in life science classes. For example, Lestari and Rosana (2020) found that utilization of a data literacy profile improved students' ability to explore data, but deficits were still noticeable in students’ ability to use data to make informed decisions. Nonetheless, Chin et al. (2016) found that student achievement increased when given choices and sources of data visualizations, which aligns to Whitman and Kellher (2016) suggestion of promoting student autonomy to advance students’ understandings. Likewise, Belland and Kim (2021) found that game-based learning could be used to provide scaffolded support to improve student’s data literacy through use of scientific argumentation and such learning activities promoted student engagement. This aligns to recommendations proposed to improve NAEP scores as integrated game-based activities and assessments were cited as a way to increase relevance, motivation, and a sense of belonging among students (Baker, et al., 2022). Similarly, Ellwein et al. (2014), Farrell et al. (2021), and Harris et al. (2012) found that authentic use of data sources connected to students’ communities improved student engagement. These findings were considered in the present research, which was situated on the conceptual framework of matrices used to describe data literacy competencies and instructional approaches teachers use to improve data literacy. Teachers use of authentic data sources to advance students’ abilities to analyze, interpret, and make sound scientific decisions were addressed.

Interventions to Improve Students' Data Literacy

Drawing on the topic of visualizing data, Usova and Laws (2021) conducted a pilot project, which centered on preparing students to read, analyze, interpret, evaluate, and synthesize sources of data through use of visualization and storytelling. A one-credit course was designed to deliver instruction centered on these data literacy elements. This course was designed by librarians and utilized interdisciplinary approaches. Fourteen students who were mostly sophomore undergraduates completed the course using face-to-face instruction, which lasted approximately two hours each week over a 6 week period. Hands-on active learning techniques were implemented, and facilitators of the course participated in training prior to teaching the course, which focused on reviewing literature, preparing data visuals, and collaboration with faculty members to discuss teaching strategies centered on data visualization. However, instruction was scaffolded to support each learner's needs to allow students data literacy to improve from simple to complex ideas centered on critically evaluating data, analyzing data, and drawing conclusions from data. Within the course, students were presented with misleading graphs and representations of data. Students accessed, appraised, organized, interpreted, and processed sources of data. Student feedback and reflections were used to determine the effectiveness of this course, which included questionnaires completed by 70% of the participants. On a scale of 1-5, the average score was 4.4 for overall quality of classroom stimulation. Many expressed appreciation for active learning instruction. Moreover, areas of improvements were expressed, which included software used and developing engaging activities during the data collection process. Students also expressed interest in learning practical data literacy skills that enhanced their learning and preparedness for careers. Although valuable, this study had limitations in its standalone structure and course design and was facilitated by librarians.

Therefore, future research should consider cross disciplinary designs among other educators using this course embedded into other content areas. Nonetheless, the implications of the study suggest that teachers can design data literacy instruction that situates on data visualization through active learning opportunities to improve student learners and prepare them to be data literate citizens.

Extending on the topic of active learning, Seymoens et al. (2020) based their preliminary research on the use of a project called DataBuzz, which emphasized participatory games and workshops to improve data literacy. The participants included students in the age range of 10-18 and adult learners that were considered illiterate in Brussels. The project focused on observing, analyzing, evaluating, reflecting, interpreting, navigating, collecting, and presenting sources of data. A game-based escape room was structured in the workshop. The authors suggest that DataBuzz offers implications for improving data literacy and future research should center on activities and concepts situated in this project.

Similar to Seymoens et al. (2020) and Usova and Laws (2021) findings of active learning and project-based activities to promote data literacy, Werning (2020) used research on making data playable through implementation of play and games when using datasets that require interpretation using visual evidence. Playful characteristics of data literacy learning were examined and data literacy components focused on curation and interpretation. The purpose of the study was to see if and how making data playable promoted data literacy and expanded definitions of data literacy. Ten higher education students were included as participants in this study. The students participated in a workshop where they explored games using real-life data, which consisted of 70% females. Each workshop was self-contained and lasted 6 hours. Participants interpretation of data was examined through implementation of creative data literacy where being data literate was interpreted as being able to read, analyze, and argue using data as evidence. Physical playing cards were used as a game, and each participant received 7 cards. Participants connected cards based on concepts illustrated. The results of the study suggested that participants enjoyed the card game as it gave them an opportunity to work with real-life data sets and connect evidence with logic and economics. Nonetheless, some participants suggested that the content in the card game was vague and needed revision. However, the implication of this brief study suggests that game-based data learning is valuable in promoting curation of data literacy and allowing students to work through real-life datasets. These findings were considered in the present study's semi-structured interviews, which addresses how teachers engage their students in learning how to curate, analyze, and interpret sources of data.

Implementing data literacy activities is often challenging as it requires individual instruction to meet the needs of students to make instruction and activities relevant for each individual. Nonetheless, authentic learning that centers on data curation is needed to achieve higher learning. Similar to Usova and Laws (2021), Carlson and Bracke (2015) conducted a case study design that centered on the design and implementation of a data literacy program to address the lack of data information literacy. The pilot program was designed to promote authentic learning experiences and engage students in use of authentic research data. Ten participants were selected. During the implementation of the program, participants met once a week for 2 hours over 15 weeks. Weekly lessons were planned and designed a week in advance to allow adjustments as needed. The weekly session topics included an introduction to data literacy, data management, data lifecycle models, discovery and acquisition, description and metadata, data security and storage issues, copyright and licensing data, mid-semester progress check, data sharing, data management and documentation, data visualization, data repositories, data preservation, data publication and curation, and a data literacy course wrap-up. Formative and summative assessments were administered, which included reflective thinking through discussions, focus group discussions and individual follow-up interviews. The results indicated that students initially lacked confidence in their knowledge and skills of data literacy. However, this improved once students began working with their peer group and engaged in collaborative discussions centered on data literacy. Overall, the program was well received among students. Several students suggested that the program allowed them to reflect on how to conduct research and approach sources of data. The participants' awareness of data management and curation issues improved. Moreover, the participants revealed that concepts that were connected to their daily lives were most engaging to them and suggested that more data samples should be connected to real-world issues and such samples should include bad and good examples of data sources. Metadata was also discussed to be immediately applicable to participants' daily lives. Overall, participants and faculty had positive perspectives toward this program and suggested it would have a positive impact on other students at a larger scale. However, participants acknowledged the challenges in this program and suggested students did not complete such a class during their first year of college. The emphasis on reflective thinking activities are similar to the metacognition strategies suggested by Whitman and Kellher (2016) that align to mind the mind, brain, and education practices centered on embedding neuroscience with teaching approaches. Therefore, these findings reiterate the importance of addressing data literacy in secondary education to improve student preparedness for higher education and the results offer valuable insight on sources of data that can be used when teaching content knowledge.

As in the case of Usova and Laws (2021), data literacy courses are becoming increasingly popular, especially in higher education. Although the courses may be in introductory content, all center on recognizing problems, reviewing data sources, selecting variables, collecting data, analyzing data, and presenting data (Davenport & Patil, 2012). Ceccucci et al. (2015) stationed their research on evaluating data science education and its implications for improving science literacy through a review analysis situated in data science. The findings suggest that data science did not always achieve necessary science literacy components. However, data science aligned to the process of science and thus had similar methodological approaches. The results indicated that data science courses were a useful alternative that allowed students to develop science literacy skills and facilitate students to understand how a data scientist would work with a subset of data to test hypotheses, clean data through organization, analyze data, and make predictions based on interpretations of datasets. This research aligns to the present study's conceptual framework, which addresses these data literacy skills in competencies matrices.

In summary, the literature indicates that overall students' data literacy skills need to be addressed to improve performance in science and prepare students for postsecondary careers and education. Nonetheless, a variety of interventions have been demonstrated to improve students' data literacy in the areas of collecting data, analyzing data, interpreting data, and using data to make decisions. Interventions that were based on active learning and project based were found to be effective in improving students' data literacy (Seymoens et al., 2020; Usova & Laws, 2021) and use of real-life data improved students' data literacy (Werning, 2020). Additionally, collaboration among peers was found to be an effective strategy when implementing interventions to improve student data literacy (Carlson & Bracke, 2015). Moreover, classes designed to serve as interventions to facilitate data literacy were found to be effective in improving student data literacy (Carlson & Bracke, 2015; Ceccucci et al., 2015; Usova & Laws, 2021).

Although active learning, collaboration, use of real-world data, and interventional courses improved student data literacy, many students are still struggling in reaching all competencies needed to be data literate. For example, Suryadi et al. (2021) found that students' ability to evaluate, interpret, and assess were lower compared to collecting data. The results suggest that students need additional support in interpreting and communicating data sources and applying findings to real-world situations. Yet, the use of interventions to improve student data literacy is likely dependent on teachers' conceptions of data literacy, which is affected by their pedagogical content knowledge, experiences, and self-efficacy.

Nonetheless, the findings of students' conceptions of data literacy provide valuable implications to the present research in developing interview questions and creating a guide for conducting observations that center on important components of data literacy conceptions and strategies in science. For example, given the results indicated that use of active learning, collaboration, and real-world data improved student data literacy understanding, questions will be asked that address authentic use of data in science classes during interviews, and this area will also be examined in artifacts and observations. Since the literature indicates that students are typically able to complete lower level data literacy competencies, such as collect and organize data, but still struggle with higher competencies, such as analyze, interpret, and use data to make decisions, participants were asked on ways they advance students from being able to collect and curate to being able to analyze, interpret, and make informed decisions using sources of data.

Teacher Conceptualization of Data Literacy

Extending on the topic of using interventions to improve student data literacy, there is an emphasis for teachers to be proficient in data literacy in order to effectively teach data literacy to students (Mandinach & Gummer, 2016). This includes knowing how to effectively evaluate assessments, develop curriculums, and revise instructional approaches and practices. However, some educators lack the skill needed to obtain and evaluate data to improve instruction. Spillane (2012) published a review article that centered on teacher conceptualization of data use in schools. The results of the review article suggested that framing the practice of data use with clear objectives in the educational setting was necessary and that institutions should monitor teachers' conceptualization of data and how data is used to make instructional decisions.

Educational data literacy is a new but evolving field as it is becoming increasingly important for educators to use data to make decisions. Papamitsiou et al. (2021) conducted a study using a descriptive research design to assess educators' data literacy, which focused on one's conceptualization of finding, evaluating, and using data to inform instructional practices. The goal of the research was to create a proposed framework that included existing frameworks aligned to competences needed for job roles and that could be used to create professional development initiatives. The research sought to determine the dimensions and competence statements of a unified educational data literacy framework for instructional designers during blended learning. Moreover, the research sought to determine the educational data literacy readiness among the participants during blended learning and if the framework represents all facets of educational data literacy needed for competence in designing and implementing blended learning. To validate the study, 210 teachers were selected as participants through purposeful sampling. Participants completed a survey in the form of a questionnaire, which was aligned to the research design. Approximately 75% of the participants expressed that they were not competent in educational data literacy readiness. Nonetheless, 89.53% of the respondents indicated that they believed educational data literacy was useful in improving instructional practices. The findings indicated that teachers are not competent in educational data literacy, but the implications of the study suggest that a framework that emphasizes competencies centered on collecting, analyzing, interpreting, and using data to make inferences should be designed to improve educational data literacy. The results of the study are also useful in creating professional development that addresses these data facets.

Extending on the use of educational data, Vanhoof et al. (2013) explored data literacy using a conceptual framework that situated on the belief that data literacy involves being able to use and convert data for valuable information base on the understanding that data literacy required strategies, skills and knowledge to locate, evaluate, synthesize, organize, and communicate sources of data and that competencies relate to data literacy is impacted based on attitudes toward data. In-depth individual interviews and focus groups were conducted among school principals. The findings indicated that many teachers were deficient in data literacy and did not feel confident in competencies related to data literacy. Many expressed that data use was limited in professional development training. Many school principals indicated challenges in interpreting data sources. Nonetheless, most had a positive attitude towards data use. Yet, principals suggested that teachers had negative attributes toward data use. These findings suggest that teachers may lack the competencies needed to be data literate, which may cause some of the negative feelings towards data use. These implications suggest that principals and teachers need support in the interpretation of data to make data-based decisions. The present research addressed this need by first identifying teachers' conception of data literacy through interviews, observations, and document analyses.

Expanding on the need to address teachers' conceptions of data literacy, Dunlap and Piro (2016) explored data literacy intervention among preservice teachers to determine how participants viewed what works in data literacy intervention and the possible impact the intervention had on decision making. Therefore, the research questions were “How do participants view what works in data literacy intervention and in what ways?” “What are the implications for our own work?” The 54 participants included pre-service teachers who were taking an instruction and assessment class. An action research design was implemented using data chats as an invention that emphasized collaborative learning. The data chats centered on increasing students' abilities to evaluate and interpret data. The chats were implemented in one 3-hour session, which focused on understanding data literacy terms. The second session focused on reading and comprehending data sets. The third session was an inquiry learning session that used discussion board analysis of numbers and strengths and weaknesses in different data sets. Qualitative data was obtained through surveys, which consisted of open-ended questions. The results indicated that explicit instruction and collaborative learning of data literacy showed positive implications in preparing pre-service teachers. These findings suggest that explicit instruction of data literacy through use of technology and a collaborative design will improve teacher effectiveness and positively impact student learning. These outcomes align to recommendations proposed to improve NAEP scores and advance students in data-driven classrooms (Baker et al., 2022). Moreover, Whitman and Kelleher (2016) suggest that explicit instruction is a teaching strategy aligned with mind, brain, and educational teaching and is important in promoting active retrieval of knowledge. Therefore, these implications of explicit instruction and collaboration were considered in the observation data collection phase of the present research.

Like Dunlap and Piro (2016), Sezen-Barrie et al. (2015) also situated their research on preservice teachers using a qualitative approach. Seven preservice grade 4-8 science and math teachers were included. The research sought to determine specific science practices participants integrated in their instruction of the plate tectonic theory and challenges faced when focusing on scientific process and teaching the tectonic theory. Each participant implemented authentic lessons to teach plate tectonics, which served as the focus of this study. Data were collected through observations, interviews, and reflections. The results indicated that teachers assisted students in using data to their own classifications, which promoted a deeper understanding of plate tectonics. Moreover, collaborative learning was useful in improving student understanding, which supported scientific concepts and interpretation of data sources. Nonetheless, the research also revealed strategies that seemed to be less effective, such as focusing on teaching definitions, which was the center focus on one participant's activities. The teacher faced obstacles related to students' preconceived understandings. Therefore, the implications of the study suggest that teachers should use data sources as evidence to teach content through application with a focus on opportunities for students to collaborate and interpret data sources related to the science topic being addressed.

Similar to Ceccucci et al. (2015) emphasis on educators' data literacy, Kippers et al. (2018) situated their research on the theory of action and examined educators' knowledge and struggle with using data as an intervention. The research focused on studying teachers' ability to set a purpose, collect, analyze, and interpret data, and take instructional action. The research was conducted in six Dutch secondary schools, and the participants included educators from these secondary schools. A mixed method design was employed, and data were collected utilizing a pre/post test data literacy test, interviews, evaluation meetings, and logbooks. The number of participants varied for each data collection method. For example, 27 participants were included in the pre/post data literacy assessment; whereas, 33 were included in the group evaluation of meetings. Moreover, 12 of these participants were selected to participate in interviews. Coding was used to analyze qualitative data, and a t test was used to analyze the literacy pre/posttest. Workshops that centered on data use served as the intervention, which was implemented in stages. The first stage involved the participants developing a clear purpose for data use. Participants worked in small groups consisting of 4-6 people to create clear reasons for data use. The second stage involved formulating questions to capture the purpose of using data. Posttest results were significantly higher than the pretest scores (M= 11.2; SD = 3.03; M =9.3; SD = 2.66, respectively). The results indicated a significant increase in data literacy among participants based on the results from the pre/post data literacy assessment ($t(26)$= -3,113; $p<0.05$). Surprisingly, setting a purpose for data collection decreased from 30% on the pretest to 29% on the posttest. However, all other areas increased. For example, collecting data increased from 49% to 61%, analyzing data increased from 29% to 41%, interpreting data increased from 36% to 47%, and taking instructional action using data increased from 64% to 76%. Therefore, participants improved in all data literacy components except for setting a purpose for data. The other components included collecting data, analyzing data, interpreting data, and instructional action from data. Nonetheless, improvements can still be made as many educators still scored less than half of the maximum score for the posttest. Thus, future studies should consider additional interventions to improve data literacy and other stakeholders' data literacy abilities.

Belland and Kim (2021) conducted a quantitative research study that sought to determine if time spent in each scaffolding stage, which included individual work and working collaboratively, predicted argument quality among high school environmental science students. The researchers used computer-based problem-based scaffolding learning literacy, collaboration, and argumentation among 24 10th and 11th grade students. Log files and a pretest/posttest informational literacy assessment were used. Time spent in the individual and collaborative stages were measured in hours. Essays were utilized to measure each student's argumentation skills, including two scores and a common rubric. Data were analyzed using a Bayesian regression model. Significant results were found in posttest scores for positive predictors in information literacy and argumentation. Moreover, a strong positive correlation was found between individual work time and time defined in the problem. Additionally, a coefficient of 0.32 was found for students' argumentative abilities, which indicated that students' argumentation skills increased by 0.32, when informational literacy skills increased by 1 on the posttest. Additionally, argumentation skills increased by 2.03 when students spend more than an hour in the individual work stage. Interestingly, group work negatively affected students' argumentation skills (beta= -0.38). These results suggest that teachers should scaffold content during individual work to improve students' argumentation skills. Thus, future studies should consider additional interventions to improve data literacy and other stakeholders' data literacy abilities. These findings connect to the present research, which sought to examine how teachers scaffold and foster data literacy among their students in science classes.

Expanding on the findings of Celik (2014) and Sander (2020), which found using real-life data to improve teachers' conceptions of data literacy, Macaroglu (2004) research found an emphasis on interdisciplinary methods. The research included 12 elementary preservice scientific literacy levels through use of interviews and field notes in Turkey. All participants were undergraduate seniors completing a science-technology and society course, which emphasizes understanding science and science literacy through interdisciplinary approaches and real-life, relevant data and content. Data were collected using student portfolios and student interviews. Document analyses and open-coding were used. The findings highlighted major themes, which included the following: Science involves data collection through observations and experiments and scientific literacy involves being able to articulate and comprehend scientific concepts and make interpretations based on scientific information provided. These findings suggest that pre-service teachers view science as involving finding data and interpreting findings based on science concepts. These discoveries were embedded into the present study's design as teachers' conceptions and use of data literacy to improve science learning was the primary focus of the research.

Extending on the topic of collaborative learning to promote teacher conceptions of data literacy, multidimensional literacy requires learners to integrate concepts and apply knowledge to society and real-world issues. Celik (2014) conducted a qualitative study research focused on nominal, conceptual, functional, and multidimensional chemical literacy in Chemistry. The purpose of this research was to determine teacher candidates' chemical literacy by measuring nominal, conceptual, functional, and multidimensional literacy components related to high school chemistry. The participants consisted of 112 science and math teacher candidates from Turkey all of which completed a high school Chemistry class prior to being enrolled in an undergraduate program. Three different questionnaires were used to obtain data, and descriptive statistics were used for the analyses. Students' acquaintance with different chemical concepts ranged from 2.09 to 2.36 on a scale range of 1-3. Less than 50% of participants were able to provide correct explanations for chemical concepts. For example, 66% of participants provided an incorrect explanation for temperature when integrated with multidimensional concepts. The results indicated that participants' level of nominal and conceptual chemical literacy was proficient. However, participants were deficient in functional and multidimensional chemical literacy. The researcher suggested that assessments that were open-ended with less multiple-choice options were more appropriate in measuring students' conceptual understanding, functional, and multidimensional understanding and thus should be incorporated in secondary science courses. These formative assessments could include portfolios, paragraph analysis, and diagnostic tests. Moreover, to improve functional and multidimensional understanding, students should be provided with application learning opportunities early in their academic careers. These implications align to Black et al. (2003) emphasis on using a variety of open-ended assessments to capture students' learning and monitor growth. Consequently, these findings offered valuable insight on assessing students' data literacy. Moreover, the literature findings allowed the researcher to consider variations in the way teachers currently implement assessments to evaluate students' knowledge of data literacy. For example, since biology is an EOC course and this exam utilizes mostly multiple-choice items, variation in the types of assessments implemented through document analyses helped reveal the current practices implemented in science classrooms to evaluate students' data literacy.

Data literacy in universities has been a topic of interest in recent years to prepare the future for innovation centered on science and technology. Drawing on Dunlap and Piro (2016) perspectives of data literacy, Yang (2022) conducted a meta-analysis research centered on teachers in a university system. The research focused on different indexes of teachers' data literacy, which included data culture, data awareness, data skills, data value, data mining, data observation, data awareness, data preservation, data analysis, data collection, data transformation, data communication, and evaluation. Most literature supported data literacy as the ability to be aware of sources of data, acquire information from sources of data, process, and analyze data. The results indicated that positive data attitudes affected participants' ability to analyze, process, share, and present sources of data. Therefore, these findings imply that training should be implemented to increase teachers' confidence and perseverance in working with data.

Extending on the need for data literacy training, Henderson and Corry (2021) conducted a meta-analysis, which included 28 articles from 2010 to 2018 that centered on data literacy among educators in K-12 schools. ERIC and JSTOR served as the databases used in this study. The scope of the search centered on data literacy and omitted standalone constructs that overlap with this topic, such as assessment literacy, research literacy, and mathematical-statistical literacy. The results indicated that teacher preparation programs should focus on collaborative opportunities targeted to improve educators' use and understanding of data literacy and use of different sources of data should be modeled. Nonetheless, the research had limited scope due to its narrow view. However, the findings offer insight on structuring learning strategies to improve data literacy and addressing teachers' previous training related to data literacy.

Like Henderson and Corry (2021), Raffaghelli and Stewart (2020) conducted a meta-analysis to investigate framing data, training, and how gaps affect pathway choices. The research investigated evidence-based approaches in education regarding data literacy. A system approach that included appraising, summarizing, and outlining concepts in the literature was used. Using 137 papers in the data analysis, the findings indicated that management and technical abilities related to data literacy was emphasized. These papers were categorized based on the following data literacy components: Critical approach to data, data hacking, data in education, data safety/management, data science, unclear theoretical positioning. Technical skills were emphasized, such as data extraction, statistical analysis, and visualization. Some articles centered on evidence-driven approaches on data literacy, but the majority did not emphasize datafication. The findings indicate that data literacy training centered on technical skills related to data use rather than datafication. Moreover, the findings suggest that professional learning needs to be revisited to include structured concepts of datafication.

Expanding on the topic of datafication, Loftus and Madden (2020) discussed ways teachers and students can use real data in different contexts through subjectification. The authors situated research on dealing with challenges associated with datafication to improve data literacy in classrooms. The participants included students in a bachelor's of science computer program who participated in a class module centered on networking, internet communication, data gathering, data handling, data processing, and data analysis. The researchers were also teachers in this research, which centered on using sources of data embedded with technology use. A collaborative modeling approach called the Bayesian Networks was utilized, which included graphical representations and connections indicated by arrows. Although this research was preliminary, the authors argued that resources within this model promoted using data to reason, make inference, and develop predictions. Nonetheless, this research offers implications that resources centered on visuals may be useful in the present study.

Likewise, Filderman et al. (2021) conducted a meta-analysis, which included articles from 1975 to 2019. The beginning date of 1975 was chosen as a start date as it was determined to be a date of when data literacy training was implemented among K-12 educators. The research sought to determine the features of data literacy training for K-12 teachers, the effect data literacy training had on K-12 teachers, and if training characteristics influenced the training. The results found that there were significant positive effects on knowledge and skills g=.67 confidence intervals (CI) (0.40, 0.93) and beliefs g=.48, CI (0.17, 0.79). Fourteen studies that addressed coaching were found to not have a significant influence on determining the effects of training (beta=-.004, CI= -0.46, 0.46). However, collaborative format was found to have a significant impact on teacher knowledge and teacher outcome (beta = –.48, 95% CI = [–1.39, 0.44]). The findings indicated that training significantly improved teacher data literacy, especially when implemented collaboratively. Content focus in the training did not have significant impact, but active learning with collective participation did, which aligns to Vygotsky's social learning theory. These findings suggest training should be implemented and strategically designed to improve teacher data literacy.

Extending on the topic of professional development, Ndukwe and Daniel (2020) used a Tripartite model, which centered on three components, and included descriptive, synthesis, and critique components. A literature review was conducted, and the researchers focused on a teaching outcome model that teaches and reflects on data literacy practices centered on teaching analytics. The SCOPS database was used with key words that centered on teaching analytics, teacher inquiry, data literacy, and visualization. The search included articles from 2012 to 2019 and 58 initially populated, and 31 were selected for the study. The results suggest that the teaching outcome model is an effective resource to use that is centered on data-informed teaching practices. Nonetheless, professional development that centers on data literacy and analytic visualization is needed along with a common data framework to ensure teachers are strategically incorporating practices that involve use of big data.

Expanding on the application of big data, Sander (2020) employed a multi-qualitative approach to investigate online resources used to improve critical big data literacy. The research sought to determine which resources and tools already exist that are used to support critical big data literacy. Snowball sampling was used to determine available tools and answer the first research question. Data were collected from social media platforms, journalists, and graphic designers. To determine how critical big data impacted people's attitudes and behaviors related to online privacy, data were collected from participants at three time points, and ten participants from a university were included, which were selected using purposeful sampling. Questionnaires, screen recordings, observations, and interviews were used to obtain data. Interventions implemented in the study were tools that addressed user privacy. The findings indicated a broad variety of data literacy tools and certain tools were more useful in teaching critical big data literacy than others. Participants expressed concerns related to data disclosure online and suggested that programs should expand data literacy to include concepts discussed in this research to promote awareness and understanding of big data practices. These findings provide insight to the present study when answering research question 1 and determining teachers' interpretation of data literacy.

Similarly, Shernoff et al. (2017) conducted an exploratory study from a pilot group of six teachers from an urban school consisting of majority minorities and socioeconomically disadvantaged to determine the effects of professional development on improving integrating data literacy activities in science classes. The participants included equal numbers of white and black ethnicities, and the average years of teaching experience was 9.8 years. Active professional development was designed and implemented in the summer. Participants attended the PD for 6 hours each day with a total of 90 hours of participation for each participant. Seven of the hours were strictly centered on data literacy, which included defining data literacy, gaining knowledge of tools used to work with data, working with data as a learner, reflecting on data, and reflections on teaching data. Participants expressed that data literacy was a clear need in the school setting. Use of active learning, collaboration, and modeling were commonly used in the PD. A content related survey was administered to participants before and after completion of the PD. Observations were conducted throughout the school year in classes, and semi-structured interviews were implemented after completion of the PD, and a focus group study was administered by an external personnel after completion of the PD. The findings indicated that many participants were initially uncertain about working with data, and confidence related to working with data increased at the conclusion of the PD compared to the beginning data survey. The PD was beneficial to some participants, but not all, and teachers experienced challenges when integrating data literacy in the context of their curriculum. These findings suggest that teachers would likely benefit from additional support that centered on pedagogical data literacy practices. Therefore, such findings were considered when identifying teachers' conception of data literacy and their involvement in training centers on data literacy.

Teacher self-efficacy is known as a teacher's self-belief to impact student learning (Whitman & Kellehr, 2016). Although there was limited research that addressed the influence of self-efficacy and teacher data literacy, identifying this area would likely provide a better understanding of teacher's conceptions of data literacy and practices used in the classroom to foster student data literacy. Taylor and Gunter (2009) conducted a quantitative study using questionnaires to determine how attitudes, social pressure, and self-efficacy relate to inquiry-based leadership, which is a leadership style that implemented question-based approaches to solve problems and improve schools. Seventy-nine school leaders were surveyed. A significant relationship was found between self-efficacy and inquiry-based leadership. Nonetheless, the relationship between self-efficacy and performance is not a new topic as much literature suggests positive self-efficacy improves overall practice (Ceylan, 2020; Young-Ju et al. 2000). Simon et al. (2022) used a pilot study to implement a three-part curricular model that incorporated a variety of activity learning activities in an online Astronomy course. One thousand and ninety-nine students enrolled in Astronomy courses from 9 institutions were included. Data were collected from student surveys and instructor interviews, and statistical analysis indicated that students' self-efficacy positively impacted data literacy, which was connected to students' ability to make meaning of scientific research. The results indicated that active learning activity (Planet Hunters Activity), which required students to engage in data literacy to advance scientific understanding shared a significant positive relationship with students' self-efficacy. Moreover, instructor interviews indicated a positive perspective tower using similar activities to engage students in interpreting a variety of data representations and increase students' self-efficacy. Views towards complexity datasets, data analysis, and interpretation was dependent on self-efficacy. Therefore, these findings suggest that self-efficacy may also have an impact on teachers' conceptions and instructional approaches with teaching data literacy.

In summary, similar to the findings for students' conceptualization of data literacy, teachers' conceptions of data literacy varied among the studies presented, but small group collaborative learning was found to increase participants' abilities in collecting data, analyzing data, interpreting data, and instructional action from data (Filderman et al., 2021; Henderson & Corry, 2021; Kippers et al., 2018). Moreover, explicit instruction of data literacy using data chats as an intervention was found to improve teachers' data literacy (Dunlap & Piro, 2016). Additionally, use of a variety of data sources, including real-life data, had positive implications towards data literacy (Celik, 2014; Sander, 2020). Nonetheless, participants still struggle with components of data literacy. For example, teachers struggled in setting a purpose for data in Kippers et al. (2018) study. Similarly, preservice teachers lacked components of multidimensional literacy in chemistry, which suggested this area should be addressed to improve data literacy among students (Celik, 2014). To address deficiencies, research suggest implementing individualized trainings to improve teachers' abilities to analyze, process, share, and present sources of data (Filderman et al., 2021; Ndukwe & Daniel, 2020; Raffaghelli & Stewart, 2020; Shernoff et al., 2017; Yang, 2022). Although limited research was available, self-efficacy has been linked to positive leadership performance and students' data literacy (Ceylan, 2020; Simon et al., 2022; Young-Ju et al. 2000), which suggest teachers' and students' data literacy is likely affected by their self-efficacy and could serve as a potential target for improving data literacy. These results helped provide a vision on addressing the research question in the present study, which sought to examine teachers' conception of data literacy. Some interview questions were related to teachers' view of useful strategies to support their own data literacy abilities and training/resources they have found useful in advancing their own understanding.

Pedagogical Content Knowledge

Teachers' content knowledge drives decisions made in the classroom and is known to have a direct link with student achievement (Lotter et al., 2007). Whitman and Kellher (2016) describes pedagogical content knowledge as ". . . knowledge that is unique to teachers and is based on the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach)" (p. 159). Therefore, pedagogical content knowledge is needed for teachers to provide effective instruction and strategies to facilitate student learning. Additionally, knowledge of students and knowledge of the context of the classroom and school is directly linked to pedagogical content knowledge (Whitman & Kellher, 2016). Liepertz and Borowski (2018) employed a quasi-experimental design to determine if there was a relationship between professional knowledge and topic-specific professional knowledge, a relationship between professional knowledge and classroom practice, a correlation between classroom practice and students' outcomes, and a relationship between professional knowledge and students' outcomes. The participants included 35 physics teachers and their 8th and 9th grade classes that they taught. Data were collected from teacher tests, student tests, and videos of classroom observations. *T*-tests were used to analyze the data. The results indicated that there was a positive, significant relationship between content knowledge and professional knowledge, and pedagogical content knowledge and practices had a significant impact on students' outcomes. Although the model used had limitations in measuring teacher professional and pedagogical content knowledge, the results offer valuable implications to the present study when observing teachers' instructional methods to teach data literacy and their individual pedagogical knowledge of teaching data literacy to advance students' learning.

Extending on the topic of pedagogical content knowledge, technology has the potential to expand and reform education in many ways to promote cross curricular approaches. With the changes in today's era, teachers must stay up to date on effective classroom strategies and resources to promote data literacy learning in science. Therefore, technology knowledge and data literacy knowledge share a close relationship. Magana (2017) suggests that to be relevant and effective, teachers need to prepare students for a "modernized future," which emphasizes data and technology (p.16). With the emphasis of ongoing development of technology, technological pedagogical content knowledge (TPACK) models are becoming an area of focus in targeting students' learning.

Cui and Zhang (2022) used a mixed methods research design through use of focus groups and survey questionnaires to discover participants' views on data literacy, feelings on integrating TPACK, and perspective on whether the TPACK design is effective. Eleven participants were included. Descriptive statistics were performed, which indicated higher means in content knowledge and pedagogical content knowledge, while the lower means reported were related to smart teaching environments, technology, and data-related dimensions of teacher knowledge. A Mann-Whitney U test was performed to assess teachers' qualifications, age, and years of teaching experience. The findings indicated that teachers in the age range of 30-40 had higher levels of knowledge and surpassed the performance of other teachers that were 50 or older. Unexpectedly, teachers that had 20-30 years of experience were found to have more pedagogical knowledge compared to those with 30 or more years of experience, and teachers with bachelor's or master's degree outperformed others. Therefore, the implications of this study were considered as participants varied in age, experience, and qualifications, which likely affected the use of strategies and resources used to advance student data literacy. Since teachers that were younger and had less years of experience out performed teachers that were older with more years of experience in this particular article, participants' exposure to use of TPACK was considered in the present study.

Extending on the emphasis of pedagogical content knowledge as a precursor to student data literacy, Cannon (2022) investigated pre-service teacher's pedagogical content knowledge related to statistical data literacy. The research sought to determine how preservice teachers used messy data to make decisions and their comfort with using statistical concepts and thinking. Eleven participants were included in the study. All participants completed a 15-week course, which emphasized pedagogical content knowledge and using messy data to conduct and develop critical statistical literacy. The first part of the course focused on central concepts, and the second half centered on application of learning. Data were collected from pre/post open-ended surveys, field notes, observations, and participant reflections. The findings indicated that participants had positive perspectives to completing the course as their confidence in working with messy data improved. Through use and practice with different data sources, participants' procedural fluency with data use transitioned to a firm conceptual understanding of statistical analyses. The results suggest that teachers can build curiosity and engagement among their students by using messy data to explore social and scientific issues in their local communities. Moreover, critical statistical data literacy prepares teachers to consider variability in data sources and use interpretation of data to make informed decisions, which can then be transferable to students' learning. This research offered valuable implications in pedagogical content knowledge that teachers are expected to have as it relates to data literacy and how this knowledge impacts student data literacy in the classroom. Consequently, this area was addressed in the present study's research questions.

In summary, the literature provides a clear connection between pedagogical content knowledge and data literacy. For example, Cui and Zhang (2022) found that teachers that were younger with less education and experience had more data literacy pedagogical knowledge than those that were older with more education and experience. These implications suggest that it is important to identify the pedagogical approaches training that were used to advance data literacy. Cannon (2022) corroborates this belief in their research, which found courses offered on pedagogical content knowledge improved data literacy among participants. This reiterates a need to provide data literacy training for teachers to advance data literacy among students.

Need for Data Literacy Trainings

The need for training that centers on improving teachers' data literacy is evident in the research cited (Filderman et al., 2021; Ndukwe & Daniel, 2020; Shernoff et al., 2017). Teacher data literacy can be defined as the ability to collect, organize, analyze, interpret, and use data to make informed decisions. Green et al. (2015) suggested that professional development should be centered on data driven decision making to improve teachers' conceptualization of data literacy. This was based on the findings after implementing data literacy training opportunities for 15 teachers and one administrator using a three day seminar platform centered on data collection, data organization, and data interpretation to make inferences and pose questions. Each seminar was implemented on a monthly basis and lasted for three hours. A variety of team activities and open discussions were implemented to promote data literacy among participants. The goal for the first seminar focused on data collection and data use. The second workshop centered on helping the teams evaluate student data. The third workshop is situated on hands-on activities to introduce students to data analysis tools and strategies. Data were obtained through formative assessments and a survey. The formative assessment allowed teachers to share what they learned for each seminar by explaining three things they learned, two things they wanted to know, and one action they wanted to take to begin teaching data literacy. Descriptive statistics were performed on the survey items, which indicated a mean increase based on pre and post data. The results indicated that teachers were eager to learn more about collecting and analyzing data and how to use data to inform instruction. The implications of this research provided insight for developing professional learning to improve teacher conceptualization of data literacy.

Similarly, McCoy and Shih (2016) found that preservice teachers needed additional training in data literacy after conducting their research on educational data science, which emphasizes interdisciplinary research to improve student learning, performance, and program practices. The researchers sought to determine the type of data access, use, and interpretation challenges in education data science and to determine support needed in a teacher-focused education data science program to improve the analytic process. Twenty-five undergraduate students, graduate students, and faculty at a university participated in the study. Data were collected using semi-structured interviews, which lasted between 30 minutes and 1 hour. All interviews were audio recorded and transcribed. Participants expressed challenges in communicating data and few had experience analyzing large sets of data. Moreover, many struggled with navigating the data and many expressed that they did not have the skills to analyze data. Participants expressed that training centered on analyzing and interpreting data in place of training focused on data collection would help alleviate data challenges.

Preparing pre-service teachers in the development of data literacy that center on collecting, analyzing, and using data to make decisions is a popular topic in many programs. Kennedy-Clark et al. (2020) situated their qualitative research on pre-service teachers' experiences of using classroom data to guide instructional decision making. Twenty-seven pre-service teachers between the ages of 20-25 were invited to participate, and three agreed, which included two females and one male. After participants completed a project and their grades were posted in a teacher internship course, reflections were administered. This reflection centered on participants' data literacy after completing an action research project in their program. Guiding questions focused on defining data literacy, development of data literacy skills, experiences in doing action research, benefits of developing data literacy, challenges encountered, and how data literacy could be embedded into preparation programs. Data were collected from participants' reflections, and thematic analysis was used to analyze the data. Additionally, dual coding was implemented to build validity in the study, and a research team collaborated to develop themes. Four main themes were found, cited action research as challenging, a belief that data literacy involves systematically using and analyzing data to guide decision making, a belief that data literacy is best developed through authentic professional development, a belief that data literacy should be embedded in various courses, a belief that data should be used to inform and transform instruction, an emphasis on integrating data literacy with teaching strategies, and a belief that data literacy is needed for teachers to enforce accountability. All four of the main themes were supported by the three participants' responses. These findings indicated that data related skills and competencies were needed to prepare pre-service teachers, and time should be spent training teacher candidates on collection, analysis, and visualization of sources of data.

Expanding on the topic of professional development to improve teachers' ability to analyze data, Danley (2020) suggests that achievement in data literacy includes a variety of abilities, which include analyzing data, using data to make inferences, and working collaboratively in data teams. The purpose of the research was to determine if differentiated professional learning communities (PLCs) improved data literacy among participants. Fifty preservice teachers enrolled in a communications arts course at the University of Central Missouri participated in data teams in this qualitative research. Prior to working with data, participants were asked questions related to their current knowledge of analyzing student data and what they hope to gain from their experiences. Based on the reflective responses, participants were placed in PLCs, which were implemented using guiding questions that focused on what they want students to learn, how learning will be measured, how and if remediation will be implemented, and how to extend learning opportunities. The participants were familiar with data collection and data teams. However, they were less familiar with analyzing data and making informed decisions using data. Mock data sets were administered to the participants, which they analyzed in data teams and presented their findings. The findings indicate that participants knew that student achievement data should be collected and used to make instructional decisions. Moreover, participants indicated that they wanted to learn more about how to use data to make instructional adjustments. Additionally, 34 of the participants indicated that the data teams and PLCs were helpful in improving analysis of data and helping preservice teachers find ways to support students. Moreover, participants expressed additional question they would like answered in the future, which included how to use data to make changes, how to communicate results to students, and training related to understanding achievement data as an in-service teacher. These results align to Whitman and Kellher (2016) emphasis on schools staying up-to-date on instructional practices with collaborative PLCs. Consequently, the findings were addressed in the present study's design as participants are asked to explain if and how PLCs were used to target data literacy among students.

As implicated by Danley (2020) and Kennedy-Clark et al. (2020), professional development allows collaboration in data literacy and learning, which has had positive implications. For example, Schramm-Possinger and Harris (2021) used a quantitative survey approach to assess 182 teachers' beliefs, contextual support, and use of data in K-12 education. Majority of the participants had at least 15 years of experience and worked in a Title 1 school or rural area. Surveys were administered to participants via email. A principal component analysis was used to analyze the data and limit the focus on the main constructs of the study. Component-based scores were used to score the surveys, and correlated constructs were examined. The survey addressed three broad categories, which included school-based factors, teachers' beliefs, and teachers' behaviors. The results indicated that teacher behavior, teacher background, and personal views impacted data use among teachers. When teachers sense support, they are more likely to use data to inform instruction. Moreover, when teachers collaborated, they were more likely to use local and standardized data to inform instruction. Therefore, collaborative data analyses positively impacted teacher use of data and improved use of data to solve problems and make decisions. Consequently, the findings suggest teachers need more practice and guidance in using data. Subsequently, these findings offered implications for professional development and pre-service teaching.

Based on the finding of Raak et al. (2021), there is a need to incorporate data drive instructional practices to improve teachers' conceptions of data, which will have an impact on student achievement. Teachers need to be able to comprehend, interpret, and use data sources to make instructional adjustments. Piro and Hutchinson (2014) situated their research on the perceptions of comfort toward data literacy after using data chats as an intervention. Non-random sampling was used to select participants, which were three sections of teacher candidates in an assessment course in teacher education. Seventy-eight participants were included, which comprised approximately 73% females. One researcher served as the instructor and the other researcher maintained an outside approach. The research employed a post-positivist approach utilizing a quasi-experimental approach with the absence of a control group. Data were collected from pre and post surveys. Data chats served as the data literacy intervention, requiring participants to analyze K-12 data in core classes. Participants were tasked with collaboratively analyzing strengths and weaknesses of data sets, creating assessments and instructional strategies based on weaknesses identified from data analyses, and writing a final report of the findings and future recommendations guided by data analysis. The findings indicated that participants' positive perceptions significantly increased after implementing data chats as an intervention in the classroom. For example, 83.8% improved their perceptions of manipulating numerical data and interpreting analyses. Moreover, 88.2% improved in their perceptions to consider distribution of student scores rather than just considering the mean in datasets. Additionally, 80.9% of participants improved in their ability to use data to differentiate instruction. Although the research only focused on teachers from one institution, the results suggest that data literacy intervention, such as data chats, should be implemented to ensure teacher candidates are literate in data sources and also support students' data literacy needs.

Learning in science has shifted from teacher-centered instruction to facilitate inquiry learning that emphasizes discovery learning, which is believed to improve authentic learning and application of knowledge (Moon, 2020). Dresner and Moldenke (2002) suggested that teachers develop an in-depth understanding of scientific concepts when spending time collecting and using data sources to engage in scientific knowledge. This level of teacher understanding likely impacts authentic, inquiry learning in science. The research reports case studies of two teachers that engaged in authentic use of data connected to forestry ecology lessons. Both teachers in this case study design indicated that collecting authentic data allowed them to develop a better understanding of science, which they believed will positively influence their instructional practices in their classrooms. Moreover, the teachers indicated that being able to practice field techniques increased their confidence in teaching these ecological topics. Following the case study of two teachers, 120 teachers participated in similar summer experiences. Data collected from surveys indicated that all teachers felt incompetent in carrying out this type of hands-on science project, but after doing so, all teachers improved in proficiency in teaching science inquiry. Furthermore, 94% of teachers indicated that they improved in implementing student field ecology projects as a result of being able to engage in the authentic projects themselves prior to instructional delivery to students. The implications of the study suggest that this type of teacher-scientist collaboration improves teacher proficiency in applying science concepts, which will positively impact their instructional support in guiding students in completing authentic science projects with use of authentic data. These findings suggest that professional learning and training should enable teachers to engage in authentic collaborative science projects to increase their knowledge and confidence in supporting students in authentic data collection and inquiry research projects.

Similarly, Stephenson and Patti (2007) found a need for individual professional development after conducting a pilot study that consisted of a pretest/posttest design using a course centered on applying data literacy to solve social problems and found undergraduates to benefit from such programs. The findings suggest that implementing programs in postsecondary education improved learners to be effective problem solvers in society. The researchers assessed 182 teachers' beliefs, contextual support, and use of data in K-12 education using a quantitative approach. Surveys were administered to participants via email. The results indicated that teacher behavior, teacher background, and personal views impacted data use among teachers. Nonetheless, many expressed a need for more practice and guidance in using data. Subsequently, these findings offer implications for professional development and pre-service teaching as did Miller et al. (2021) and Ndukwe and Daniel (2020).

Taking the argument in a different direction, Raak et al. (2021) study suggested that teachers did not find school context data meaningful. The researchers utilized a phenological study design to capture the lived experiences and interpretation of meaning of 21 teachers from six different schools in Estonia. The participants were purposefully selected and interviewed. The research sought to determine teachers' perception of data use to understand school context, data use practices among teachers, teacher data literacy skills, collaboration among teachers, and the responsibility of the school leader in data use. Overall, data was viewed as student information among teachers. Teachers believed that the purpose of data was to provide students with feedback, and this data may vary from questionnaires, observations, or discussions. Nonetheless, participants believed that collecting data regularly was not necessary unless a problem arises. Moreover, the teachers did not commonly see data as a source to evaluate their own instructional practices and make improvements. Therefore, the participants did not view data as a meaningful instrument. These findings suggested that professional development should be implemented and directed towards improving data literacy among teachers so that teachers can learn how to use data effectively to improve and revise instruction.

Examining the need of data competencies in a different direction, Cezar and Maçada (2021) conducted research on 321 participants who worked in data-rich professions to determine the relationship between data literacy, perceived data overload, and professional performance. Data were collected through interviews, and a factorial analysis was used to analyze the data. The results indicated that there was a positive relationship between data literacy and professional performance. The implications of the study suggest that data literacy is needed in a wide range of businesses and organizations. This aligns to Wolff et al. (2016) emphasis on data literacy in today's society. For example, the author stated that "In modern life, people are interacting with data on a daily basis" (Wolff et al., 2016, p. 16). Understanding types of data and communication of data sources is essential for daily activities as "Collected data is processed and presented in a variety of different ways to support news articles, advertisements, consumer advice, political debate, or policy-making" (Wolff et al., 2016, p.16). Yet, data alone has little use. Consequently, one must understand sources of data, collection of data, interpretation of data, and communication of data. To make informed decisions, people must understand how to read data sources and consider strengths and limitations of sources of data. Therefore, without a proficient understanding in data literacy, people become susceptible to believing biased interpretations. As a result, data literacy is an important element outside of education as it is needed to make informed decisions that impact one's future and the society we live in. Consequently, addressing data literacy at an early stage would help prepare students for post-secondary decision making.

Drawing on the topic of teachers' data literacy skills, van den Bosch et al. (2017) conducted a study to determine 23 Dutch elementary in-service teachers' comprehension of graphs compared to experts. A think-aloud activity, creation of student data graphs, and graphing tests were implemented to obtain data, which lasted 10-12 weeks for each participant. Standard and student graphs were used. The think-aloud activities were analyzed in reference to three codes, which included accuracy, completeness, and sequential coherence. Descriptive statistics and a Pearson correlation were used to analyze the data. The results indicated that teachers' graphing interpretation was much lower than the experts' comprehension, which included M= 2.83 and M=3.71, respectively. Moreover, teachers' think aloud were shorter than the experts, but there was no significance found in this area $p > 0.05$. Additionally, teachers struggled in the interpretation of the graphs as only 6 were able to make at least one data to the instruction link. Furthermore, there was a significant positive correlation between teachers' data to data comparison and self-reported questions ($p<0.05$, $r= 0.65$). Overall, the study indicated that comprehension of data graphs were inconsistent among the participants, which suggest that additional training should be implemented that center on using and interpreting sources of student data to improve teaching practices.

The use of authentic data can also be used to establish a teacher-scientist partnership where authentic data is collected and analyzed through collaborative efforts. Giamellaro et al. (2020) situated their exploratory, phenological case study research design to determine teachers' experiences related to teacher-scientists collaborative projects. The research sought to determine if teachers developed a sense of story in this partnership. If so, the research sought to determine to what extent they identified themselves as agents in authentic learning through use of stories to transfer knowledge and practice from science to students. The participants of the study included

33 science and mathematics teachers, which were recruited via email. Teachers participated in science-collaborative activities. Data were collected from individual interviews, focus groups, and observations. Data were analyzed using co-coding to identify themes. The findings indicated that teachers conceptually assess data and scientific topics by making personal connections to scientists. Nonetheless, teachers experienced challenges with bringing authentic data to these classes but had a higher likelihood of doing so when data were contextualized. Moreover, the results indicated a positive effect on using narratives to explain data connected to science topics. The implications of the study suggest that contextualization of authentic data can be used to improve data literacy in creative ways, such as through storytelling, to positively impact student learning in science.

Extending on teachers' data literacy practices and comprehension, Cavalluzzo et al. (2013) aimed their large-scale research in determining the causal impact of using a data program to improve understanding and use of data in mathematics instruction. Specifically, the researcher sought to determine if students' achievement improved after receiving a using data treatment program and if teachers had positive attitudes towards this intervention compared to traditional methods. Moreover, the research teachers reported more use of data and if and/or how collaboration tied into this program. The participants of the study included 11,000 students and 800 teachers from 60 schools in urban areas in the United States. The using data program served as an intervention in the study, and data teams were formulated to collect data at schools. A block experimental randomized research design was used, and a mixed method approach was used to obtain data from participants. Student achievement over a two year period between 4th and 5th grade were analyzed, and surveys were administered to obtain teachers' attitudes and knowledge regarding data to improve instruction. Moreover, interviews, observations, and focus groups were administered to obtain qualitative data. Although this study was presented at a conference when it was currently being implemented, preliminary data suggested that the use of data intervention increased collaboration among teachers and improved student achievement. These findings imply that targeted interventions should be used to drive data literacy instruction to improve student learning.

In summary, there is an evident need to incorporate training to improve in-service and pre-service teachers' conceptualization of data literacy. Teachers were more likely to be able to collect data but had deficiencies in being able to communicate data sources (McCoy & Shih, 2016). Therefore, training should center on application of a variety of data (Danley, 2020; Stephenson & Patti, 2007). Moreover, such training should take place to ensure teachers have the data literacy competencies needed to evaluate a variety of data sources (Cezar & Maçada, 2021; Kennedy-Clark et al., 2020). This is especially important when integrating data literacy into the curriculum, such as science courses. Nonetheless, it is important to note that concepts are not formed in isolation and thus personal beliefs and experiences shape idea formation as was found in the research cited (Kennedy-Clark et al., 2020; Raak et al., 2021; Schramm-Possinger & Harris, 2021; Stephenson & Patti, 2007). Additionally, collaborative learning and use of real-life data was found to be effective in improving teachers' ability of interpreting data and using data to make decisions (Cavalluzzo et al., 2013; Piro & Hutchinson, 2014; van den Bosch et al., 2017). Although training has proven to improve instruction, Whitman and Kellher (2016) suggest that effectiveness of implementation is dependent on the design of the PD. For example, the authors suggest that professional learning should be ongoing and progressive based on the needs of the teacher with use of reflective practices. Consequently, these findings provide valuable insights to the present study in forming interview questions that consider participants' experiences. Moreover, these findings reiterate the present research illustrated need and significance as data literacy among teachers must be addressed to improve student achievement.

As indicated in the literature (Danley, 2020; Lestari & Rosana, 2020; McCoy & Shih, 2016; Papamitsiou et al., 2021; Suryadi et al., 2021), there is a matrix of data literacy competencies with many struggling to reach advanced data literacy learning in science. The present research's conceptual framework acknowledged this matrix, which included basic, intermediate, and advanced data literacy competencies and was aligned to Gibson and Mourad (2018) focus and was similar to Vanhoof et al. (2013) conceptual framework. Additionally, since much of the literature centered on individual experiences and sense making of data literacy (Belland & Kim, 2021; Bodzin & Shive, 2003; Bowler et al., 2019; Sezen-Barrie et al., 2015; Shernoff et al., 2017), the present research employed a transformative learning theory to obtain teachers' interpretations of their beliefs and experiences through critical reflection and meaning schemes, which is a central focus in this learning theory (Bush et al., 2020; King et al., 2019; Perry, 2021).

Summary

The literature provided an insight of teachers' conceptions of data literacy, students' conceptions of data literacy, effective interventions, and data sources needed to improve conceptual understanding of data literacy. Use of authentic data is linked to improved data literacy learning, and such data allows students to use relevant data to solve real-world issues (Dichev & Dicheva, 2017; Gould et al., 2014; Kjelvin & Schultheis, 2019; van 't Hooft et al., 2012). Conceptual understanding is improved through use of authentic data and can be used to engage students in scientific discourse (Llewellyn, 2013; Vahey et al., 2012). The conceptual framework used in the present study situated on a matrix of data literacy facets and competencies. Likewise, the present research also used the transformative learning theory as a way to obtain teachers' conceptions through critical reflection and construction of meaning schemes.

The emphasis on active learning, learning associated with real-world data, and interdisciplinary methods found in the literature aligns with John Dewey's theory of education, which emphasized democracy. Dewey's views focused on a learner-centered ideology through use of real-world and problem-solving situations to stimulate the mind to evolve. He also believed that experience is deeply related to learning, and therefore prior knowledge should be connected to new knowledge when teaching, which were all repeated findings in the literature (Frank, 2017; Magana, 2017). Similarly, Whitman and Kelleher (2016) Suggested that prior knowledge was an important element in establishing deep learning, which prompts understanding.

Students need scaffolded support when working with data sources (Kjelvin & Schultheis, 2019; Wolff et al., 2019). Moreover, interdisciplinary strategies have been linked to improve students' learning (Dichev & Dicheva, 2017; Jordan et al., 2019; Macaroglu, 2004; Vahey et al., 2012). Several interventions were found to provide valuable insight in improving student data literacy, such as technology used to visual data sources (Gibson & Mourad, 2018; Rahmawati et al., 2020), project-based learning that incorporated active learning strategies (Erwin, 2015; Eshun & Graft-Johnson, 2012), and interventions centered on collaborative learning (Belland & Kim, 2021; Carlson & Bracke, 2015; Cavalluzzo et al., 2013; Danley, 2020; Dunlap & Piro, 2016; Ellwein et al., 2014; Filderman et al., 2021; Henderson & Corry, 2021; Kippers et al., 2018; Piro & Hutchinson, 2014; Raak et al., 2021; Schramm-Possinger & Harris, 2021; Shernoff et al., 2017; van den Bosch et al., 2017; Wolff et al., 2019).

In addition to the need to address students' conceptual understanding of data literacy, the literature also demonstrated an evident need to improve teacher conceptualization of data literacy (Celik, 2014; Dunlap & Piro, 2016; Filderman et al., 2021; Kippers et al., 2018; Raffaghelli & Stewart, 2020; Shernoff et al., 2017; Yang, 2022). To improve teacher conceptualization, much of the literature cited a need for professional development that centers on differentiated interventions (Miller et al., 2021; Raffaghelli & Stewart, 2020; Shernoff et al., 2017; Stephenson & Patti, 2007; van 't Hooft et al., 2012). Since teachers have an important role in fostering data literacy to improve students' conceptual understanding (Llewellyn, 2013), it is necessary that the deficiencies in teachers' conceptual understanding are identified and addressed.

Based on the literature review conducted, limited studies were available that directly answered proposed research questions. Therefore, the proposed present study offered thoughtful insight of data literacy instructional practices and conceptions among science teachers in a rural high school. The present study sought to examine teachers' conceptions of data literacy, teachers' expectations of student data literacy in science, and strategies used to foster data literacy in life science and physical science classes. The findings offered valuable implications in providing training to current and future educators that center on advancing competencies of data literacy facets. Since the research sought to obtain information of teachers' expectations, conceptions, and past experiences a qualitative study using semi-structured interviews was chosen as a primary data collection method with document analyses and observations serving as supplementary data sources. The subsequent chapter addresses these instruments and data collection methods in detail.

Table 3

Concept analysis chart

STUDY	PURPOSE	PARTICIPANTS	DESIGN/ ANALYSIS	OUTCOMES
van 't Hooft et al. (2012)	Compare test scores using cross disciplinary methods.	576 seventh graders from two schools	Quantitative: Pretest/posttest	Significant results indicated knowledge and literacy skills increased when real-life content and connections were made using the intervention.
Dichev & Dicheva (2017)	Used an interdisciplinary curriculum approach to improve student data literacy	18 undergraduates	Quantitative: Pretest/posttest, t test	Data literacy embedded in courses improved students' science data literacy
Suryadi et al. (2021)	Assessed students' ability to obtain, analyze, and interpret data	60 students from five high schools	Quantitative: 6-item essay test using a quantitative scoring	Students' data literacy understandings were below satisfactory in physical science.
Zucker et al. (2014)	Assessed teachers' perceptions towards using smartgraphs as a data literacy tool.	26 schools and included 29 teachers, 72 sections of physical science, and 1,700 students in 8th and 9th grade.	Mixed methods: student test, teacher feedback	Teachers indicated that their comfort and confidence increased when using smartgraphs activities.
Chin et al. (2016)	Addressed the impacts of choice-based game assessments in improving data literacy and visualization	93 10th grade students in biology	Quantitative *F* Test	Time spent in the online games predicted student achievement. Incorporating student choices improved students' visualization ability.
Lestari & Rosana (2020)	Assessed the effects of an intervention used to improve students abilities to exploring data, selecting data, converting data, and using data for decision making	235 students in 8th grade	quantitative descriptive	Students were more literate in exploring data and deficient in using data for decision making.

Belland & Kim (2021)	Sought to determine if time spent in each scaffolding stage, which included individual work and working collaboratively, predicted argument quality among high school environmental science students.	24 10th and 11th grade students	Quantitative: Bayesian regression model	Students' argumentation skills increased, but collaboration was found to not be effective.
Usova & Laws (2021)	Centered on preparing students to read, analyze, interpret, evaluate, and synthesize sources of data through use of visualization using a one-credit course.	14 undergraduate students	Qualitative: student feedback and reflection	Students perceived the course and hands-on activities improved their use of data.
Carlson & Bracke (2015)	To determine if students had positive perceptions towards a data literacy class	10 undergraduates	Qualitative: case study design, focus groups and interviews	Students' confidence improved, collaborative assignments were effective, and real-life data sources increased motivation.
Dunlap & Piro (2016)	To determine how participants viewed what works in data literacy intervention and the possible impact the intervention had on decision making.	54 pre-service teachers	Qualitative: Open-ended questions in a survey	Explicit instruction and collaborative learning of data literacy showed positive implications in preparing pre-service teachers.
Kippers et al. (2018)	Focused on teachers' ability to set a purpose, collect, analyze, and interpret data, and take instructional action.	27 students from 6 secondary schools	Mixed Methods: Interviews, pretest/posttest design, *t* test	Participants improved in all data literacy components except for setting a purpose for data.
Celik (2014)	To determine teacher candidates' chemical literacy by measuring nominal, conceptual,	112 science and math teacher candidates	Qualitative: Questionnaires	Participants were deficient in functional and

	functional, and multidimensional literacy components related to high school chemistry.			multidimensional chemical literacy.
Shernoff et al. (2017)	To determine the effects of professional development on improving integrating data literacy activities in science classes.	6 teachers	Qualitative: Observations, semi-structured interviews	The PD increased confidence but some teachers experienced challenges when integrating data literacy in the context of their curriculum.
Stephenson & Patti (2007)	Assessed the impacts of a course centered on applying data literacy to solve social problems by focusing on teachers' beliefs, contextual support, and use of data.	182 teachers	Quantitative: Pretest/posttest design, surveys	The course improved learners to be effective problem solvers in society.
Kennedy-Clark et al. (2020)	To determine participants' experiences of using classroom data to guide instructional decision making.	27 pre-service teachers	Qualitative: Reflective open-ended questions	The results emphasized PDs centered on data literacy, cross disciplinary approaches, use of data to inform and transform instruction, and integrating a variety of data literacy teaching strategies.
Danley (2020)	To determine if PLCs improved participants' data literacy.	50 preservice teachers	Qualitative: Open ended questions using mock data.	Data teams and PLCs improved data literacy, but additional support on understanding how to use data to make changes.
Schramm-Possinger and Harris (2021)	To determine teachers' beliefs, contextual support, and use of data	182 teachers	Quantitative: Surveys	Teacher behavior, teacher background, and personal views impacted data use among teachers. A sense of support improved the use of data.

Raak et al. (2021)	The research sought to determine teachers' perception of data use to understand school context, data use practices among teachers, teacher data literacy skills, collaboration among teachers, and the responsibility of the school leader in data use.	21 teachers from six different schools	Qualitative: Phenological research	Believed that collecting data regularly was not necessary and did not view data as a meaningful instrument.
van den Bosch et al. (2017)	To determine teachers' comprehension of graphs compared to experts	23 Dutch elementary teachers	Quantitative: Descriptive statistics and a Pearson correlation	Comprehension of data graphs was inconsistent.
Cavalluzzo et al. (2013)	To determine the causal impact of using a data program to improve understanding and use of data in mathematics instruction.	11,000 students and 800 teachers from 60 schools	Mixed Methods: Longitudinal study observations, interviews, focus groups	Specific data literacy interventions aligned to students' needs and that are used to drive instruction, are positively perceived by educators
Ellwein et al. (2014)	To determine if student-centered activities that included authentic data improved data literacy.	10 instructors and 243 undergraduate students	Quantitative: Surveys	Instructors and students had positive perspectives of using authentic data to explore and engage collaboratively to solve real-life problems.
Farrell et al. (2021)	To determine perspectives of using real-life data through an online format to improve students' ability to collect, analyze, and interpret data.	14 teachers	Quantitative: Surveys	Using data to improve community issues improved data literacy.

Wolff et al. (2019)	To determine the impacts of an inquiry setting on data literacy.	3 teachers	Qualitative: ethnographic research design, observations and photographs	Younger students needed scaffolded support in formulating questions designed to inquiry lessons and students benefit from collecting their own data as it promotes students to critically consider the quality of data sources.

Chapter III: Methodology

With the changes in today's society and emphasis on data literacy as part of functional citizenship and global competitiveness, discovering teachers' conceptions of students' data literacy, expectations of students' data literacy, and strategies used to improve data literacy in science education provided insights for future teacher professional development and educational programs preparing pre-service teachers. Identifying effective instructional strategies in the classroom was needed to improve student learning. Evans (1989) suggests that teachers' conceptions are cultivated based on cultural knowledge that includes ". . . beliefs, values, expectations, mental models, and formulas used in generating and interpreting classroom events" (p.212). Moreover, Lotter et al. (2007) states that "Teacher beliefs often act as filters through which information about students, learning, and instructional strategies flow" (p. 1319). Therefore, teachers' feelings, values, needs, beliefs, purposes, and experiences shape expectations of instructional approaches and implementation of instructional practices (Evans, 1989). Consequently, this reiterates the importance of identifying teachers' conceptions of students' learning and instructional approaches used to foster student data literacy in science classes. Thus, the goal of the present study was to explore teachers' conceptions of data literacy and student data literacy, identify strategies used to foster data literacy, and examine the difference between life science and physical science teachers in advancing data literacy among high school students. Chapter III outlines the research design, setting, population, instruments, data collection, data analysis, and trustworthiness of the data.

Problem and Purpose

Previous research on the present topic has focused on teachers' conception of data literacy in regards to being data literate to perform teaching responsibilities, such as using data from assessments to guide instructional practices and using data to make inferences about school and student needs (Dunlap & Piro, 2016; Henderson & Corry, 2020; Kennedy-Clark et al., 2020; Papamitsiou et al., 2021; Raak et al., 2021; Spillane, 2012; Vanhoof et al., 2013). Additionally, much of the literature is situated on addressing pre-service teachers' conceptions of data literacy rather than practitioner educators (Cannon, 2022; Conn et al., 2020; Dunlap & Piro, 2016; Kennedy-Clark et al., 2020; Schramm-Possinger & Harris, 2021), and limited research addresses differences in life science and physical science student data literacy (Celik, 2014; Dunlap & Piro, 2016; Macaroglu, 2004; Sezen-Barrie et al., 2015). Likewise, strategies to improve data literacy varied among the literature included, but majority of the studies cited students and teachers were more likely able to reach lower data literacy competencies, such as the ability to obtain data, compared to advance competencies, such as the ability to analyze, interpret, and use data to make decisions (Kippers et al., 2018; Lestari & Rosana, 2020; Papamitsiou et al., 2021; Sugiarti et al., 2021; Suryadi et al., 2021; Vanhoof et al., 2013).

Similar to the studies that found students struggling in progressing in data literacy abilities, the district's state standardized scores demonstrate that students are struggling in reaching advanced data literacy competencies. This is based on the fact that science standards are heavily weighted in data literacy understanding and application and that the school's and the district's past and recent scores are below the state's average for science (Georgia Department of Education, 2023).

Governor Brian Kemp's signed House Bill 444 in 2020 reduced the number of courses that were required to partake in state testing. Biology is now the only course that has an end-of-course (EOC) assessment. Prior to this change, biology and physical science both included an EOC assessment. Past EOC results suggest that students are struggling in reaching data literacy proficiency in both courses. This was similar to the findings in the literature review and informal discussions held with teachers in the school and district. Therefore, based on the examination of the literature and local district's needs, there was a relevant need to examine teachers' conceptions of student data literacy and strategies used to improve student data literacy. The present research included life science and physical science teachers to allow a comparative analysis between the two.

Whitman and Kellerher (2016) state that ". . . there is no greater influence on student outcome than teacher quality" (p. 3). Moreover, 30 percent of variance in student achievement is impacted by teachers (Whitman & Kellerher, 2016). Consequently, conducting research on teacher conceptions related to factors that directly affect student achievement is imperative. Therefore, the purpose of the present study was to discover the conceptions high school life and physical science teachers have toward student data literacy and strategies used to improve life science and physical science education in a rural school district located in west-central Georgia. Given the fact that data literacy is conceived in different ways in the literature and is a noticeable concern in the science curriculum in the school and district, discovering conceptions and strategies used to improve data literacy will aid in developing effective instructional trainings and a cohesive science curriculum that targets students' data literacy needs to improve student learning in science. The present research has the potential to tailor instructional support for teachers to help provide them with strategies to improve data literacy based on their conceptions of student data literacy and experiences with strategies to foster data literacy in life science and physical science classes. Additionally, the present study could advance educator preparation programs and promote data literacy instruction to be a component of pre-service training in college courses. Furthermore, the present study has the potential to guide in-service teachers in their instructional methods to foster data literacy and expand the application of data in science courses to ensure students become data literate citizens and are prepared for the data driven society for postsecondary education and careers.

Research Questions

The following research questions guided the present study: 1. What are secondary science teachers' conceptions of data literacy? 2. What specific data literacy knowledge and skills do teachers expect their students to possess? 3. What are teachers' conceptions of how students perform or work through different concepts related to data literacy? 4. What specific instructional strategies do teachers use to scaffold and foster data literacy, and how do these instructional strategies and conceptions of data literacy differ between life science and physical science teachers? These questions were established used the context of the school district in which the research was implemented. This context is addressed in the subsequent sections.

Research Design

Within the field of educational research, qualitative research is a popular design as it has the ability to provide in-depth knowledge of human experiences through use of an inductive process (Thomas, 2006). Sutton and Austin (2015) state that "Qualitative research can help researchers access the thoughts and feelings of research participants, which can enable development of an understanding of the meaning people ascribe to their experiences" (p. 230). Likewise, Merriam and Tisdell (2016) suggested that qualitative research has the greatest potential of impacting people's lives by focusing on discovering and understanding human perspectives and understandings. Nonetheless, when employing qualitative research, it is important that the study design is clearly described with detailed information (Bowen, 2009; Sutton & Austin, 2015), which is addressed in the subsequent sections. Instead of a quantitative research design, a qualitative research design was chosen as it provides a dynamic method for exploring a problem identified and allows exploration of an issue through open-inquiry to understand human behaviors, beliefs, experiences, expectations, values, and assumptions (Choy, 2014; Merriam & Tisdell, 2016; Sutton & Austin, 2015; Walters, 2001).

The present qualitative study employed an interpretive research paradigm (Alharahsheh & Pius, 2020), which centers on the concept that reality is subjective and socially constructed, suggesting that interpretations will vary based on one's reality and lived experiences. Unlike positivism, which assumes that reality is stable, interpretivist research suggests that reality is subjective and diverse based on differences in cultures, perspectives, and experiences. Moreover, interpretivism centers on seeking rich insights from an individual's sense of meaning through emphasis on difference in humans. The interpretivist paradigm was chosen for the present study because it allows the researcher to address different factors that shape one's reality by focusing on an in-depth study that seeks to examine teachers' conceptions of data literacy based on individual experiences in science classes (Alharahsheh & Pius, 2020; Merriam & Tisdell, 2016).

In addition to an interpretivist qualitative paradigm, a case study design (Merriam & Tisdell, 2016) was used to examine teachers' conceptions of data literacy in high school science classes. This type of research design is interested in discovering human interpretations of their lived experiences. A qualitative research design is effective in answering "what," "why," and "how" questions as it relates to human experiences in the world through use of robust data collection. Additionally, this type of study design allows a researcher to gather rich data through interviews, observations, and document analyses in the natural setting and then take this data to create an understanding of the topic being explored (Hoepfl 1997; Merriam & Tisdell, 2016; Sutton & Austin, 2015). Therefore, qualitative research was chosen as the appropriate study design to answer the four research questions that situate "what" conceptions teachers have about data literacy and "how" teachers foster data literacy among their students in science classes.

Bowen (2009) describes case studies as ". . . intensive studies producing rich descriptions of a single phenomenon, event, organization, or program" (p. 29). Exploratory case studies are effective in exploring a topic or phenomenon that is little known and has yet to be clearly understood (Baxter & Jack, 2008). In this case study design, the focus was on discovery to obtain a deeper understanding on the topic or phenomenon being explored. An exploratory case study design was chosen as it allows the researcher to gain a better understanding of the phenomenon of data literacy in science classes. The exploratory case study was an appropriate design for the proposed research because it allows the topic of teachers' conceptions of student data literacy to be explored as limited research addresses this topic in-depth and is not well understood. The exploratory case study design allowed the research questions that center on "what" conceptions teachers have and "how" teachers foster data literacy to be explored through use of in-depth interviews, observations, and document analyses (Bowler et al., 2019; Giamellaro et al., 2020; Merriam & Tisdell, 2016; Vahey et al., 2012). Moreover, since no predetermined outcome is proposed, this research design was further aligned to the present research needs (Merriam & Tisdell, 2016).

The exploratory case study design allows the gathering of data centered on data literacy conceptions and experiences with strategies to improve data literacy in high school science classes (Baxter & Jack, 2008; Merriam & Tisdell, 2016). Therefore, the goal of this exploratory case study design was to gather data centered on teachers' conceptions of data literacy in life science and physical science classes. Through use of in-depth interviews, observations, and document analyses, teachers' conceptions of data literacy was obtained using a matrix of data literacy facets and understanding as indicated in the present research's conceptual framework and aligned to previous research (Gibson & Mourad, 2018; Papamitsiou et al., 2021; Vanhoof et al., 2013). Likewise, to obtain information regarding teacher' conceptions, expectations, and experiences, interviews, observations, and document analyses were selected and aligned to the transformative learning theory as teachers' critical reflective practices and sense making of data literacy was a primary focus to obtain data in the interviews. This aligns with much of the literature, which situated on addressing interpretation of experiences and beliefs (Belland & Kim, 2021; Bodzin & Shive, 2003; Bowler et al., 2019; Sezen-Barrie et al., 2015; Shernoff et al., 2017).

The findings of this study can inform future curriculum revisions and provide useful insights for pre-service and in-service teachers to promote and support student data literacy within their science classrooms (Jabareen, 2009). Table 4 demonstrates the alignment of the research questions with the instruments that will be used to answer each question.

Table 4

Research design confirmation.

Research Question	Instrumentation/ Analysis	How will the strategy answer the research question?
1. What are secondary science teachers' conceptions of data literacy?	Semi-structured interviews Audio recorded Transcribed Analysis: Open coding, axial coding, and thematic analysis	Interview questions will be used to answer teachers' ideas and experiences of data literacy.
2. What specific data literacy knowledge and skills do teachers expect their students to possess?	Semi-structured interviews Audio recorded Transcribed Analysis: Open coding, axial coding, and thematic analysis	Interview questions will include expectations of students' data literacy.
3. What are teachers' conceptions of how students perform or work through different concepts related to data literacy?	Semi-structured interviews Audio recorded Transcribed Analysis: Open coding, axial coding, and thematic analysis	Interview questions will be used to answer teachers' ideas and experiences of data literacy among their students.
4. What specific instructional strategies do teachers use to scaffold and foster data literacy, and how do these instructional strategies and conceptions of data literacy differ between life science and physical science teachers?	Semi-structured interviews Audio recorded Transcribed Analysis: Open coding, axial coding, and thematic analysis Observations Observation guide Field notes Analysis: Open coding, axial coding, and thematic analysis Documents Analysis: Open coding, axial coding, and thematic analysis	Interview questions that target strategies used to foster data literacy will help answer this RQ. Observations will help determine specific instructional strategies used to foster data literacy. Documents will provide examples of activities used to foster data literacy and examples of how data literacy is evaluated among students.

Binding the Research

Case research studies allow an in-depth approach to explore a complex, real-life situation through a bounded system design. This type of design allows the researcher to focus on boundaries of the topic being studied to allow an in-depth exploration. The exploratory case study was bounded within the context of two high schools located in the same district to allow examination of teachers' conceptions of data literacy and strategies used to foster data literacy between life science and physical science classes. Moreover, the study explored data literacy through the lens of eight teachers that actively taught life science and physical science classes. The research lasted approximately seven weeks and thus was bounded temporally (Merriam & Tisdell, 2016).

Role of Researcher

The researcher has an important role in qualitative research through data collection processes and thus must maintain objectivity. Sutton and Astin (2015) state that "The role of the researcher in qualitative research is to attempt to access the thoughts and feelings of study participants" (p. 226). In the present study, I served as the researcher by conducting interviews, classroom observations, and document analyses. Whitman and Kellher (2016) suggest that teacher research has an important impact on improving education. The researcher has been an educator for approximately six years in the school, which was one of the research sites of the present study. The researcher had a direct involvement in the development of the science curricula and continuous collaboration with colleagues, which led to the development of this research centered on the problem of data literacy in science and teachers' conceptualizations of data literacy.

The researcher worked in the same department as seven of the selected participants in the study but did not supervise any of the participants. Consequently, this likely improved participants' comfort with transparency when interviews were conducted (Krueger & Casey, 2009). Since the majority of the sample included teachers from where the researcher resided, the researcher assumed the role of an insider researcher (Greene, 2014). Implementing the research in the school where the researcher worked and developed professional relationships likely increased the depth of data collected. Moreover, knowledge of the culture and issues surrounding data literacy in science allowed facilitation of conversations when interviews were conducted. Additionally, familiarity of the setting and academic difficulties in the school district likely increased accessibility within the school. Therefore, the researcher utilized prior knowledge of the school districts' setting and expertise in science instruction to conduct this research. Furthermore, the researcher maintained a professional relationship with all participants in the study (Merriam & Tisdell, 2016).

Additionally, conducting the research in a setting that the researcher was familiar with aided in the development of questions centered on the researcher's knowledge of the problem being investigated. However, assuming the role of an insider researcher posed some bias. For example, the rapport the researcher had with the participants could have led to potential bias and loss of objectivity in the research (Greene, 2014). Thus, to help lessen bias, the researcher engaged in reflexivity to acknowledge prior assumptions, beliefs, and experiences, which impacted the implementation of the study (Reid et al., 2018). Recognizing and eliminating research bias is essential to increase trustworthiness of the study. Consequently, the researcher set aside all preconceived notions through use of bracketing. Moreover, a research journal was utilized to document any potential bias recognized to lessen objectivity and subjectivity bias throughout the implementation of the study (Merriam & Tisdell, 2016).

Population and Setting

The school district where the research was conducted consisted of 19 schools in the district and three traditional high schools. The other two high schools in the district served as alternative placement schools for students in 9-12. Approximately 12,160 students were enrolled in the public schools in this district. The demographics within the district were as follows: 43.9%

Black, 40.5% White, 8.3% Hispanic/Latino, 5.1% multi-racial, Asian/Pacific Islander 2.1% and 0.1% American Indian/Native American. Of the student population, 45% are females, and 52% are males. Additionally, students with disabilities and English language learners consist of 12.7% and 5.0% of the student population, respectively (Georgia Department of Education, 2023). One of the research site schools was chosen due to the easy access to data and rapport established with participants.

The two research sites were located in a rural area and considered high-needs schools based on the Georgia Department of Education requirements for students receiving free and reduced lunches. The district, school where the researcher resided, and other high school included in the study percentage of students that were economically disadvantaged based on eligibility for receiving free or reduced lunches were 74.8%, 38.9%, and 100% respectively. The school was a close representative of the population in the community and consists of approximately 1,400 students attending this school, which included grades 9-12. The demographics of the student population in the school included the following: 53.6% White, 35.7% Black, 4.8% Hispanic, 4.4% multiracial, 1.4% Asian, and 0.1% Native Americans. Of the student population, 54% were females, and 46% were males. Additionally, 10.7% include students with disabilities, and 1.6% were English Language Learners (Georgia Department of Education, 2023).

Unlike the demographics of the student population, the certified teacher population in the district was ethnically less diverse. For example, of the teacher population, 641 (78.08%) were White, 152 (18.51%) were Black, 15 (1.83%) were Hispanic, 9 (1.10%) were multiracial, 3 (0.37) were Asian, and 1 (0.12%) was Native American. Moreover, of the 821 teachers in the district, 643 (79.31%) were females and 178 (21.68%) were males. The level of education varied among the teachers in the district. For example, 261 (31.79%) held a bachelor's degree, 381 (46.41%) held a master's degree, 156 (19.0%) held a specialist's degree, 21 (2.56%) held a doctoral degree, and 2 (0.24%) held a one or two year vocational certificate. Additionally, 805 (98.05%) held a professional teaching certificate and 16 (1.94%) held a provisional certificate. Moreover, 11,376 made up Georgia's administrative population of which 539 (4.74%) held a bachelor's degree, 2,851 (25.06%) held a master's degree, 5,751 (50.55%) held a specialist degree, 2,231 (19.61%) held a doctorate degree, and 4 (0.04%) held a one or two year vocational certificate.

Similar to education, years of experience varied among teachers in the school. For example, 47 (5.72%) had less than a year of experience, 305 (37.14%) had 1-10 years of experience, 231 (28.14%) had 11-20 years of experience, 199 (24.24%) had 21-30 years of experience, and 39 (4.75%) had more than 30 years of experience. The mean years of experience was 15 years (Governor's Office of Student Achievement, 2023).

The teacher demographic, education, and experience was similar to the state's average. For example, of the 120,327 certified public school PreK-12 teachers in Georgia 80,645 (67.02%) were White, 32,361 (26.89%) were Black, 3,295 (2.74%) were Hispanic, 2,033 (1.69%) were multiracial, 1,778 (1.48%) were Asian, and 215 (0.18%) were Native American. Moreover, 95,718 (79.54%) were females, 24,609 (20.45%) were males. Likewise, the mean years of experience for teachers in the state was 14 years. The administrator demographics for the state included the following: 6,708 (58.97%) White, 4,269 (37.53%) Black, 196 (1.72%) Hispanic, 136 (0.20%) multiracial, 55 (0.48%) Asian, and 12 (0.11%) Native American. The mean years of experience for administrators was 21.

The selected research site demographics, education, and years of teaching experience was similar to the state and district. There was a total of 83 certified staff, which included five administrators and 78 certified teachers, at the research's school where she worked. Of the certified staff in the school, 82% were White and 18% and Black. Moreover, 64% were females, and 36% were males. Table 5 demonstrates the education level by degrees among the certified teachers and administrators in the school. Additionally, Table 6 illustrates the years of experience among the certified teachers and administrators in the building.

Table 5

Frequency and percentage of education level of teachers and administrators in the schools.

	Teachers		**Administrators**	
Education Level	N	%	N	%
Bachelor's	19	24%	0	0
Master's	39	50%	0	0
Specialist	16	21%	3	60%
Doctorate	4	5%	2	40%

Table 6

Frequency and percentage of years of experience for teachers and administrators.

Years of Experience in education	**Teachers**		**Administrators**	
	N	%	N	%
<1	0	0	0	0
1-3	10	13%	0	0
4-10	18	23%	0	0
11-20	14	18%	2	40%
21-30	33	42%	3	60%
>30	3	4%	0	0

Sample

This single exploratory case study included life science and physical science teachers. Eight participants from the school district were included as the unit of analysis. Consequently, purposeful sampling, also known as purposive sampling, was used to recruit participants (Hoepfl, 1997; Suri, 2011). Purposeful sampling allows the researcher to target a selected sample that will aid in supplying rich data to answer the research questions. Although there are limitations to using purposeful sampling, participants were intentionally selected based on the research questions, population in the school, and defined characteristics, which helped lessen bias in the sampling process of the present research. Additionally, convenience purposeful sampling was employed. Convenience sampling is ". . . based on time, money, location, availability of sites or respondents and so on" (Merriam & Tisdell, 2016, p. 98). This type of sampling was chosen due to the research being conducted in the researcher's school district where she worked (Merriam & Tisdell, 2016; Papamitsiou et al., 2021; Sander, 2020).

Participants

Eight science teachers from different backgrounds with different experiences were included trathe present study. This number of participants was decided based on the in-depth information needed to answer the research questions, the exploratory case study design, and the availability of science teachers in the research site school. Considering the low performance in science courses at the research sites, these participants were chosen as the best possible population in answering the research questions related to data literacy in science classes. Although mathematic teachers have experience with data literacy, these populations were eliminated from the research design since the focus of the research is on science classes (Merriam & Tisdell, 2016).

Since teachers have many duties causing a heavy workload, their participation in the present study will be time consuming. Therefore, the researcher recognized that recruiting participants for the present study may be challenging. Consequently, to increase participation, a $25 Visa gift card was provided to each participant at the completion of the study. Due to an initial low response rate within the school where the researcher resided, participants were elicited from another school in the district after obtaining IRB approval. Thus, this broadened the scope of the sample and research.

Participants were informed of the study’s purpose, the incentive to participate in the study, and the confidentiality of their participation in the research. Ensuring participants' confidentiality is an important element of conducting insider research (Greene, 2014). Informed consent was obtained from each selected participant. Table 7 includes descriptive characteristics of the selected participants in the present study. Each participant’s name was replaced with a pseudonym to preserve anonymity in the research. The accuracy of the information presented in the table was verified based on the answers provided on the questionnaire, which was sent after participants completed and returned the consent form to the researcher (Appendix E).

Table 7

Characteristics of participants

Teacher	Subject	Gender	Race	Years in Teaching High School Science	Highest Education Degree
1	Physical	Male	White	3	Masters
2	Life	Female	White	1	Specialist
3	Physical	Female	White	16	Doctorate
4	Life	Female	Multi-racial	6	Masters
5	Life	Female	White	<1	Bachelor's
6	Physical	Female	White	<1	Doctorate
7	Physical	Female	Black	2	Masters
8	Life	Female	Black	<1	Masters

The researcher acknowledged the lack of gender and racial diversity among the participants included in the present study. However, these participants were selected based on the teachers included in the science department and teachers willing to participate in the study. Moreover, the demographics of the selected sample are an approximate representation of the school's teacher population characteristics as represented in Tables 5 and 6.

Life science courses include biology, environmental science, anatomy, whereas, physical science classes include forensics, chemistry, physical science, and physics. The purpose of intentionally including an equal number of life science and physical science teachers was to discover if there were differences in data literacy conceptions and instructional approaches used to foster data literacy. Although all selected participants were from the same school district, limited collaboration took place between life science and physical science teachers. Common professional learning communities (PLCs) took place within content areas rather than among the department. Therefore, life science teachers had minimal interaction with physical science teachers from a collaborative course design perspective. Consequently, by including life science and physical science teachers in the present study, the research was able to capture a better view of teachers' conceptions, expectations, and instructional strategies used to foster data literacy in science education. Furthermore, including physical and life science teachers in the present study helped illuminate common and contrasting instructional strategies used to foster data literacy.

Prior to implementing the study, an Institutional Review Board (IRB) approval was obtained at Columbus State University, a letter of cooperation from both principals from each school was obtained, and district consent from the school system was retrieved. Moreover, once participants were selected, each participant completed a consent form, which was kept in a locked cabinet through the conduction of this research.

Instrumentation

The researcher served as the primary instrument in this qualitative research, which allowed responsive and adaptive strategies during data collection and analysis (Merriam & Tisdell, 2016). Qualitative research involves the collection of large amounts of data, which requires multiple data sources. The present study utilized interviews, observations, and documents as forms of instruments to obtain data and establish triangulation (Angers & Machtmes, 2005; Guion, 2002; Walters, 2001). Much qualitative research includes the use of different instruments that were used in the present research to increase credibility in the research findings (Bowen, 2009; Vahey et al., 2012).

Interviews

The present research sought to examine teachers’ conceptions of data literacy and information pertaining to strategies used to foster data literacy in science classes. Therefore, teachers’ voices had an important role in addressing the research topic. Consequently, interviews were chosen as an instrument to obtain participants' views. This instrument was used as the primary data collection source (Bowen, 2009). Interviews are effective in allowing the researcher to obtain in-depth data related to a phenomenon being studied. There are different ways interviews can be conducted, which includes structured interviews, semi-structured interviews, and unstructured interviews. Structured interviews do not deviate from predetermined questions/prompts; whereas, semi-structured interviews allow variation in questions based on respondents' responses through use of follow-up questions, and unstructured interviews do not follow any predetermined questions or order (Merriam & Tisdell, 2016; Segal et al., 2006).

Semi-structured interviews are commonly used in educational research to explore a phenomenon or variation within a group of people as this instrument provides the researcher to engage in two-way conversations and allow participants to explain their thinking through authentic open-ended discussions that prompt rich data. This form of interview facilitates participants to share narratives of their individual perspectives and experiences through use of follow-up questions to reveal hidden information that may not be fully disclosed through structured interviews (Barriball & While, 1994). Moreover, semi-structured interviews allow a deep comparison of participants' responses in regards to interpretation of sense making and meaning of experiences (Hannan, 2007; Merriam & Tisdell, 2016).

Nonetheless, rigorous development of semi-structured interview questions is vital to enhance objectivity and trustworthiness of qualitative research (Kallio et al., 2016). In the present study, semi-structured interviews were conducted in-person based on the convenience for each participant. The researcher utilized eighteen predetermined questions (See Appendix H). These questions were designed based on the findings in the literature review (Table 5). Open-ended questions were used in the interview, which allowed the participants to elaborate in their response to demonstrate their understandings, opinions, beliefs, experiences, and expectations (Merriam & Tisdell, 2016). This data collection method is aligned to the exploratory research design to allow participants to respond in their own words as they provide their conceptions and experiences related to data literacy in science classes. Follow-up questions were asked as needed to ensure collection of rich data to provide an in-depth analysis of the topic that aided in answering the research questions. The order of the questions was carefully chosen to allow participants to warm up to the environment and topic of data literacy (Krauss et al., 2009). Table 8 demonstrates the alignment of literature for each item in the interview.

Table 8

Alignment of interview questions to research questions

Item	Literature	Research Question
1	Belland & Kim, 2021; Chin et al., 2016; Ellwein et al., 2014; Farrell et al., 2021; Harris et al., 2012; Jordan et al., 2015; Lestari & Rosana, 2020; Medova et al., 2022; Sugiarti et al., 2021; Suryadi et al., 2021; Zucker et al., 2014	1
2	Carlson & Bracke, 2015; Dichev & Dicheva, 2017; Erwin, 2015; Harris et al., 2012; Hooft et al. 2012; Hume & Coll, 2010; Llewellyn, 2013; Medova et al., 2022; Roberts & Brugar 2017; Sugiarti et al., 2021; Wolff et al., 2016	2
3	Bodzin & Shive, 2003; Bowler et al., 2019; Hooft et al., 2012; Hume & Coll, 2010; Kjelvin & Schultheis, 2019; Llewellyn, 2013; Rahmawati et al., 2020; Vahey et al., 2012	3
4	Belland & Kim, 2021; Carlson & Bracke, 2015; Cavalluzzo et al., 2013; Danley, 2020; Dunlap & Piro, 2016; Ellwein et al., 2014; Erwin, 2015; Eshun & Graft-Johnson, 2012; Filderman et al., 2021; Gibson & Mourad, 2018; Green et al., 2015; Henderson & Corry, 2021; Kippers et al., 2018; Piro & Hutchinson, 2014; Raak et al., 2021; Schramm-Possinger & Harris, 2021; Sezen-Barrie et al., 2015; Vanhoof et al., 2013; Zucker et al., 2014	4
5	Belland & Kim, 2021; Carlson & Bracke, 2015; Cavalluzzo et al., 2013; Danley, 2020; Dichev & Dicheva, 2017; Dunlap & Piro, 2016; Ellwein et al., 2014; Filderman et al., 2021; Henderson & Corry, 2021; Jordan et al., 2019; Kippers et al., 2018; Macaroglu, 2004; Piro & Hutchinson, 2014; Raak et al., 2021; Schramm-Possinger & Harris, 2021; Shernoff et al., 2017; Vahey et al., 2012; van den Bosch et al., 2017; Wolff et al., 2019	4
6	Belland & Kim, 2021; Dichev & Dicheva, 2017; Kippers et al., 2018; Rahmawati et al., 2020;Vahey et al., 2012; van 't Hooft et al., 2012; Zucker et al., 2014	3

7	Bodzin & Shive, 2003; Ellwein et al., 2014; Giamellaro et al., 2020; Gould et al., 2014; Harris et al., 2012; Hume & Coll, 2010; Kjelvin & Schultheis, 2019; Raak et al., 2021; Stephenson & Patti, 2007; Wolff et al., 2019	4
8	Belland & Kim, 2021; Bowler et al., 2019; Green et al., 2016; Llewellyn, 2013; Rahmawati et al., 2020; Roberts & Brugar, 2017; Sugiarti et al., 2021; Suryadi et al., 2021; Taylor & Gunter 2009; Wolff et al., 2019	4
9	Bodzin & Shive, 2003; Dichev & Dicheva, 2017; Dresner & Moldenke, 2002; Ellwein et al., 2014; Farrell et al., 2021; Giamellaro et al., 2020; Gould et al., 2014; Harris et al., 2012; Kjelvin & Schultheis, 2019; Llewellyn, 2013; Vahey et al., 2012; van 't Hooft et al., 2012; Wolff et al., 2019	4
10	Cezar & Maçada, 2021; Danley, 2020; Dresner & Moldenke, 2002; Filderman et al., 2021; Green et al., 2015; Kennedy-Clark et al., 2020; McCoy & Shih, 2016; Miller et al., 2021; Ndukwe & Daniel, 2020; Piro & Hutchinson, 2014; Raak et al., 2021; Raffaghelli & Stewart, 2020; Schramm-Possinger & Harris, 2021; Shernoff et al., 2017; Stephenson & Patti, 2007; van den Bosch et al., 2017; Yang, 2022	3
11	Bodzin & Shive, 2003; Chin et al., 2016; Dichev & Dicheva, 2017; Kjelvik & Schultheis, 2019; Lestari & Rosana, 2020; Llewellyn, 2013; Medova et al., 2022; Sugiarti et al., 2021; Vahey et al., 2012; van 't Hooft et al., 2012	3 and 4
12	Danley, 2020; Miller et al., 2021	3
13	Belland & Kim, 2021; Chin et al., 2016; Dresner & Moldenke, 2002; Gibson & Mourad, 2018	4
14	Bodzin & Shive, 2003; Cannon, 2022; Chin et al., 2016; Dichev & Dicheva, 2017; Harris et al., 2012; Hume & Coll, 2010; Kennedy-Clark et al., 2020; Schmoker, 2011; Simon et al., 2022; Spillane, 2012; Van den Bosch et al., 2017	3 and 4
15	Dunlap & Piro, 2016; Kippers et al., 2018; Papamitsiou et al., 2021; Sezen-Barrie et al., 2015; Spillane, 2012; Vanhoof et al., 2013; Yang, 2022	1
16	Belland & Kim, 2021; Bodzin & Shive, 2003; Cannon, 2022; D'Ignazio, 2017; Ellwein et al., 2014; Farrell et al., 2021; Gould et al., 2014; Harris et al., 2012; Jordan et al., 2015; Kjelvin & Schultheis, 2019; Llewellyn, 2013; Medova et al., 2022; Miller et al., 2021; Sugiarti et al., 2021; Vahey et al., 2012	2 and 3
17	Ellwein et al., 2014; Loftus & Madden, 2020;Medova et al., 2022; Sezen-Barrie et al., 2015; Shernoff et al., 2017	2, 3, and 4
18	Belland & Kim, 2021; Celik, 2014; Dunlap & Piro 2016; Kippers et al., 2018; Mandinach & Gummer, 2016; Papamitsiou et al., 2021; Sezen-Barrie et al., 2015; Spillane, 2012; Vanhoof et al., 2013; Yang, 2022	1

Observations

Observations are a form of data collection frequently used in qualitative research, where the researcher obtains data where the phenomenon takes place in a natural setting. Thus, observations allow collection of firsthand data using a systematic process aligned to a research purpose. The researcher decides what to observe based on the study's purpose and brings their knowledge and experience to the natural setting. Often, informal observations take place to allow the researcher to become acclimated with the environment and people that will be observed. To be effective, the researcher must be a cautious observer and take accurate and descriptive field notes, which serves as data sources heavily relied on in observations. Field notes taken during the observation are raw data that should be quickly converted to a written narrative by the researcher (Hoepfl, 1997; Merriam & Tisdell, 2016).

Similar to the possible flexibility in interviews, observations can be conducted in a structured or unstructured way. Nonetheless, it is important that the researcher determines what to observe as all information that is attainable in an observation cannot possibly be documented. Classroom observations with use of an observation guide was used to obtain data of teachers' strategies and support used to foster student data literacy in science classes. Thus, this guide (Appendix I) helped the researcher determine what to observe and aided in systematic observations for each participant being observed. When the researcher identified the topics included in the guide, the researcher elaborated on how such data literacy areas were implemented in the classroom (Merriam & Tisdell, 2016).

Documents

Merriam and Tisdell (2016) describe documents as ". . . a wide range of written, visual, digital, and physical material relevant to the study (including visual images)" (p. 162).

Document analyses is a research instrument commonly used in qualitative research, which can provide the researcher with background information, supply additional knowledge to research, and serve as a method of verifying findings. Bowen (2009) defines this process as ". . . a systematic procedure for reviewing or evaluating documents" (p, 27). The richness of data supplied in the documents is dependent on the document obtained. Therefore, to ensure documents supply the research with robust information, it is important that the researcher clearly describes each document used. Although documents have several limitations, this source of instrument is useful in supplying behind the scene information when used with other qualitative approaches (Bowen, 2009).

Data is extracted from documents, which is then coded to generate meaning and understanding. Sources of data may include excerpts, quotations, or entire passages within the document that are used to develop themes. This instrument is frequently used with other instruments to triangulate the research to increase credibility and lessen bias. There are several strengths and limitations associated with using documents in research. For example, it can be difficult to establish authenticity of documents, and many documents are not created for the intended purpose of research (Bowen, 2009). Therefore, they may lack necessary information and/or alignment to the framework of the research. Nonetheless, as opposed to interviews and observations, documents are stable and thus offer objective data. Additionally, documents can offer generous amounts of information needed to answer research questions, are typically inexpensive, and can be used in the same manner as other qualitative data collection methods. Moreover, documents are typically readily available, cost effective, stable, and non-reactive. That is, documents are unaltered due to the presence of the researcher, which may have an impact on interviews and observations. Thus, documents supply the researcher with additional objective information that is needed to validate findings. Consequently, documents were chosen as an instrument in this present research as it is commonly employed in case study designs, which aligns to the present research (Angers & Machtmes, 2005; Bowen, 2009; Merriam & Tisdell, 2016). The present study utilized documents to supply additional knowledge to the research to answer research question four (Bowen, 2009; Hoepfl, 1997; Merriam & Tisdell, 2016). Each participant was asked to share an activity that they use to improve students' data literacy and a form of assessment that they use to evaluate students' data literacy.

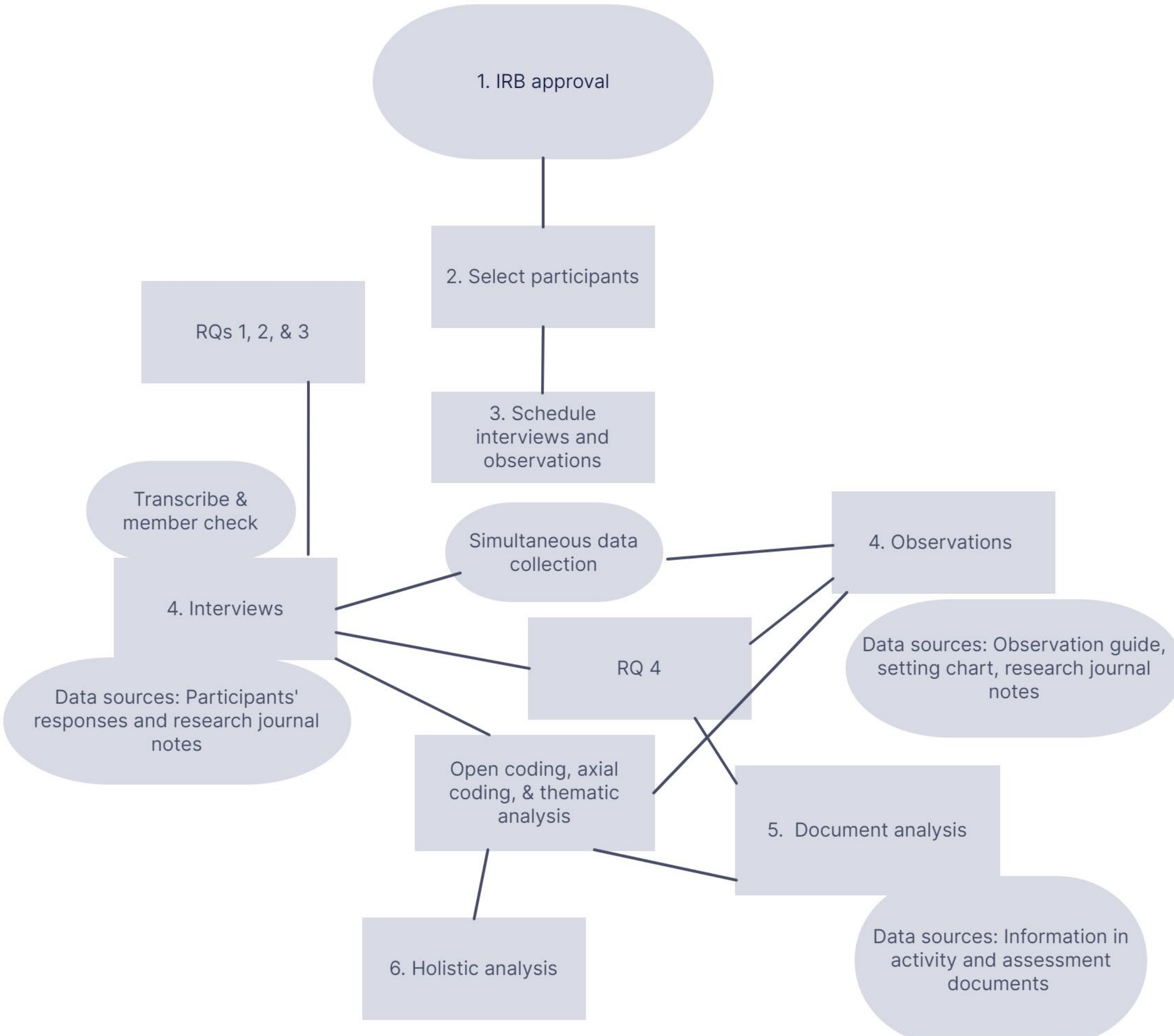
Data Collection

Prior to obtaining any source of data, approval from the Institutional Review Board at Columbus State University to include human participants was secured. The email confirming approval to conduct the study was saved and documented (see Appendix A). Moreover, a district consent form was completed (Appendix B). The completed IRB form was also documented (Appendix C). Once all proper approval was obtained, an email was sent to solicit science teachers to be participants in the present study (Appendix D.) Thus, direct emails to select potential participants was used as the mode of recruitment. Teachers who agreed to serve as participants in the present study were asked to complete the consent form. Once the consent form was obtained, each participant was asked to complete a short questionnaire, which addressed their levels of education, teaching experience, current position, primary subject taught, gender, and race (Appendix E). For the purpose of this research, primary was defined as teaching 50% or more of physical science or life science classes. A copy of the consent form was supplied to each participant for their records. The questionnaire was used to ensure an approximate equal representation of life science and physical science teachers. Moreover, the information obtained in the questionnaire was used to provide a rich description of each participant to improve credibility and transferability in the present study (Foreto et al., 2018). Once the consent form and questionnaire was completed, participants who met the required research criteria were contacted via email to schedule an interview and classroom observation (Appendix G). Google calendar was used to schedule interviews and observations for participants, which were conducted in-person. Participants were reminded of the purpose of the research and their right to accept or decline participation in the study.

Interviews and observations were conducted simultaneously and based on each participant's convenience. Document analyses followed interviews and observations. To increase participants' willingness to participate in the study, each participant was offered a $25 Visa gift card at the completion of their participation in this study. Data collection was triangulated to increase validity and reliability in the study (Angers & Machtmes, 2005; Bowen, 2009; Guion, 2002). Therefore, interviews, classroom observations, and document analyses were conducted to obtain data. Figure 5 demonstrates the methodological overview of the present study. Items numbered in the figure demonstrate the chronological order the data collection steps took place. For example, the researcher obtained IRB and district approval to conduct the research, which was followed by selecting participants and then scheduling interviews and observations, which were implemented simultaneously and followed by document analyses.

Figure 5

Methodology flow chart.



Interviews

Interviews are one of the most common data collection methods in qualitative research. Once selected participants completed the informed consent, they were contacted via email to schedule an interview at a time that is convenient to them. Google calendar was used to schedule interviews, which were conducted based on the time participants selected. Interviews were scheduled before school, after school, or during planning blocks. Each interview scheduled was anticipated to last approximately 1 hour. However, most lasted 30-40 minutes. All interviews were private with only the researcher and participant present. The same semi-structured interview questions were used to lead each interview. This type of interview structure permits the researcher to ask follow-up questions when additional information is needed. The researcher asked questions and allowed time for participants to process the questions and respond (Merriam & Tisdell, 2016).

Questions were asked in a specified order, and follow-up questions were asked to gain a better understanding of participants' responses and keep the conversation on topic. Moreover, follow-up questions allowed topics that are revealed by participants to be expanded and potential examples to be included. Although participants' verbal responses were audio recorded, non-verbal responses were also documented in journal entries as this was another important form of language and thus source of data (Nowicki, 2016). Probing approaches were used to facilitate the interview process, which included verbal and non-verbal techniques. For example, moments of silence were used as a non-verbal technique to allow participants the opportunity to process the question that was asked and allow time to respond. Additionally, other non-verbal cues included making eye contact with the participant, awareness of body language, and nodding when participants responded when necessary to ensure comfort. Examples of verbal techniques that were used to conduct the interview include repeating questions when necessary, using follow-up questions when additional information was needed, rephrasing questions, and clearly communicating all questions in the interview template (Krauss et al., 2009; Nowicki, 2016).

All semi-structured interviews were audio recorded using an app on the researcher's phone and transcribed by hand using MicrosoftWord to type interviews verbatim. The transcript was checked and corrections were made as necessary. The transcribed interviews and interpretations were member checked to improve credibility and validity in the present research. Member-checking allowed participants' to review the transcribed transcript to ensure their perspectives were accurately conveyed (Koelsch, 2013; Merriam & Tisdell, 2016). Participants received a copy via email of the researcher's initial analysis results of the interview to allow member checking and approval. If changes were necessary, participants were asked to supply these within 10 days of receiving the transcription. Therefore, interviews were analyzed as they were completed, which helped inform future interviews that were conducted.

A research journal was utilized to document field notes when conducting interviews. This was useful in documenting data that was not captured on the audio tape, such as non-verbal cues, environment, and behaviors (Sutton & Austin, 2015). At the conclusion of the interview, each participant was thanked for taking the time to share their personal experiences and informed that they will receive an email within 5 days of the interpreted interview for member checking (Appendix F).

Observations

Since the researcher was already acclimated with the environment and participants, informal observations did not take place as the researcher held existing knowledge of the context and people being observed. Thus, getting acquainted with the research site was not necessary. The focus of the observation was teachers who agreed to serve as participants in the present study. One observation was conducted for each teacher, and the researcher scheduled observations based on data literacy lessons being implemented. Observations were conducted during the approximate same time frame as interviews. However, this was dependent on each teacher's lessons and schedule. An email was sent to participants to schedule observations (Appendix G). Participants were asked to schedule an observation for a day and time that they implement a data literacy lesson in their science classes. Google calendar was used to schedule observations.

Merriam and Tisdell (2016) recommends observations should be an hour or less due to the amount of data that the researcher will obtain. Consequently, the present research conducted observations for 45 minutes for each participant. The researcher was a passive participant (Ergler, 2017) while conducting observations. Each observation began at the start of the block to ensure consistency among all observations. Moreover, all observations were conducted in-person, but the researcher did not interact with the participants. Thus, the researcher sat in an area away from the participants and took notes using an observation guide and a research journal. Therefore, the degree of involvement was low, which aligns to the passive participant.

A diagram of the classroom setting was drawn for each observation, which was used as a source of field notes. This diagram depicted where the researcher sat, point of implemented instruction, and classroom structure. Highly descriptive field notes were taken throughout the duration of each observation. Moreover, since reflexivity is an important element of qualitative research, field notes included reflective notes, which addressed the researcher's ". . . feelings, reactions, hunches, initial interpretations, speculations, and working hypotheses" (Merriam & Tisdell, 2016, p. 151). All field notes were detailed and include information of the setting, activities observed, and direct quotes. Thus, verbal and non-verbal forms of communication were documented as evidence for this data collection method (Merriam & Tisdell, 2016).

Moreover, an observation guide was used to obtain data during the observation, which helped enforce consistency in the research (Appendix G). This guide was developed based on the literature review conducted. Therefore, the guide aided in keeping the researcher focus on critical components of fostering data literacy. The frequency of the topics included in the observation guide were documented for each observation. Additionally, the guide was used to elaborate on research-based approaches to data literacy. Therefore, if the researcher identified a topic that was included in the observation guide being implemented in the classroom, then the researcher elaborated on their observation and provided critical details, such as how a strategy was implemented, to aid in answering research question 4. As soon as the researcher left the observation site, the researcher sat in a quiet location and recorded additional notes of what was observed. Following observations, debriefing took place to gather teachers' conceptions of the knowledge students gained to improve data literacy and offer clarification for any questions that may have arisen during the observation. Additionally, write-ups of field notes were completed within 3 days of completing each observation. These write-ups were converted to narrative to ensure all important information was captured (Hoepfl, 1997; Merriam & Tisdell, 2016). An example of a narrative is included in Appendix J.

Documents

Since documents are typically available in the research setting, participants were asked to supply preexisting documents that they have previously used. Since documents are limited in the amount of data supplied to a research study, a few documents were retrieved to aid in capturing data literacy in science classes. Each participant was asked to supply the researcher a copy of an activity they have used to teach data literacy and an assessment they have given their students to evaluate their data literacy skills and understandings. Participants were asked to ensure the documents are relevant to student data literacy in their classes. All documents were assessed for authenticity by determining the author of the document, intended audience of the document, and goal of the document. Document analyses followed interviews and observations (Bowen, 2009; Merriam & Tisdell, 2016).

Data Analysis and Management

Qualitative data analysis took place in the form of coding, which is a lower-level data analysis that is later used to develop themes (Witt, 2013). The codes used were based on the research questions: 1.What are secondary science teachers' conceptions of data literacy? 2. What specific data literacy knowledge and skills do teachers expect their students to possess? 3. What are teachers' conceptions of how students perform or work through different concepts related to data literacy? 4. What specific instructional strategies do teachers use to scaffold and foster data literacy, and how do these instructional strategies and conceptions of data literacy differ between life science and physical science teachers?

Data collection and data analysis occurred concurrently. Thus, as data were collected, the researcher began analysis. Data analysis included responses transcribed from interviews, data from observations, document analyses, and additional notes taken from journal entries. Data collected from different sources were initially analyzed independently. Thus, data for interviews were initially analyzed separately from observations and documents. Once data were analyzed for each data collection source, data were combined for a holistic analysis. The subsequent sections describe the sequence of data analysis for each instrument following a holistic analysis.

Data Management

Since this qualitative research design sought to examine teachers' conception and experiences with study data literacy and make sense of participants' perspectives, one of the most important parts of the data analysis was "...to be true to the participants" (Sutton & Austin, 2015, p. 227). Therefore, proper management and development of a strategic plan for analyzing and coding data was essential. Consequently, organization is key to the analysis process, and tracking one's own thoughts as data is analyzed will also be helpful in the analysis process.

Therefore, data from interviews, observations, and documents were compiled into separate files, and an inventory of all data was created.

Data storage procedures were carefully and consistently followed throughout the study. Two copies of datasets were kept in different locations to ensure data is not lost or destroyed. An electronic version and paper copy were kept. All data were stored on a computer that was password protected and only utilized by the researcher. Folders were created for each participant, and pseudonyms were used for each participant. All data on paper were stored in a secure location and organized in a locked filing cabinet. At the completion of this study, all data were destroyed (LeCompte, 2000; Merriam & Tisdell, 2016; Taylor-Powell & Renner, 2003). RQs 1, 2, and 3 were answered using interviews. RQ 4 was answered using interviews, observations, and documents. Data from all three instruments were analyzed using open coding, axial coding, and thematic analysis. The subsequent sections describe the analyses in detail.

Transcribing and Member Checking Interviews

Each semi-structured interview was audio recorded with a voice app on the researcher's phone called Voice Recorder. All interviews were transcribed verbatim using Microsoft Word to manually type transcripts, and all interviews were member checked to establish validity in the present study. Transcripts were checked multiple times to check for errors. Notes were made as the researcher transcribed, such notations of laughter, silence, and other data sources relevant to the interviews. The researcher analyzed each interview and sent major findings to participants for member checking (Appendix F) (Sutton & Austin, 2015; Walters, 2001). This ensured clarification and confirmed all responses were accurately documented to establish validity. These findings were presented in a Microsoft Word document for each participant with all 18 item questions of the semi-structured interview listed in sequential order with a summary of each participant's responses for each item based on the researcher's initial analysis and interpretation. Thus, participants saw a brief summary of the findings for 100% of the items in the interview. Member checking allowed participants to verify the accuracy of the interpretations of their interviews responses and make any corrections necessary to convey their conceptions, expectations, and experiences of science data literacy. All participants were involved in the member checking process, and all participants agreed with the researcher's interpretations and no disagreements found.

Analyzing, Coding, and Theming Interviews

Once participants approved the transcript, interviews were analyzed and coded to make sense of the data obtained. As interviews were completed and transcribed, they were analyzed. Thus, analysis began when the first transcript was completed and member checked. The researcher read the transcripts multiple times, documented reflections while analyzing the data, and noted tentative themes. As transcripts were read, comments were noted in the margins that were relevant to answering the research questions. This process took place for each interview and then tentative findings were compared to previous interview data and findings. Thus, all data were simultaneously collected and analyzed. This process aided in establishing tentative themes and prevented the researcher from becoming too overwhelmed with the large amount of data. Preconceived themes were set aside to allow categories to emerge from the data (Thomas, 2006; Witt, 2013).

Responses to each research question were organized to allow comparisons among participants. Raw data were read multiple times. As data is analyzed, the research purpose and questions were continuously referenced. Open-coding (Merriam & Tisdell, 2016) was used to welcome any information the data entails. This form of coding allowed codes to emerge from the data set. To do this, portions of the data were coded with single words or short phrases. During this analysis, data were highlighted to differentiate codes, and notes were made. All interviews were coded together to identify common themes and subthemes in the dataset. The researcher engaged in inductive thinking and coding (Thomas, 2006), which allowed the researcher to obtain codes from raw data without any preconceived notions. This served as the first level of coding. Participants' words and phrases were used to create codes. Axial coding (Merriam & Tisdell, 2016) was employed to explore the connections of how themes and subthemes across the data relate. Moreover, axial coding allowed grouping of open codes that arose from the researcher's interpretation of the data during the initial phase of the analysis process. A constant comparative method was used to develop themes and subthemes (Merriam & Tisdell, 2016).

Following axial coding, thematic analysis (Bowen, 2009; Merriam & Tisdell, 2016) was employed to establish themes and subthemes in the datasets. Bowen (2009) describes thematic analysis as ". . . a form of pattern recognition within the data, with emerging themes becoming the categories for analysis" (p. 32). This type of analysis allowed the researcher to examine connections and further refine categories to develop themes. Therefore, to implement thematic analysis, the researcher used patterns to analyze and interpret data sources (Merriam & Tisdell, 2016).

All data were read multiple times, and open coding and axial coding were used to discover alignment in emerging categories. To establish validity and reliability in the present study, an inter-coder was used for a portion of the data set. Once this section of the data was analyzed by the inter-coder, the researcher compared and contrasted the codes that were developed.

Observation Analysis

Data were simultaneously collected and analyzed. Data obtained from the setting sketch, observation guide field notes, and research journal were quickly transcribed into narratives within three days of each observation. The research journal allowed the research to include reflective notes. Data from observations were first organized and compiled into one file for analysis. As data were read and re-read, impressions were documented. Similar to the coding process for interviews, open-coding, axial coding, and thematic analysis were used (Merriam & Tisdell, 2016).

Document analyses

All documents that were obtained and analyzed directly related to the research problem and purpose. Documents were examined, read, and interpreted using open coding, axial coding, and thematic analysis techniques. Careful analysis through in-depth examination and reading of the documents is needed in this process. To conduct thematic analysis, selected data in the documents were coded and categorized to develop themes. Predefined themes identified from the interviews and observations were used since the document analyses served as supplementary to the research design. Nonetheless, if new information was discovered, additional themes were developed. The researcher remained objective while conducting document analyses to ensure all materials are fairly and accurately analyzed. Moreover, the researcher examined all documents with a critical eye to establish meaning and contribution to the research topic. Documents were assessed for completeness in covering components of the research topic. These documents were evaluated based on the authenticity and originality of each document (Bowen, 2009; Fereday & Muir-Cochrane, 2006).

Holistic Data Analysis

Once each data collection method was analyzed individually, interviews, observations, and documents were analyzed together to identify emergent themes across all datasets, which was similar to the research methods employed by Bowen (2009). The holistic analysis included open coding, axial coding, and thematic analysis. This was useful as document analyses was likely to provide fragmented information needed to answer the research questions. Thus, a holistic review helped broaden the scope of the data collected and analyzed to address data literacy. Moreover, a comparative analysis was conducted to identify similarities and differences, if any, between life science and physical science teachers (Bowen, 2009; Merriam & Tisdell, 2016).

Unit of Analysis. The unit of analysis of the present research focused on a few words, brief notes, and short phrases within sentences. If words were repeated and conveyed as the same meaning in the same paragraph/explanation, then they were coded as one code. Nonetheless some words were coded independently, which was dependent on its meaning related to how the researcher interpreted the data. For example, words that indicated uncertainty and visuals were mostly coded individually.

Coding. Data were compiled and analyzed using coding, which Sutton and Austin (2015) describes as ". . . the identification of topics, issues, similarities, and differences that are revealed through the participants' narratives and interpreted by the researcher" (p. 228). Coding allowed the researcher to easily access pieces of data and dive deep into the data collected that examines each participants' conceptualization and experiences of data literacy in science classes. Coding took place using Microsoft Word (Merriam & Tisdell, 2016).

Open-coding was employed, and themes were not identified until all data were worked through and analyzed multiple times. During the open-coding process, data were broken into discrete parts, and impressions in the data were noted by commenting on topics that were surprising or identified as common trends across the data. Moreover, journal entries were used as complementary data sources to fill any gaps or context data that may not be documented in the interview transcripts.

Axial coding was employed, which allowed the researcher to relate data together to form codes and categories. During this data analysis, codes were re-organized and relationships in the codes identified in the open coding process were revealed to develop categories. Data were organized using analytic questions, and visual devices were used to organize data. The data was organized based on the present study's purpose and key questions in the research were referred to regularly to ensure data analysis aligned to answering the research questions using a comparative analysis method to narrow categories.

All data were read multiple times to identify emergent categories. As the data is read, notes were made that connected topics and common vocabulary found in the data. This was used in the coding process of the research. Moreover, thematic analysis will be employed to identify patterns, which was used to establish themes.

Theming. Sutton and Austin (2015) describe theming as ". . . drawing together codes from one or more transcripts to present the findings of qualitative research in a coherent and meaningful way" (p. 229). Themes were identified to bring meaning to the data in the research. These themes were identified based on relevant pieces found within the dataset. The themes that were used in this research were selected based on trends and common topics found in the data after reading and rereading data from interviews, observations, and documents. Therefore, these items were identified based on frequency in the dataset. Themes were recognized using a similar category of codes. Different colored highlighters in Microsoft Word were used to identify themes from the codes, which will receive descriptive labels. When common trends were found across themes, these categories were grouped together or separated by theme and subtheme categories. The researcher consistently considered her own bias and tried to set all such aside to ensure the results are accurate. Once main themes were identified, the study narrowed to find supporting subthemes. Data and themes were synthesized, and conclusions were supported with examples from observations, documents, and quotes from interviews. All themes and subthemes were responsive to the study's purpose, exhaustive, and conceptually congruent (Merriam & Tisdell, 2016; Sutton & Austin, 2015).

Data Trustworthiness

Trustworthiness of data is essential in qualitative research and is known as how confident the research demonstrates true findings based on data, methods, and interpretations used. The use of different data sources improved the trustworthiness of the research findings and implications in educational research.

In qualitative research, reality is constructed through in-depth analysis of data. four dimensional criteria that impacts methodological rigor and trustworthiness of a study include credibility, dependability, confirmability, and transferability (Forero et al., 2018; Guba & Lincoln, 1981; Stahl & King, 2020). Moreover, validity and reliability are important to establish in qualitative studies to ensure sound research that is accurate and replicable. The first step to ensuring validity and reliability of a study is to conduct the research in an ethical way (Merriam & Tisdell, 2016; Patino & Ferreira, 2018).

Validity

Qualitative research has become increasingly popular in the field of education as it offers dynamic solutions through valuable insights of human experiences (Walters, 2001). Yet, with this research paradigm, trustworthiness of the data must be considered and steps in the research design and process must be carefully taken to ensure validity, reliability, credibility, and dependability is in place. Validity in research relates to how well the results of a study illustrate the true findings among participants alike. Validity can further be broken down into internal and external validity. Internal validity, also known as credibility, refers to the truth in a study, whereas, external validity, also known as transferability, refers to the truth in real-life (Patino & Ferreira, 2018).

Instruments. The conception of validity that is needed is based on the research design and paradigm being used. To establish validity and ensure data obtained corresponded to data literacy with instruments used in the present study, all interview questions were carefully designed and aligned to previous literature and the specified RQs of the present study. Moreover, semi-structured interviews were chosen as these types of interviews have higher validity than unstructured interviews and allow an in-depth exploration of a topic through use of follow-up questions that may be deemed necessary to capture one’s interpretations of experiences (Segal et al., 2006). The guide that was used to conduct observations helped establish validity in the study. Documents are stable sources of evidence and thus increase the validity.

Data collection and analysis. The alignment of the instruments used, and research purpose established validity in the present study. However, inductive reasoning emphasized in the qualitative framework posed risks of research biases, which can occur consciously or unconsciously as data is analyzed and interpreted based on existing beliefs and expectations.

Therefore, to address this area and improve validity, the researcher implemented bracketing (Merriam & Tisdell, 2016), where presumptions were set aside to allow an in-depth analysis of the data to discover new understandings (Walters, 2001). Moreover, when obtaining data literacy documents from teachers, each was asked to supply an example of an activity they used to foster data literacy and a form of evaluation they used to assess students' learning. Consequently, by requesting specific types of documents, the research maintained consistency, which aided in establishing validity when documents were analyzed and coded.

The present research established validity in a variety of ways. For instance, detailed procedures were carefully followed, multiple data sources were collected, detailed descriptive notes were taken, and member checking was implemented. The latter increased validity as member checking can be used as a means to assess transactional validity but also bridge the gap between transactional and transformational validity (Koelsch, 2013; Merriam & Tisdell, 2016).

Reliability

Reliability is known as the consistency of data collected over time (Bruton et al., 2000). Merriam and Tisdell (2016) describes reliability as "…the extent to which research findings can be replicated" (p. 250). In qualitative studies of social sciences, achieving reliability is challenging as human behavior is never static. Nonetheless, an important element of establishing reliability in qualitative research is determining if the findings are consistent with the data obtained. Thus, the accuracy of an instrument is essential in establishing reliability (Merriam & Tisdell, 2016).

Instruments. Semi-structured interviews were chosen as an instrument in the present research as these types of interviews have higher reliability than unstructured interviews but still allow the participants to speak freely through open-ended discourse and use of follow-up questions. Although structured interviews have a higher reliability than semi-structured interviews, the latter was chosen to be used in this research to allow rich data to be collected (Bruton et al., 2000; Segal et al., 2006). A common critique of observations is situated on the fact that human perception is unreliable and thus data from observations are highly subjective. However, adhering to a strategic protocol when conducting observations can improve reliability of data collected. Thus, the observation guide that was used while conducting classroom observations helped establish reliability in the present study as it aided in promoting consistency of data collection and guided the researcher on areas to focus on ("look for") while obtaining data (Bowen, 2009; Segal et al., 2006). Moreover, documents were stable and thus helped establish reliability.

Data collection and analysis. In addition to the specified instruments used to establish reliability in the present study, other procedures were incorporated to maintain reliability in the present study. For example, the use of an inter-coder (Merriam & Tisdell, 2016) for a section of the dataset increased reliability. Additionally, the use of comprehensive data increased reliability. Document analyses was used to obtain examples of data literacy activities and assessments that teachers have used to foster data literacy. By requesting each participant to supply an activity and form of evaluation used to assess student data literacy learning, consistency in types of materials obtained from teachers helped establish reliability in the present study (Bowen, 2009; Segal et al., 2006). Lastly, the researcher followed the data collection protocol carefully and documented any changes in the research journal, which was used as an audit trail to increase reliability (Bowen, 2009; Merriam & Tisdell, 2016; Segal et al., 2006).

Credibility

Credibility is somewhat analogous to internal validity as it refers to the confidence that can be placed in the truth of the findings in qualitative research (Sutton & Austin, 2015). Stahl and King (2020) describe credibility as referring to "how the findings are with reality" (p. 26).

Instruments. The semi-structured interviews allowed consistency and flexibility during the data collection process to permit opportunities of expansion when additional information is needed to be explored. Similarly, the observation guide helped provide consistency in the observation, but the researcher also used a research journal to document other information relevant to the research question, which offered flexibility. Likewise, the instructions for retrieving the documents were consistent (Angers & Machtmes, 2005; Bowen, 2009; Greene, 2014; Guion, 2002; Foreo et al., 2018; Merriam & Tisdell, 2016).

Data collection and analysis. The data collection methods that were used increased the richness of the data collected and thus positively influenced the credibility of the present study. Moreover, triangulation strengthen the credibility of the present research. This aided in obtaining a variety of data sources that was used to confirm the emerging findings, which also allowed comparison of data sources. Additionally, an inter-coder/triangulation analyst (Merriam & Tisdell, 2016) was employed in the present research for a section of the data source to compare findings and increase credibility. Consistent implementation through use of common protocols for semi-structured interviews, observation guide, and ensuring the materials that were obtained for document analyses adhered to specific requirements increased the confidence and thus credibility of the present research. Furthermore, the researcher engaged in reflexivity, which aided in establishing credibility in the present research (Angers & Machtmes, 2005; Bowen, 2009; Greene, 2014; Guion, 2002).

The exploratory case study design allowed the researcher to use direct quotes from participants to communicate conceptions and expectations of data literacy. Similarly, member validation also increased credibility as taking data and interpretations of findings back to the participants allowed clarification on any areas that need to be addressed. Moreover, journal entries used to track an audit trail of the research allowed for reflections and questions to be noted. Furthermore, abnormalities from the proposed research procedures were documented in the research journal (Cofie et al., 2022; Stahl & King, 2020; Sutton & Austin, 2015).

Dependability

Dependability in qualitative research relates to the consistency and reliability of the findings and ability to repeat a study (Sutton & Austin, 2015). Merriam and Tisdell (2016) stated that "…if the findings of a study are consistent with the data presented, then the study can be considered dependable" (p. 252).

Instruments. To increase the confidence that each participant's conceptions and experiences are accurately captured, the research was triangulated through use of semi-structured interviews, observations, and document analyses (Guion, 2002). Data from these instruments was systematically sorted to identify recurring themes. Triangulation of the data also increased dependability in the research as it ensured that participants' conceptions, expectations, and experiences were captured in a variety of ways. Moreover, by triangulating the research, rich data were retrieved, which aided in answering the research questions (Angers & Machtmes, 2005; Bowe, 2009).

Data collection and analysis. The rich description of the study's protocol and detailed steps that were carefully followed during the data collection and data analysis increased dependability of the study. Moreover, the journal documentation established dependability. Any changes to the protocol was carefully documented in the research journal. Furthermore, the findings were communicated in a narrative using rich data to support the results that were discussed (Foreo et al., 2018; Merriam & Tisdell, 2016).

There were strategic steps in place to ensure dependability is met in the research. For example, only one researcher was responsible for gathering data. All data and materials collected during the conduction of this research were saved on a password protected computer, and a second copy was saved on paper in a locked cabinet. Moreover, reflective practices were implemented to increase the dependability of the research. For example, a research journal was utilized, which allowed the researcher to keep track of any discrepancies in the research, document any preconceived notions, and record any unusual observations that were recognized during the research.

Confirmability

Confirmability refers to the objectivity of the study and thus quality of the research findings based on interpretations obtained from the data. Sutton and Austin (2015) state that confirmability refers to "…the extent to which the findings of a study are shaped by the respondents and not researcher bias, motivation, or interest" (p. 229). Therefore, this relates to the assurance that data interpretations are clearly derived from data sources. Stahl and King (2020) describe confirmability as "…getting as close to objective reality as qualitative research can get" (p. 28). The continuous practice of reflexivity increased confirmability, and the use of a research journal aided in noting any changes or issues that arose, which was necessary to establish confirmability in qualitative research. Moreover, checking the data multiple times improved confirmability (Foreo et al., 2018; Greene, 2014; Reid et al., 2018).

Transferability

Transferability or generalizability relates to illustrating that the results have applicability to other situations and thus findings can be applied to other circumstances (Merriam & Tisdell, 2016; Sutton & Austin, 2015). Stahl and King 2020 state that "Transfer is only possible when a thick description provides a rich enough portrayal of circumstance for application to others' situations…" (p. 27) and that the transfer of a study is a "suggestion that must itself be researched for its applicability to a new context" (p. 27). Moreover, Merriam and Tisdell (2016) suggested that the researcher has a responsibility of providing the study's context in detail to allow "…readers to compare the fit with their situations" (p. 256). Therefore, the thick description of the context of where the research was carried out was similar for other schools in the district and across the state making the results of the study transferable to other schools. Additionally, the detailed description of data collection methods and participants included in the research aided in establishing transferability.

Although achieving generality is not a primary focus in qualitative studies, other methods in the research design aided in illustrating the applicability of the present research to other situations. For instance, participants were selected using purposeful sampling to obtain teachers that are representative of the educator population in the school (Foreo et al., 2018; Merriam & Tisdell, 2016).

Limitation and Delimitations

Limitations

This qualitative study took place in a local school and posed several limitations that should be addressed. For example, the setting with a limited number of participants contributed to a small sample size and thus limited the scope of the research. Moreover, the time constraint for which the present study was conducted is another limitation of the study as a longer timeframe would have likely provided richer data. Access to participants was based on convenience and thus limited the pace of the data collection process to some degree. Additionally, the lack of racial and gender diversity among the participants was a limitation of the present study, which potentially restricted generalizability of the results to other populations. Nonetheless, the limited racial diversity among the participants is representative of the district's, schools', and departments' teacher population.

Furthermore, since this was a case study design, generalizability of the study's results was limited. Use of purposeful sampling had limitations, such as the possibility of excluding subgroups needed for a diverse study, causing a limited external validity. Additionally, this sampling technique is prone to bias due to the subjectivity of the researcher's selection of the sample (Suri, 2011). Furthermore, the use of document analyses posed some limitations, such as bias selectivity and the possibility of insufficient detail (Bowen, 2009; Sutton & Austin, 2015).

The researcher's role in the present study's setting also posed risks to validity in the research, also known as reactivity. For example, the researcher served as the primary instrument in the present research. Consequently, it was important that the researcher honestly acknowledged biases she possessed and her own potential influence. To lessen this issue in the research, it was important that the researcher understood her role and impact on participants (Walters, 2001). Nonetheless, obtaining objectivity through an insider researcher design is difficult to achieve. Therefore, a disadvantage of insider research is the impact of self-perception and thus potentially influencing the research to be too subjective. A way to lessen subjectivity in this type of research design is to maintain a distance. However, assuming the role as an insider researcher made it challenging to establish distance. Similarly, being too close to the culture where the study was carried out could have led to researcher bias (Green, 2014).

Delimitations

Nonetheless, there are several delimitations in the study. For example, participants were easily accessible since the research was conducted in the same district that the researcher worked. Purposeful sampling allowed the researcher to select participants that were likely willing to participate in the study and supply rich data to help answer the research questions. Although only a small sample size was included, this size allowed rich data to be obtained to improve external validity. The observation guide helped establish consistencies across observations.

Moreover, the researcher's role as an insider researcher posed several advantages. For example, the researcher was orientated with the environment and participants. Similarly, by conducting the study through an insider researcher role, the researcher was more likely to engage in natural interactions and thus had knowledge of how to approach participants (Greene, 2014).

Expected Findings

In the present qualitative exploratory case study, the researcher expected to discover different conceptions of data literacy among participants and different conceptions of student data literacy among participants. Nonetheless, the researcher expected to find that participants emphasized data literacy as an essential component of students' learning in science education and a need to address certain facets of data literacy, such as analyzing data and using data to make decisions to improve student learning in science.

Since there is a different emphasis in the life science and physical science curricula, the researcher expects to find results varying among life science and physical science teachers.

Therefore, it was expected that the participants used different approaches to foster data literacy in their science classes.

Ethical Assurance

IRB and District Compliance

In any study that includes humans as participants of a study, ethical issues are likely to arise and thus must be addressed. By acknowledging and revealing potential ethical issues in the present study, the trustworthiness of the study was preserved. Moreover, the ethical soundness of the present study was established through the IRB that was obtained from the university, the permission that was obtained from the school system, and the agreement form that was obtained from participants.

Beneficence and Confidentiality

Beneficence in a study that involves humans as participants/subjects is a responsibility that a researcher has to ensure all participants are treated ethically and that their well-being is a top priority (Pieper & Thomson, 2016). All participants were treated fairly, ethically, and morally throughout the study. Each participant was selected via email and provided an overview of the study's purpose and their part in the study should they agree to participate. Each participant was made aware of their privacy rights and voluntary rights to participate and withdraw from the study at any time. Likewise, to ensure confidentiality of each participant, pseudonyms were used to protect the names of all data collected from participants. Similarly, the district's and schools' names were protected in the present research to ensure confidentiality agreements were maintained. All data pertaining to participants were stored in a password protected computer and locked filing cabinet.

Researcher's Role

The following includes a position statement from the researcher's views: I believe proficiency in data literacy is needed to mastery many science concepts. However, teachers have different views toward the importance and incorporation of data literacy lessons and strategies. For example, some teachers incorporate a variety of hands-on activities to engage students in data literacy and encourage their students to collect, analyze and interpret authentic data. Yet, others target recall of essential vocabulary within science standards and use labs as an opportunity for students to obtain data but only focus on a basic level of data literacy rather than advanced application and conceptual understanding.

The role of the researcher was acknowledged as the approaches that were taken in the research were influenced by the researcher's years of experience in the school and knowledge of students' performance as it related to data literacy in science classes. The teacher shared a positive, professional relationship with all participants that were included in the study. Furthermore, the researcher's personal connection with the culture of the school district, educational background, and long term member of the community that the school district resides in helped establish a firm connection with the participants and the implementation of the study. This connection influenced a passion to answer the present study's research questions so that positive changes can be made to improve students' learning and build a stronger community.

Summary

Being a data literate citizen is becoming increasingly important in today's data driven society. The emphasis on data literacy is evident in many high school life science and physical science standards, and teachers have an important role in facilitating and supporting students' data literacy to improve learning in science classes. Yet, many teachers struggle with data literacy themselves. In the chosen research site, teacher conceptions of data literacy and student data literacy was not well understood. Moreover, little collaboration among life science and physical science teachers took place. Consequently, strategies used to foster data literacy were opaque. Nonetheless, there was an evident need to identify data literacy and practices used to foster data literacy as the district's past and recent EOC scores demonstrated underperformance in science compared to other high schools in the state and the state's average score. Consequently, the research questions of the present study addressed teachers' conceptions of data literacy, teachers' conceptions of students' data literacy, teachers' expectations of students' knowledge and skills needed to perform well, and strategies used to foster data literacy in life science and physical science classes as well as difference between life science and physical science teachers.

Chapter III presents a qualitative interpretivist paradigm using an exploratory case study design to discover teachers' conception of student data literacy and strategies used to foster data literacy for life science and physical science high school classes. Purposeful, convenience sampling was used to select eight science teachers at the two research sites. These participants varied in gender, age, race, education, and experience. Prior to conducting the research, IRB documentation, district consent forms, and participant consent forms were obtained. Although the researcher serves as the primary instrument in qualitative studies, the present study utilized semi-structured interviews, observations, and documents to answer the research questions. Semi-structured interviews and observations were conducted in-person. Interviews were transcribed and member-checked, which increased validity of the present study. An observation guide, setting chart, and highly descriptive field notes were used as data sources for observations. Moreover, each participant was asked to supply a data literacy activity and form of assessment.

All protocols were carefully followed and any changes were documented in an audit tail to preserve validity and reliability. Moreover, member checking, triangulating data sources, and rich descriptions improved validity, reliability, and credibility of the present research. Data obtained from interviews, observations, and documents were individually analyzed using opening coding, axial coding, and thematic analysis. This was followed by a holistic analysis of all data to identify common themes and subthemes in the data obtained. The results of the analysis were used to write the findings of the study, which are presented in Chapter IV. This chapter includes a summary of the findings for each RQ, which are presented in tables. This is followed by a detailed discussion of the findings for each RQ in sub-sequential order. Themes are subthemes are included as major headings and further broken down by categories, which are discussed in detail Figures are used to display connection of categories used to discover themes and subthemes.

Chapter IV: Data Analysis and Results

Limited research addresses teachers' conceptions of student data literacy and strategies used to foster data literacy between life science and physical science high school classes. Similar to the identified research problem, Lestari and Rosana (2020), Sugiarti et al. (2021), and Suryadi et al. (2021) found that students are struggling in reaching advanced data literacy competencies in physical science and life science classes. The problem of the present research is underdeveloped data literacy among students in science in the district where the research is being carried out. At the research site where the researcher resides, 59.81% of students scored below proficiency in the science EOC. Moreover, 49.1% of students who took the recent EOC Biology exam scored below proficiency in the district (Georgia Department of Education, 2023). Since data literacy is heavily embedded in the science standards, deficiency in data literacy is directly impacting student achievement in science courses.

Teacher conceptions and expectations of student data literacy in science classes is not clearly defined. Like students' conceptions of data literacy, Papamitsiou et al. (2021) and Vanhoof et al. (2013) found that teachers' data literacy was also deficient, and Kippers et al. (2018) identified teachers struggling in advancing data literacy understanding. A variety of strategies have been identified to improve student data literacy, such as use of authentic data connected to real-world problems (Bozin & Shive, 2003; Dichev & Dicheva, 2017; Erwin, 2015; Hume & Coll, 2010; Kjelvin & Schultheis, 2019; van 't Hooft et al., 2012; Wolff et al, 2019), a focus on competencies rather than skills (Wolff et al., 2019), use of real data to construct and support scientific argumentation (Jordan et al., 2019; Llewellyn, 2013; Vahey et al., 2012), use of interdisciplinary methods (Dichev & Dicheva, 2017; Jordan et al., 2019; Macaroglu, 2004; Vahey et al., 2012), pedagogical data literacy approaches that incorporate technology

(Rahmawati et al., 2020), collaboration (Belland & Kim, 2021; Usova & Laws, 2021), and student choices and visuals (Chin et al., 2016; Usova & Laws, 2021). Nonetheless, at the research site, little collaboration takes place between life science and physical science classes since common professional learning communities are separated based on similar classes teachers were assigned. Thus, strategies currently being implemented to foster data literacy in the classroom are not well understood across science subjects. Therefore, illuminating teachers' conceptions, expectations, and strategies used to foster data literacy will likely improve student achievement by revising curriculum and designing targeted professional development tailored to improving data literacy instruction. Thus, the purpose of this qualitative exploratory case study was to discover the conceptions teachers have towards student data literacy, strategies that teachers use to foster data literacy, and differences, if any, between life science and physical science teachers' conceptions and approaches to teaching data literacy among high school students. This chapter provides the results from the study with a detailed description of how the data were analyzed in connection with the study's purpose and framework. Data were collected through semi-structured interviews, classroom observations, and document analyses (Thomas, 2006). All interviews were transcribed and summarized, which was followed with member-checking after each interview. The semi-structured interview model consists of some predetermined questions. However, this type of interview model allowed the researcher to ask follow-up questions to gain a better understanding of teachers' perspectives, experiences, and beliefs based on their responses. This form of data collection allowed in-depth data of narratives to be obtained through explorative follow-up questioning. Semi-structured interviews were chosen as a primary source of data collection method because it allowed an in-depth analysis of teachers' experiences and conceptions by asking open-ended questions with follow-up questions based on responses (See Appendix H). Additionally, teacher observations allowed real-life situations of data literacy strategies being implemented to be obtained. This provided an in-depth understanding of teachers' conceptions of data literacy and how strategies are implemented to improve data literacy in science classes (Merriam & Tisdell, 2016; Sutton & Austin, 2015; Walters, 2001).

The researcher had approximately 9 years of experience in teaching, which included 5 years of experience in teaching higher education and 6 years of experience in the school where the research was conducted. Therefore, the present research was designed and implemented while the researcher worked as a certified science teacher in the district where the research was employed. The researcher’s position as a science teacher provoked interest in the research topic to gain a better understanding of conceptions and strategies related to fostering data literacy among students. Prior to collecting data, all teachers were informed of the researcher’s position in the building and role in the study.

Research Design

A single exploratory case design (Baxter & Jack, 2008) was employed to answer the research questions, and the research was bounded in two research sites, which were local, public high schools that serve more than 30% socioeconomic disadvantaged students. The use of this research design allowed an in-depth investigation to be conducted using multiple data sources to answer the research questions. This research design allowed the researcher to play an extensive role in the data collection process to ensure rich data was obtained to provide an in-depth analysis and understanding of the research topic.

Participants

This single exploratory case study was conducted in two local rural high schools located in west-central Georgia. The research site included two high schools, which consisted of grades 9-12 with diverse demographics that represent the diversity in the community. Purposeful sampling was used to select eight teachers that would offer rich data to the study based on the likelihood of their willingness to participate in the study. To ensure all teachers met the requirements of the study, each teacher was asked to complete a background questionnaire after returning the signed consent form to the researcher. By asking the classes each teacher primarily taught, the researcher was able to categorize each teacher as a life science or physical science teacher. If teachers taught more than 50% of physical science classes, then they were placed in the physical science category. Similarly, teachers who taught more than 50% of life science classes were placed in the life science category. All teachers were science educators within the same school district but had different experiences and levels of education based on degrees obtained. For the purpose of the present study, data regarding years of experience teaching high school science classes was obtained. Thus, teachers may have had additional teaching experiences outside of the high school science setting. The years of experience among the teachers range from less than one year to 16 years. Moreover, 62.5% indicated they were White, 25% indicated they were Black, and 12.5% indicated they were bi-racial. Table 9 indicates the demographics of each teacher in the study. This data was obtained from the questionnaire sent after each teacher returned the signed-consent form agreeing to voluntarily participate in the present study.

Table 9

Teacher demographics

Teacher	Years of experience	Type of science teacher	Race	Gender	Level of Education
1	3	Physical	White	Male	Masters
2	1	Life	White	Female	Specialist
3	16	Physical	White	Female	Doctorate
4	6	Life	White	Female	Masters
5	<1	Life	White	Female	Bachelor's
6	<1	Physical	White	Female	Doctorate
7	2	Physical	Black	Female	Masters
8	<1	Life	Black	Female	Masters

The reminder of Chapter IV addresses findings for each RQ in order using major themes and subthemes. RQ findings are addressed in order below each theme and subtheme. Connection of categories used to identify themes and subthemes for each RQ are discussed and illustrated using flowchart figures. Each category revealed to support major themes and subthemes are supported with evidence obtained in the present study.

Findings

The following section will discuss the findings of the research. The research questions that directed the present study included the following: 1. What are secondary science teachers' conceptions of data literacy? 2. What specific data literacy knowledge and skills do teachers expect their students to possess? 3. What are teachers' conceptions of how students perform or work through different concepts related to data literacy? 4. What specific instructional strategies do teachers use to scaffold and foster data literacy, and how do these instructional strategies and conceptions of data literacy differ between life science and physical science teachers? These research questions were addressed through the explorative case study design and the study's conceptual framework.

All data were coded using open coding (Merriam & Tisdell, 2016) to welcome any ideas that were displayed, and this was followed by axial coding (Merriam & Tisdell, 2016), which allowed the data to be connected to discover emergent and overlapping categories. The data and categories identified were analyzed for similarities and differences. Moreover, thematic analysis (Merriam & Tisdell, 2016) was implemented to discover common themes among the multiple sources of data.

Teachers' responses to items 1, 15, and 18 in the interview were used to answer RQ 1; whereas, teachers' responses to items 2, 16, and 17 were used to answer RQ 2. Furthermore, teachers' responses to items 3, 6, 10, 11, 12, 14, and 16 in the interview were used to answer RQ 3. Lastly, teachers' responses to items 4, 5, 7, 8, 9, 11, 13, 14, and 17 in the interviews, classroom observations, and document analyses were used to answer RQ 4.

In the subsequent sections, the findings will be discussed for each RQ, and tables are included to display data used to support major findings in the research. The quantity of codes and categories aligned to the themes and subthemes are illustrated in tables. Much of the codes overlapped for all RQs. The researcher used the same codes rather than invented new codes across research questions when data were similar or the same to support previous codes discovered. For example, words and phrases such as uh, um, I'm not sure, and I don't know were all coded for uncertainty across all research questions to instill consistency in the present research. Likewise, words such as see, hear, and sight were all coded for senses. The researcher chose to use the same code when deemed appropriate as many of the responses, answers, and data were repetitive, which led the researcher to believe this was the best way in analyzing the data. However, as new ideas and meanings were identified, new codes were developed. Thus, each RQ also included unique coding to answer each distinct question, which are discussed below.

RQ 1

One hundred and fifteen codes were found from the initial analysis of the data to answer RQ 1. Many of the codes were identical or very similar to other codes used for RQs 2, 3, and 4. For example, codes such as feel, see, explain, communicate, and whatever overlapped for all RQs. However, some only overlapped with one RQ. For example, the code test/test scores overlapped with RQ 3, performance and context clues overlapped with RQ 2, vocabulary, half-life, and infer/inferences overlapped with RQ 4, and videos overlapped with RQs 3 and 4.

Moreover, unique codes for RQ 1 included knowing/understanding what's behind, dependence on previous learning, abilities, application, terminology, up to interpretation, don't really agree, swept under, getting through to them, feeding off, Google it, solubility curve, engage, theories with concepts, exactly, and central thing.

The codes were then combined to form 41 categories. Like the codes used, the categories identified overlapped across the RQs. For example, sense, active learning, models, visuals, help/assistance, skills, translation, uncertainty, broad/flexible, connection to other subjects, challenge, and clarification overlapped with all RQs. Moreover perfect world overlapped with RQs 3 and 4, depth of knowledge overlapped with RQ 2, and apologetic overlapped with RQ 4.

Additionally, unique categories for RQ 1 included meeting learners, opposition, effectiveness, straight forth, and facts. The categories were reanalyzed to find further connections to develop themes and subthemes from the dataset. Four themes and three subthemes were identified for RQ 1. The quantity of codes and categories used to reveal the themes and subthemes in the present research are illustrated in Table 10 for RQ 1. Additionally,

Table 11 illustrates the codes used and connected to support each theme and subtheme for RQ 1. Likewise, Table 12 demonstrates the alignment of major findings to categories, which were derived from the codes for RQ 1. As evidence to support these categories for RQ 1, Table 13 displays the percentage of teachers that revealed each category.

RQ 2

One hundred and thirty-nine codes were found from the initial analysis of the data to answer RQ 2. Some of the codes overlapped. For example, tables, charts, understand, um, and I guess overlapped across all RQs, while others overlapped with only one of the RQs, such as passage, which overlapped with RQ 1. Nonetheless, many were unique to RQ 2, such as base off, 8^{th} grade, go back, better job, studied it, analyze it a bit further, I'm learning, tier 2, one on one, pick apart, notice, pay attention, jury deliberation, Steven Avery, cell phone usage, they don't get them up to speed, starting from scratch, lower expectations, at least, easy, we went outside, loner, why did you write that?

The codes were then combined to form 40 categories. Like the codes for RQ 2, categories overlapped across the RQs. For example, observe, visuals, prior knowledge/knowledge, real-life, broad/flexible, models, technology, words, forgotten, and collaboration were revealed as categories for all RQs, while others only overlapped with one RQ, such as performance, which overlapped with RQ 1, and superficial, which overlapped with RQ 3. Other categories, such as reteach, details and direction, overlapped with RQs 3 and 4, while explicit overlapped with RQs 1 and 4, and perfect world overlapped with RQs 1 and 3. Similarly, examination and reflection overlapped with RQ 4. Nonetheless, like the unique codes discovered for RQ 1, RQ 2 also had unique categories revealed, such as facilitate, integrated subjects, enhance, desire, and optimistic.

After the categories were revealed, they were reanalyzed to find further connections to develop themes and subthemes from the dataset. Four themes and one subtheme were discovered for RQ 2. The quantity of codes and categories used to reveal the themes and subtheme for RQ 2 in the present research are illustrated in Table 14. Additionally, Table 15 illustrates the codes used and connected to support each theme and subtheme for RQ 2. Likewise, Table 16 demonstrates the alignment of major findings to categories, which were derived from the codes for RQ 2.

RQ 3

One hundred and eighty-two codes were found in the initial analysis of the data to answer RQ 3. Comparable to the other RQs, many of the codes overlapped. For example, codes that overlapped for all RQs included show, demonstrate graphs, attention, present, labs, think/thinking, feel/felt, observe, see/saw, listen, explain, and interpret. Additionally, some codes, such as intentional and realistic overlapped with only RQ 4.

Nonetheless, new codes were also revealed. For instance, some examples of unique codes revealed for RQ 3 included previous encounters, background, middle school, mixture is a solution, clear/clear cut, DOK, level 1 to level 2, isotopes, shoe print, bounce ideas mind bottling, huge growth, better writer/better lab reporter, expand, able to locate, go through an answer, absorb materials, ask/asking how reflective questions, understand where and what, aptitude for science, grade, need it, we should, figure out, step further, harder article, train/training, the only way, uncomfortable, similar to what is taught, we haven’t really done that yet, and realistic.

The codes were then combined into 56 categories. Comparable to the other RQs, categories overlapped. For example, assistance/help, challenge, visuals, models, active learning, collaboration, broad/flexible, and vague overlapped across all RQs. Moreover, gradual progression, dynamic, practicality, comparison, and intentional overlapped with RQ 4. Examples of unique categories for RQ 3 included elaboration and surprising. The categories were reanalyzed to find further connections to discover overarching themes and subthemes from the dataset. Four themes and one subtheme were discovered for RQ 3. The quantity of codes and categories used to reveal the themes and subthemes for RQ 3 are presented in Table 17. Moreover, Table 18 demonstrates the codes used to identify each theme and subtheme, and Table 19 illustrates the categories revealed from the codes to discover the themes and subtheme for RQ 3.

RQ 4

Three hundred and forty-nine codes were initially found in the analyses of the data to answer RQ 4. A variety of the codes included for RQ 4 were unique and overlapped. For example, think, prior knowledge, understand, clarification, explicit, I feel, seen, explain, read, kind of, um, I guess, I don’t think, labs, and collaboration were codes that overlapped across all RQs. However, examples of unique codes included KWL/KWL questioning, stories, know your audience, functioning adults, premade/pre-done, and zone out and stare.

The codes were then combined into 63 categories, which overlapped with other RQs. For example, sense, vagueness, uncertainty, clarification, broad/flexible, active learning, assistance/help, and understanding overlapped across all RQs. However, unique categories were also revealed for RQ 4, such as positive reinforcement and storytelling. Afterwards, the categories were analyzed to find additional connections to discover the overarching themes and subthemes. Five themes and one subtheme were discovered for RQ 4. The quantity of codes and categories used to reveal the themes and subtheme for RQ 4 are presented in Table 20.

Moreover, Table 21 demonstrates the codes used to identify each theme and subtheme, and Table 22 illustrates the categories revealed from the codes to discover the themes and subtheme for RQ 4. The subsequent section illustrates the themes, subthemes, categories, and codes discovered for each RQ following an in-depth discussion of the research findings.

Table 10

Quantity of codes and categories used for RQ 1.

Themes	Subthemes	Categories	Codes
Teachers believe students' prior learning experiences determine their data literacy	Teachers' perceptions affect their translation of data literacy; Teachers believe data literacy learning involves observation and detection of effective instruction	21	Teachers believe students' prior learning experiences determine their data literacy: 11; Teachers' perceptions affect their translation of data literacy: 28; Teachers believe data literacy learning involves observation and detection of effective instruction: 13
Teachers lack confidence with data literacy		6	17
Teachers believe data literacy can be represented in many ways	Teachers believe interdisciplinary connections is important in data literacy	Teachers believe data literacy can be represented in many ways: 3; teachers believe interdisciplinary connections is important in data literacy: 6	Teachers believe data literacy can be represented in many ways:11; teachers believe interdisciplinary connections is important in data literacy: 25
Teachers believe there is a need for discrete understanding		5	10

Table 11

Themes and corresponding coding for RQ 1

Themes	Subthemes	Codes
Teachers believe students' prior learning experiences determine their data literacy	Teacher perception affect their translation of data literacy; Teachers believe data literacy learning involves observation and detection of effective instruction	Knowing/understanding what's behind, dependence on previous learning, abilities, understand/understood, learn, performed/performance application/apply, skills, skill-set, ideally, and level Subthemes 1: Listen, see, look, feel, watching, charts, graph/graphing, tables, data tables, diagrams, x and y axes, chuckles, laughs, smiles, sarcastic, interpret/interpretation, explain, communicate, read, say/saying, passage, context clues, article paragraph, vocab, terminology, up to interpretation, don't really agree, swept under Subtheme 2: Understood materials, getting through to them, help understand, formative assessment, tests/test scores, observation/observant, evidence, foundation, starts, effective, feeding off, modules, videos
Teachers lack confidence with data literacy		Uh, um, guess, mumbles, don't know, can't remember, not a great deal, not really, basically, pretty much, quite, Google it, elaborate, repeat, clarity, sorry, rigor
Teachers believe data literacy can be represented many ways	Teachers believe interdisciplinary connections is important in data literacy	Teachers believe data literacy can be represented many ways theme: labs, conduct, learn by doing, build, use, activity/activities, utilize/utilizing, research, simple labs, demonstrate, show, relate/relevance; Subtheme: Teachers believe interdisciplinary connections is important in data literacy: Whatever, count as data, different, English, reading, reading comprehension, math, geometry, physical science, physics, chemistry, algebra, regular math, math problems, analyze, create, general concepts, infer, show students solubility curve, graphing solubility curve, demonstrate half-life by graphing, engage, theories with concepts
Teachers believe there is a need for discrete understanding		Exactly, central thing, definitely, yes, no, information, answering, findings, again, repeat response

Table 12

Themes and corresponding categories for RQ1

Themes	Subthemes	Categories
Teachers believe students' prior learning experiences determine their data literacy skills.	Teacher perception affect their translation of data literacy	Reading, perfect world, knowledge, prior knowledge, skills, depth of knowledge
	Teachers believe data literacy learning involves observation and detection of effective instruction	Subthemes 1: Senses, visuals, humor/sarcasm, translation, words, vocabulary, inconsistencies, opposition, forgotten Subtheme 2: Assessment, observation, base foundation, effectiveness, meeting learners, online resources, technology
Teachers lack confidence with data literacy		Uncertainty, vague, clarification, apologetic, help/assistance, challenge
Teachers believe data literacy can be represented many ways	Teachers believe interdisciplinary connections is important in data literacy	Connecting: Active learning, model, relevance; interdisciplinary: Broad/flexible, connection to other subjects, ways to use data, importance, connecting data to concepts, theories with concepts
Teachers believe discrete understanding of data literacy is needed		Explicit, certain, straight-forth, facts, reiterate

Table 13

Frequency of teachers who revealed categories for RQ 1

Categories	Percentage of teachers that revealed categories
Uncertainty apologetic, assistance/help, challenge	8/8 =100%
Senses	7/8=87.5%
Translation	7/8=87.5%
Broad/flexible	6/8=75%
Knowledge/prior knowledge	6/8=75%
Facts	5/8=62.5%
Vague	5/8 = 62.5%
Visuals	5/8=62.5%
Ways to use data	4/8=50%
Words	4/8=50%
Active learning	3/8=37.5%
Assessments	3/8 = 37.5%
Clarification	3/8=37.5%
Importance	3/8=37.5%
Humor/sarcasm	3/8=37.5%
Reiterate	3/8=37.5%
Skills	3/8=37.5%
Straight forth	3/8=37.5%
Connection to other subjects	2/8=25%
Certain	2/8=25%
Model	2/8=25%
Observation	2/8=25%
Vocabulary	2/8=25%
Base foundation	2/8=25%
Apologetic	1/8 = 12.5%
Assistance/help	1/8 = 12.5%

Challenge	1/8 = 12.5%
Connecting data to concepts	1/8 = 12.5%
Theories with concepts	1/8 = 12.5%
Perfect world	1/8 = 12.5%
Depth of knowledge	1/8= 12.5%
Inconsistencies	1/8= 12.5%
Opposition	1/8=12.5%
Forgotten	1/8=12.5%
Effectiveness	1/8=12.5%
Meeting learnings	1/8=12.5%
Online resources	1/8=12.5%
Technology	1/8=12.5%
Relevance	1/8=12.5%
Explicit	1/8=12.5%

Table 14

Quantity of codes and categories used for RQ 2.

Themes	Subthemes	Categories	Codes
Teachers believe students' prior learning experiences determine their data literacy skills	Teacher perception affect their translation of data literacy	Teachers believe students' prior learning experiences determine data literacy skills: 12; Teacher perception affect their translation of data literacy: 6	Teachers believe students' prior learning experience determine data literacy skills: 32; Teacher perception affect their translation of data literacy: 43
Teachers lack confidence with data literacy		2	5
Teachers believe data literacy can be represented many ways		8	39
Teachers believe discrete understanding of data literacy is needed		9	12
Teachers believe there are inadequacies in students' data literacy		3	8

Table 15

Themes and corresponding coding for RQ 2

Themes	Subthemes	Codes
Teachers believe students' prior learning experiences determine their data literacy skills.	Teacher perception affect their translation of data literacy	Teachers believe students' prior learning experiences determine their data literacy skills: Base off, understanding, know, they did know, 8th grade, proficiency, rigorous, level, start, beginning, studied it, analyze it a bit further, able, how, mastered the school, confidence, better job, I'm learning, why did you write that?, go back, gone over and over, time, loner, amount of time, their own, identify those who need additional help, tier 2, difference, help, break it down, one-on one, scaffold techniques Teacher perception affect their translation of data literacy: Notice, evidence, observant/observation, focus on, interpret/interpretation, tell/telling, communicate, predict/make predictions, information, conveying, say/say it out loud, what I consider, own explanation analyze, pick apart, questions, ask why, answer, graphing, tables, charts, pie chart, line graph, bar graph, x and y axes, flow chart, feel, see, Lexile, author trying to say, article, say, reading (in the context of words), title, context clues, passages, pick out, talk, label
Teachers lack confidence with data literacy		Um, kinda, ah, quite
Teachers believe data literacy can be represented many ways		Show, do, plot, put together, create, use, up out of their seats, get involved, walk, lab that we're doing, get their own data, doing the process, plot and come up, group/small group, teamwork teammate, discussing, population trends, scientific concepts, concept of motion, anything, whatever/whatever works, everything, cell phone usage, officers, relate to their world, applies, we went out and marked, use their cell phones, outside, own data, screen time, jury deliberation, Stephen Avery
Teachers believe discrete understanding of data literacy is needed Teachers believe there are inadequacies in students' data literacy		Definitely, expect, improve, I want, ideal world, hopefully, correct, yes, no, trends, looking in between, pay attention, focus, picking up information, They don't, get them up to speed, lower expectations, starting from scratch, lost, basic, at least, easy

Table 16

Themes and corresponding categories for RQ 2

Themes	Subthemes	Categories
Teachers believe students' prior learning experiences determine their data literacy skills.	Teacher perception affect their translation of data literacy	Teachers believe students' prior learning experiences determine their data literacy skills: Prior knowledge/knowledge, depth of knowledge, starting point, depth of learning, skills, belief, performance, reflection, reteach, schedule, individual, diverse, facilitate Teacher perception affect their translation of data literacy subtheme: Observation, translation, examination, visuals, senses, and words.
Teachers lack confidence with data literacy		Uncertainty and vagueness
Teachers believe data literacy can be represented many ways		Models, active learning, collaboration, concepts with data, broad/flexible. real-life, integrated subjects, and technology
Teachers believe discrete understanding of data literacy is needed		Explicit, expectations, enhance, desire, perfect world, optimistic, certain, direction, and details.
Teachers believe there are inadequacies in students' data literacy		Below expectations, forgotten, superficial

Table 17

Quantity of codes and categories used for RQ 3

Themes	Subthemes	Categories	Codes
Teachers believe students' prior learning experiences determine their data literacy skills.	Subtheme: Teacher perception affect translation of how students work through concepts related to data literacy.	16	Teachers believe students' prior learning experiences determine their data literacy skills: 65 Teacher perception affect translation subtheme: 11
Teachers lack confidence with data literacy		7	20
Teachers believe data literacy could be represented many ways		19	66
Teachers believe there are student learning inadequacies in data literacy		5	6
Teachers believe flexibility is needed in the curriculum		9	14

Table 18

Theme and corresponding coding for RQ 3

Themes	Subtheme	Codes
Teachers believe students' prior learning experiences determine their data literacy skills.	Subtheme: Teacher perception affect translation of how students work through concepts related to data literacy.	Previous encounters, know/knowing how, background, middle school, study, in-depth, basic concepts, mixture is a solution, simple labs, huge growth, learn how, able/able to use/being able to show data, table skills, how to read a table, pick out what you need, specific skills, better writer/better lab reporter, able to locate, go through and answer, absorb materials, ask/asking how reflective questions, understand it, understand where and what, aptitude for science, focusing, clear/clear cut, designed to be specific, paying attention, picking it apart, focusing on those levels, alignment, standards, match, quiz, standardized testing, reading articles, read the question, assessments, exams, test, informal assessment/formative assessment, formative/summative, grade, need it, we should, figure out, want them thinking, hard data, step further, little deeper, harder articles, college level, they can't, hard time, challenge, struggle, more challenging DOK, level 1 to level 2, rigorous, not passing, help/helpful, tier 2, I try/me trying, train/training, starting with easier articles, and relying on teammate Subtheme: Observe/observant, feel/felt, see/seen/seeing, I saw, listen, watching, explain, interpret, the curriculum tells you, we get a little silly with it, and **laugh.
Teachers lack confidence with data literacy		The only way, mumbles, kinda/kind of, fairly, not sure, uh, I guess, don't know/don't think, **looked to the side of the classroom, **looked nervous, um, I don't remember actually, maybe, left with questions, I feel like we haven't really done that yet, repeat question, clarify question, mind bottling, and uncomfortable
Teachers believe data literacy could be represented many ways		Show, demonstrate, model, similar to what is taught, similar graphs, present, plotting, graph, visual, chart, table, periodic table, diagram, patterns, graphic organizer, pictures, cell phone, video, textbook, Chromebook, PowerPoint in canvas, progress learning, quizzes, Google for, worksheet, Google slide presentation, articles, words, sentence, scenario, I wish, shoe print or gunpowder residue, community, extrapolate, constantly changing, groups, two, four or two, three four, pair, join a group, work in pairs, bounce ideas off each other, discussions, more people, getting together, sharing, it's amazing, confidence, equation, math, compare, labs, do the physics part, running, hopping, walk, generate data, write down/write their answers /write/writing, search, active and passive transport, concept of motion, electron configuration, isotopes, analyze/analyzation, locate different data points, whatever, broad/flexible, and open mind
Teachers believe there are inadequacies students' data literacy		Motivation, we don't give it a lot of attention, won't be effective, lost, surface, and not much
Teachers believe there is a need for flexibility in the curriculum		Intentional, time, pacing, consideration, meet learners, reteach, expand, over and over, practice/practice problems, review activities, we need a good week to review, made them, and realistic

Table 19

Theme and corresponding categories for RQ 3

Themes/subthemes	Subtheme	Categories
Teachers believe students' prior learning experiences determine their data literacy skills	Subtheme: Teacher perception affect translation of how students work through concepts related to data literacy	Knowledge/prior knowledge, depth of learning, simplicity, learning, skills, understanding, details, alignment, assessment, necessary, reasoning, challenge level, assistance/help, attempt, coach, and gradual progression Subtheme: Observations, senses, translation and humor
Teachers lack confidence with data literacy		Limited options, vague, uncertain, limited experience, clarification, confusion, and discomfort
Teachers believe data literacy could be represented many ways		Model, visuals, technology, resources, words, perfect world, relevance, application, dynamic, collaboration, surprising, self-belief, other subjects, comparison, active learning, concepts with data, ways to use data, broad/flexible, and objectivity
Teachers believe there are student learning inadequacies in data literacy		Lack of motivation, overlooked, ineffective, forgotten, and superficial
Teachers believe flexibility is needed in the curriculum		Intentional, schedule, planning, diverse, meeting learners' needs, elaboration, repetition, force, and practicality

Table 20

Quantity of codes and categories used for RQ 4 from three data sources.

Themes	Subthemes	Categories	Codes
Teachers believe students' prior learning experiences determine their data literacy skills.	Teacher perception affect their translation of data literacy	Past experiences: 13 Perception: 9	Past experiences: 79 Perception: 66
Teachers lack confidence with data literacy		6	19
Teachers believe there are student learning inadequacies in data literacy		9	33
Teachers believe flexibility is needed in the curriculum		13	56
Teachers believe preparing students for their future was vital		13	96

Table 21

Themes and corresponding coding for RQ 4 from three data sources

Themes	Subthemes	Codes
Teachers believe students' prior learning experiences determine their data literacy skills.	Teacher perception affect their translation of data literacy	Past experiences: Think, prior knowledge, remember, recap, understand why, asking why and how questions, question banks, create their own, how to, making sense, digging into, understand the theory, in-depth, questions geared towards data, problems, asking students to elaborate, difficult, hard, tier 2, gifted, regular Ed, building on each other, college level, struggle, not as rigorous, cannot proficiently, not give them every single thing, following directions, two or three step problems, multiple steps, step by step, don't understand, students shook their head no, no idea, help, steer them, probing questions, guide, address questions, answer questions, direct assistance, teacher providing clarification, explicit instruction, examples, ask teacher for clarification, teacher elaborate, start/starting point, filling in gaps, rely on teammates, strategic questioning, beginning, elementary, middle school, refer to lesson we've done before, labeling, different context, metric system, break down problems, prefix chart, notes on periodic table, focus on the basics, laying the foundation, feedback, solicit opinions, predictions, inferences, extrapolate, clearer, focus, more specific, unpack, targeted, break down, deconstruct, detail, recognize all data sources, standards, matches, and consistent Subtheme Perception: I feel, seen, watching, interpret, talk, fluent in that language, explain, read, conclusion, write, articles, vocabulary, scramble them, words, unscramble, don't scribble, cardstock, rank, PowerPoint, website, promethean board, video, quizzes, online, internet, progress learning, mastery connect, booklet, green dots, Chromebook, cellphone, electronic pen, soft music, controller, calculator, email, analyze, actually look at them, compare, versus, similarities and differences, differences between, relationship, graph, graphic organizer, window notes, periodic table, data chart, Frayer model, data graphing, picture, image, draw, display, flowchart, colored pencils and markers, water bottle, population growth curve, visuals, Aufbau diagram, protein sheet, mini sketch, showing, model, provide an example, demonstrate, and illustrate
Teachers lack confidence with data literacy		Kind of, sort of, quite, might, um, uh, I guess, talking to self, uncertainty in body languages, I can't think of, I haven't learned that, I may be way off, I am making myself uncomfortable, left with questions, repeat question, have question clarified, I am not sure I am understanding, sorry, and I don't think I really do that
Teachers believe there are student learning inadequacies in data literacy		Lab participation has been poor, they are lazy, bored, won't participate, sleep, zone out and stare, sit and play on their phones, not paying attention, aren't interested, hard to get their attention, they don't want to get in groups, try to motivate, lose them, they don't care, they just want the period to end, some student not working, no attempt to answer, no one responded, continue to stay seated, redirect, head down, complain, try, made, we have to get them, lost, change, improved labs, premade/pre-done, questions that are already there, won't be effective, intentional, and listen/slow down and listen
Teachers believe flexibility is needed in the curriculum		Individually, mixture, meet students where they are, one on one, one on two, English, writers, mathematics, Lexile, other content, choices/choose, aren't any rules, I'm open, volunteer, whatever, broad, everything about data, constantly changing, evolving, realistic, considerations, spend time, timer, overview of the next week, not enough, every day, length of time varies, different, 30-40%, incorporate every single day, whole class based

	on that, 20% generous, every lecture, slide or two, few slides dedicated, notes/guided notes, confident, the more they saw, exposed, repetition, the more they are swoon, practice, the more you study, drill them, repeat, reteach, over and over, keep going back, practice problems, review it, they took it again, homework, review questions, activator, and encounter it/know what this is
Teachers believe preparing students for their future is vital	Lab, hands-on, present orally, own data, walking/running/hopping/walking backwards, obtain themselves, investigate, calculate, station activity, measure various objects, students made, current, national, medical research, physics research, engineering research, local water pollution, distance to Columbus, energy in Georgia, radioactive half-life, their lives, real-life, water intoxication/drinking contest, precipitation level, heat index, drug crimes, shampoo/ conditioner/lotion, relevant, connect, apply, new issues, community, salad dressing, items likely familiar to students, cases, protein needed for us to function, maintain homeostasis, Newnan, food in the stomach, sprays, your cells, interest, care about that, a hook, like that part, enjoy it, get them involved, want to discuss, fun, students participating in activities, students answering questions, game, candy, peer interaction, discussion, groups, collaborate, conversations, work together, interact, conversations, audience critique, skill based, specific skills, observant, observational skills, noticed, KWL/KWL questioning, I should do that, I need to work on that, What do you think?, I'm still learning, I have never really thought of data literacy, stories, share, later in life, workforce, life skill, when they get older, job, helping them go out in the real-world, functioning adults, careers, present, know your audience, looking a person in the eyes, know how to speak to adults, justification/justify, claim, prove, and why or why not

Table 22

Themes and corresponding categories for RQ 4 from three data sources

Themes	Subthemes	Categories
Teachers believe students' prior learning experiences determine their data literacy skills.	Teacher perception affect their translation of data literacy	Past experiences: Reasoning, knowledge/prior knowledge, understanding, challenge, assistance/help, gradual progression, feedback, direction, details, alignment, and consistency Perception: Senses, translation, words, organization, technology, examination, comparison, visuals, and models
Teachers lack confidence with data literacy		Vagueness, uncertainty, clarification, apologetic, and limited experience
Teachers believe there are student learning inadequacies in data literacy		Unengaged, attempt, force, forgotten, need for improvement, premade, need for change, ineffective, and purposeful
Teachers believe flexibility is needed in the curriculum	I	Individualization, need for differentiation, other subjects, autonomy, broad/flexible, dynamic, practicality, schedule, variation, note taking, confidence, repetition, and recognition
Teachers believe preparing students for their future was vital		Active learning, relevance, engagement, positive reinforcement, collaboration, skills, observational skills, reflection, storytelling, post-secondary, effective communication, and justification.

Findings for each RQ

RQ 1

Categories discovered from the initial codes for RQ 1 included uncertainty, certain, vague, straight-forth, help/assistance, clarification, apologetic, connection to other subjects, skills, knowledge/prior knowledge, visuals, humor/sarcasm, active learning, assessment, senses, observation, model, reiterate, vocabulary, words, inconsistencies, opposition, broad/flexible, theories with concepts, translate, ways to use data, connecting data with concepts, effectiveness, base/foundation, forgotten, depth of knowledge, reasoning, meeting learners, relevant, online resources, technology, explicit, importance, perfect world, facts, and challenge. The categories were then further condensed through axial and thematic coding, which resulted in the discovery of the following themes: teachers believe students' prior learning experiences determine their data literacy skills, teachers lack confidence with data literacy, teachers believe data literacy can be represented many ways, and teachers believe discrete understanding of data literacy is needed

Additionally, interdisciplinary connections and views of data literacy were discovered to be a subtheme to teachers' ideas of representing data literacy. Likewise, teachers believe discrete understanding of data literacy is needed included two subthemes, which were teacher perception affect their translation of data literacy and teachers believe differentiation is needed to meet students' data literacy needs.

RQ 2

Categories discovered from the initial codes included prior knowledge/knowledge, depth of knowledge, starting point, depth of learning, skills, belief, performance, reflection, reteach, schedule, individual, diverse, facilitate, observation, translation, examination, visuals, senses, words, uncertainty, vagueness, models, active learning, collaboration, concepts with data, broad/flexible, real-life, integrated subjects, technology, explicit, expectations, enhance, desire, perfect world, optimistic, certain, direction, and details, below expectations, forgotten, and superficial. The categories were then further condensed through axial and thematic coding, which resulted in the discovery of the following themes: teachers believe students' prior learning experiences determine their data literacy skills., teachers lack confidence with data literacy, teachers' ideas of representing data literacy, teachers believe discrete understanding of data literacy is needed, and teachers believe there are student learning inadequacies in data literacy. Additionally, teachers believe students' prior learning experiences determine their data literacy skills were found to be closely connected to teacher perception affect their translation of data literacy making the latter a subtheme.

RQ 3

The following categories were discovered in the analysis of data used to answer RQ 3: Knowledge/prior knowledge, depth of learning, simplicity, learning, skills, understanding, details, alignment, assessment, necessary, reasoning, challenge level, assistance/help, attempt, coach, gradual progression, limited options, vague, uncertain, limited experience, clarification, confusion, uncomfortable, model, visuals, technology, resources, words, perfect world, relevance, application, dynamic, collaboration, surprising, self-belief, other subjects, comparison, active learning, concepts with data, ways to use data, broad/flexible, objectivity, lack of motivation, overlooked, ineffective, forgotten, superficial, intentional, schedule, planning, diverse, meeting learners' needs, elaboration, repetition, force, and practicality.

The categories were then further condensed using axial coding and thematic analysis to develop the following themes to answer RQ 3: teachers believe students' prior learning experiences determine their data literacy skills., teachers lack confidence with data literacy, teachers believe data literacy could be represented many ways, teachers believe there are student learning inadequacies in data literacy and teachers believe flexibility is needed in the curriculum. Additionally teachers believe students' prior learning experiences determine their data literacy was found to be closely connected to teacher perception affect their translation of data literacy making the latter a subtheme.

RQ 4

The following categories were discovered in the analysis of data used to reveal RQ 4: Reasoning, knowledge/prior knowledge, understanding, challenge, assistance/help, gradual progression, feedback, direction, details, alignment, and consistency, senses, translation, words, organization, technology, examination, comparison, visuals, models, vagueness, uncertainty, clarification, apologetic, limited experience, unengaged, attempt, force, forgotten, need for improvement, premade, need for change, ineffective, purposeful, individualization, need for differentiation, other subjects, autonomy, broad/flexible, dynamic, practicality, schedule, variation, note taking, confidence, repetition, recognition, active learning, relevance, engagement, positive reinforcement, collaboration, skills, observational skills, reflection, storytelling, post-secondary, effective communication, and justification.

The categories were then further condensed using axial coding and thematic analysis to develop the following themes and subtheme for RQ 4: teachers believe students' prior learning experiences determine their data literacy skills., teachers lack confidence with data literacy, teachers believe there are inadequacies in the science curriculum, teachers believe flexibility is needed in the curriculum, and teachers believe preparing students for their future was vital. Additionally teachers believe students' prior learning experiences determine their data literacy skills were found to be closely connected teacher perception affect their translation of data literacy making the latter a subtheme.

The subsequent section will discuss the themes and subthemes discovered and their implications towards answering each RQ of the present research.

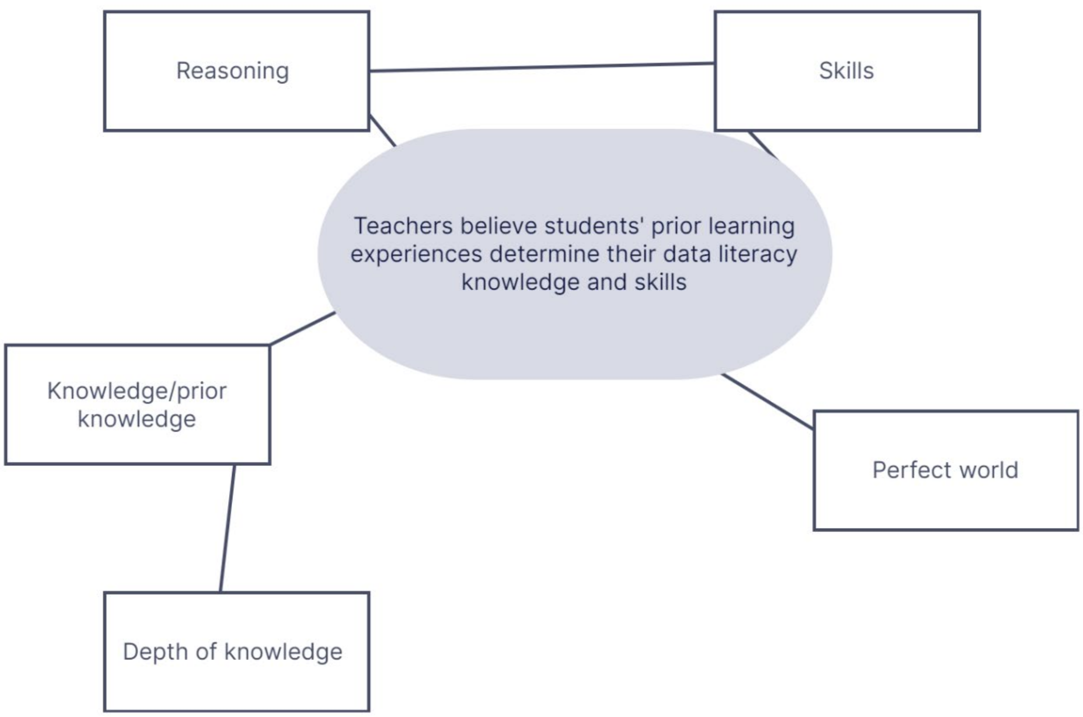
Teachers Believe Students' Prior Learning Experiences Determine Their Data Literacy Skills

RQ 1. The teachers believe students' prior learning experiences determine their data literacy skills theme were identified after discovering the categories reasoning, knowledge/prior knowledge, depth of knowledge, perfect world, and skills. Figure 6 displays the connection of the categories, which were found to be connected in several ways. For example, teachers discussed how students’ data literacy was dependent on their knowledge and prior knowledge, which was described as often below expectations. For instance, Teacher 1 referenced students’ performance in prior math class as affecting students' data literacy. Thus, emphasis on performance revealed skills to be connected to prior knowledge indicating students' past experiences with skills and knowledge pertaining to math affected students' data literacy. As teachers described their views of past experiences affecting students' data literacy, they explained their reasoning for this. For example, Teacher 5 stated, "…not everybody has a strong math background," while Teacher 1 described how students were "…ideally supposed to come into the class knowing how to do…" data literacy but how it depended "…on how well they performed in the regular math."

Consequently, these categories revealed teachers believe students' prior learning experiences determine their data literacy skills.

Figure 6

Connection of categories used to reveal teachers believe students' prior learning experiences determine their data literacy knowledge skills for RQ 1.



Knowledge/prior knowledge. The category knowledge/prior knowledge was found throughout teachers' responses as teachers emphasized previous learnings and student understandings. The codes that were used to identify this topic were knowing, dependence on previous learning, abilities, understanding, and learning. For example, Teacher 1 emphasized students' data literacy being dependent on previous learning by stating in response to item 1, "But that depends on how well they performed in the regular math." Similarly, Teacher 2 stressed knowledge in response to item 1 by replying, "It's vital that they know how to read data like the charts, tables, and interpret it and to use it." Additionally, Teachers 7 and 8 explained the importance of students understanding data in their responses to item 15. For instance, Teacher 7 said her definition of data literacy was, "…being able to communicate in such a way that demonstrates that you have an understanding of the data that has been set before you." Comparably, Teacher 8's response to item 15 included, "…I think that students probably do a lot better if they can get a grip on, you know, how to understand data literacy."

Depth of knowledge. Depth of knowledge was indicated when teachers described the level of knowledge students had about data literacy as they described what they knew about data literacy. For instance, Teacher 1 revealed depth of learning in his response to item 18 by explaining that depth of learning was a problem and the lack of foundational knowledge needed to perform well in data literacy in science was deficient. Specifically, he stated, "That's not the problem. The problem is this level. It starts in physical science…."

Perfect world. Perfect world was indicated when teachers described what data literacy learnings they would like for students to possess. Several of the teachers explained what they would like students to know in an ideal world. For example, Teacher 1 said in response to item 1, "They are ideally supposed to come into the class knowing how to do this, but that depends on how well they performed in the regular math." Consequently, this led to the development of perfect world as a category. This response was similar to Teacher 8's response to item 2 in the interview, as she explained how she had to lower her expectations of prior knowledge she expected her students to possess.

Skills. Skills were indicated when teachers responded with emphasis on putting knowledge to practice. For example, Teacher 5 stressed skills in her statement to item 5, which included, "Uh, I feel like even test taking skills could count as data…." She also replied, "Um, definitely those skills because I learned that they don't quite know them so that is something that they really need to learn." Similarly, Teacher 1 explained how student skills were dependent on past performances in math by stating, "But that depends on how well they performed in the regular math." Likewise, Teacher 8 emphasized skill sets by explaining her definition of data literacy, which included, "…I know students need to understand, have those skill sets before leaving high school."

Reasoning. Reasoning was indicated when teachers described their thought process in their response to data literacy. As teachers described their conceptions of data literacy, they explained their thinking processes. For example, Teacher 1 explained in his response to item 18, "…I think they need a good understanding of Algebra and Geometry again in high school and whatever." Similarly, Teacher 6 explained her reasoning of listening and being observant by stating "I think the most important thing is…is to be patient and listen to what um, the students are saying or observing" in her response to item 18. Likewise, Teacher 2 explained how the interview questions had her thinking more about data literacy in response to item 18, which she stated, "It definitely makes me think about it a lot more."

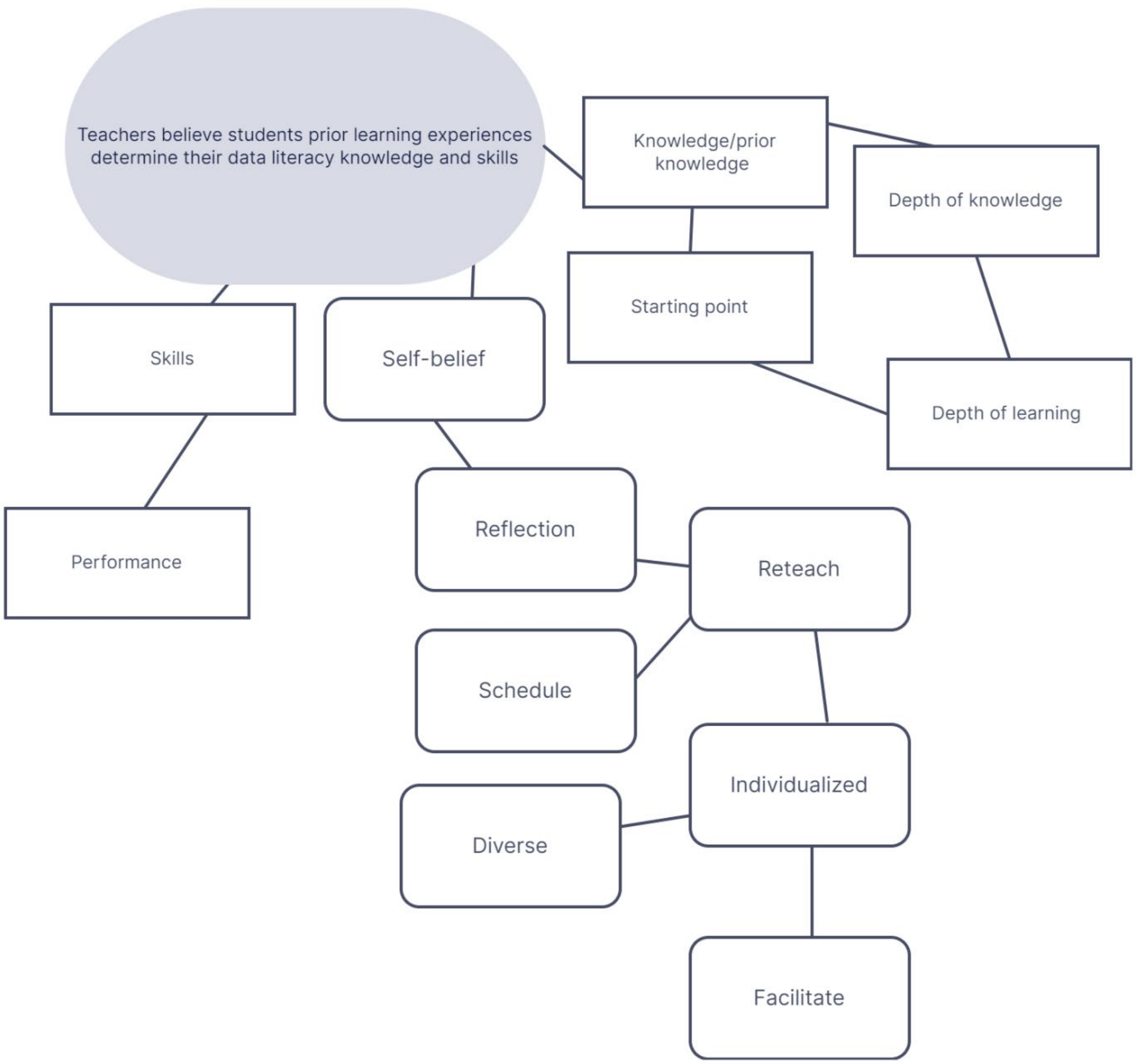
The findings demonstrated teachers' conceptions of data literacy are centered on students' past experiences. Overall, teachers viewed data literacy as important for students to achieve; however, nearly all cited that students' past experiences will affect their data literacy in their class. Teachers' conceptions of data literacy and views of past experiences affecting students' data literacy varied based on their reasoning. However, the majority of teachers recognized the importance of students' past experiences affecting their knowledge and skills of data literacy in science.

These findings suggest that teachers believe early exposure and experiences with data literacy and connection with prior knowledge was essential in improving students' data literacy knowledge and skills in science. Likewise, although teachers' responses centered on students' past experiences, the findings suggest that teachers' past experiences, prior knowledge, and views of learning goals shaped individual teacher's conceptions of data literacy. Therefore, limited past experiences, prior knowledge, and views of learning goals likely contribute to restricted understanding of data literacy leading to a lack of confidence as also revealed among the teachers.

RQ 2. The following categories revealed teachers believe students' prior learning experiences determine their data literacy skills for RQ 2: prior knowledge/knowledge, depth of knowledge, starting point, depth of learning, skills, belief, performance, reflection, reteach, schedule, individual, diverse, and facilitation. Knowledge/prior knowledge was found to be connected to depth of knowledge and starting point as teachers explained how they must know students' knowledge and depth of knowledge to develop a starting point of data literacy expectation. Thus, the starting point was found to be connected to depth of learning. Knowledge/prior knowledge was also found to be connected to skills, which was correlated to teachers’ expectations of students’ performance with data literacy. Moreover, directly connected to past experiences was belief as teachers expressed the importance in student confidence, which affected students’ data literacy knowledge and skills as Teacher 3 suggested. Likewise, teachers were reflective in their explanation of their expectations of student data literacy and skills as teachers shared from their experiences and described what they have found. This led to the connection of reflection to reteach as Teacher 7 was reflective and explained how she had to reteach students since they did not meet her expectations. Nonetheless, she explained that this was challenging due to limited time in the curriculum. Thus, schedule was used as a category to code for timing and connected to reteach. Nonetheless, several of the teachers described the importance of helping students meet their expectations through individualization, which was connected to reteach. Moreover, individualization was connected to diversity as teachers had different approaches to meet learners' needs and facilitate learning as teachers described how they aided in advancing students’ data literacy to meet their expectations. Figure 7 displays the connection of categories used to discover the teachers believe students' prior learning experiences determine their data literacy knowledge and skills for RQ 2.

Figure 7

Connection of categories used to reveal teachers believe students' prior learning experiences determine their data literacy knowledge and skills for RQ 2.



Knowledge/prior knowledge. Knowledge/prior knowledge was indicated when teachers expressed how students' knowledge and prior knowledge affected their expectations of students' data literacy in science. For example, Teacher 7 stated, "I expect them to know how to use the periodic table of elements proficiently." Nonetheless, she explained how this was not always the case by saying, “Quite a number of them took Physical Science in the 8th grade, and they have uh, lost whatever they did know about the periodic table…” suggesting prior knowledge expectations were not met, which then impacted her expectations in the class.

Depth of knowledge. Depth of knowledge was indicated when teachers described the knowledge needed for students to reach their expectations of data literacy. Teacher 3 explained how students had limited experiences and did not know how to complete a multi-step problem. She stated, “I tried to give one of my sets of kids a problem like this, and they all just looked at me like I was crazy because they didn't know….” Similarly, in Teacher 2’s response to item 17, she explained how she will “…refer to a lesson…” that was previously taught as a way to help students overcome challenges associated with data literacy in science. Likewise, Teacher 7 referred to students’ prior knowledge as a foundation for understanding Chemistry as she described her expectations of data literacy knowledge and skills that she expected her students to possess. Like the findings for knowledge/prior knowledge, Teacher 7 stated, “Quite a number of them took Physical Science in the 8th grade” but how they had “…lost whatever they did know about the periodic table….” She elaborated and said, “The periodic table is almost like a foundation and if you do not know how to use it proficiently, you will struggle.”

Starting point. Starting point was indicated when teachers described how expectations were low at the beginning of their course. For example, Teacher 7 explained that the “…expectation is a bit farfetched,” at the starting point of her course due to limited prior knowledge. This was similar to Teacher 8’s explanation of how she had to lower her expectations to meet students where they are at when they enter her class.

Depth of learning. Depth of learning was indicated when teachers described their expectation of student learning in data literacy. For example, Teacher 7 explained ways to increase depth of knowledge through depth of learning. She emphasized students studying in-depth for deep understanding. She stated, “I expect them to be proficient in reading that periodic table because we have gone over and over and over…we've…really studied it.”

Skills. Skills were indicated when teachers described the data literacy skills students needed to meet their expectations. This category was found to be directly connected to past experiences and performance. For example, Teacher 4 described that her students needed “Better observation skills.” Teacher 6 explained how she thought her students did “…a better job…” after she explained and modeled observational skills. Likewise, Teacher 8 explained that if students can develop conclusions and predictions, then “…that means that you have mastered the skills…” Moreover, Teacher 7 explained her expectations of students’ data literacy as dependent on their skills and “…being able to take data off of the periodic table…” Similarly, Teacher 1 emphasized data literacy skills as being “…able to use data points anywhere in the curve…”

Performance. Performance was indicated when teachers described how students’ past experiences and skills impacted the way they performed in their class. Teacher 6 explained how she believed her students were stronger in data literacy than some of her other classes and thus performed better. For example, she stated, “…I think they do a better job than some of my other classes…with paying attention.”

Self-belief. Self-belief was indicated when teachers described the confidence needed for students to reach their data literacy expectations. Like skills, self-belief was found to be directly connected to the theme of past experiences. For example, Teacher 2 described how experiences in the classroom help build students’ confidence to reach her expectations of data literacy knowledge and skills in Biology. Teacher 2 explained how she improved confidence and clarification by implementing small group work that helped her “…identify those who needed additional…" help. This was similar to Teacher 3's emphasis on collaborative work to increase students' confidence when they engaged with challenging science articles.

Reflection. Reflection was revealed when teachers were reflective in their own practice but also encouraged student reflection in data literacy. For example, Teacher 7 said, "I'm learning…" as she explained how she had to refine her expectations due to deficiencies in students' past data literacy learning. Moreover, Teacher 4 incorporated reflection as she had her students analyze cell phone usage data and its effect in their performance in Biology. This category was found to be connected to self-belief and reteach.

Reteach. Reteach was indicated when teachers described how students' data literacy deficiencies and lack of prior knowledge required them to reteach concepts. Reflection led to the discovery of reteach as Teacher 7 explained that she would have to "go back" and "go over and over and over…" to have students meet her expectations of students' data literacy. Consequently, this led to the findings of schedule as a category.

Schedule. Schedule was indicated when teachers described time as a factor in their expectations of students' data literacy. Time spent and amount of time were common codes identified in the dataset. Therefore, this led to the category development of schedule. Teacher 1 described how he believed students needed to be more active in their learning. He explained student engagement from his past experience of students working with data in his response to item 16. Specifically, Teacher 1 said, "…a time to get them up out of their seats because we spend too much time in our seats. I think that's another problem…."

Moreover, Teacher 7 described how she had high expectations for her students to be able to read and interpret data in the periodic table and stated, "In fact, uh, I've spent a lot of time on it." Similarly, Teacher 6 described how she slowed down in her lesson when she recognized students did not understand materials. She stated, "…it's a lot easier for me to slow down and listen…." She further explained the negative consequences of rushing through lessons and how it impacted students' sense of caring. Teacher 6 described how she "loses" students if she tries rushing through a lesson and explained, "…they don't know what's going on, and they don't care." She also described how this impacted her purpose of teaching by stating, "…then I lose my whole point of teaching."

Extending on different perspectives of timing, Teacher 4 described a different approach and explained how she had her students identify the amount of time they spent on their phones. This activity allowed the students to be reflective in the way they spent their time, and the data they retrieved was also used to create graphs and develop conclusions.

Individualization. Individualization was indicated when teachers described meeting the needs of each student. Like schedule, which was connected to reteach, individualization was also connected to this category. Teacher 8 described the importance of meeting students where they are and finding ways to get them to a higher learning level. Individualization was identified as Teacher 8 explained how her expectations of students' data literacy knowledge and skills were not met.

Facilitation. Facilitation arose as teachers described how they helped students reach their expectations of data literacy knowledge and skills and engage in data. For example, Teacher 8 responded to item 16 and described how she gets students engaged by showing them data sources and then breaking "…it down step by step…." Likewise, Teacher 1 described how he facilitated learning for students struggling with content in his response to item 17 in the interview. Particularly, he stated "I found that one-on-one or one-on-two, I am much better at explaining than if there is a big group of distractions." Nonetheless, he said, "Now, if you're not going to come up to me, then it is going to be difficult." Moreover, he indicated that he "…struggled with this one," and then also said, "My answer is, I don't know if I can answer it." Similarly, Teacher 2 responded to item 17 and described how she facilitated data literacy learning for students struggling with data literacy in her class. She explained that "A table might pop up, and they struggled with it, and I had to come help and kind of have leading questions or guiding questions that helped them answer it…." Consequently, this indicated that Teacher 2 utilized guided questions as a way to facilitate data literacy and address data literacy challenges in science.

Taking facilitation of data literacy learning in a different direction, Teacher 3 explained how she incorporated step-by-step worksheets to help students complete more complex problems in her response to item 17. For example, she explained how she initially asked students to complete a multi-step problem without the step-by-step worksheet and she stated, "They all just looked at me like I was crazy because they didn't know…." Consequently, when she "…recreated the worksheet and added to it to find A and have them find B in order to get to C, then they understood…." Teacher 3 further explained how students would first use the step-by-step worksheet that was similar to a flowchart and how she would "…throw it to them without the flowchart…" after students had exposure and practice.

These findings assert that teachers' expectations of students' data literacy are dependent on their views of past experiences affecting students' data literacy. For example, if a teacher views a student to have limited knowledge, skills, and experience in data literacy, then they described how they would have to lower their expectations. Most of the teachers indicated that a lack of prior knowledge in data literacy influenced their initial expectations of students' data literacy. Common data literacy knowledge that teachers explained students often lacked included the ability to interpret data connected to scientific concepts, the ability to interpret data presented in graphs, tables, and charts, and the ability to generate graphs from data obtained. For example, Teacher 4 explained how she expected her students to create and interpret graphs but quickly found out they were deficient in this area when she implemented an activity centered on this at the beginning of the semester in her Biology classes. Moreover, Teacher 1 explained how his students lacked prior learning experiences with connected data to science concepts and described how students often struggled with describing the meaning of data obtained related to topics in his physical science classes. These findings imply that early experiences could offer positive implications in improving students' data literacy and ensuring teachers uphold high expectations at the high school level.

RQ 3. Like RQ 1 and 2, the theme teachers believe students' prior learning experiences determine their data literacy was revealed using the categories knowledge/prior knowledge, depth of learning, simplicity, learning, skills, understanding, details, alignment, assessment, necessary, reasoning, challenge level, assistance/help, attempt, coach, gradual progression.

Knowledge/prior knowledge was directly connected to this theme as teachers explained how students' knowledge and prior knowledge affected their data literacy in science. Additionally, knowledge/prior knowledge was found to be directly connected to depth of learning, assessment, skills, challenge level, and reasoning. This is because students' knowledge and prior knowledge was dependent on the depth of learning they had related to data literacy. Likewise, students' skills in how they worked through concepts related to data literacy was dependent on their knowledge and prior knowledge. These differences led to the development of challenge level connected to knowledge/prior knowledge as teachers suggested the challenge of the concepts related to data literacy was dependent on their students' knowledge/prior knowledge. Furthermore, teachers explained how different assessments could be used to determine students' knowledge/prior knowledge related to data literacy in science. Lastly, reasoning was found to be connected to knowledge/prior knowledge and past experiences as these categories were revealed when teachers explained how students reasoned and worked through concepts related to data literacy, which was dependent on their past experiences, knowledge/prior knowledge, learning, and depth of learning.

Like knowledge/prior knowledge, understanding was found to be directly connected to the past experience theme, knowledge/prior knowledge, assessment, depth of learning, details, and necessary. This is because students' understanding of how to work through science concepts related to data literacy was dependent on their past experiences, prior knowledge, and depth of knowledge, which could be detected through different assessments. Likewise, the way students focused on details of concepts with data literacy was dependent on their understanding of data literacy.

Learning was revealed when teachers explained how students' learning affected their skills in data literacy, which also affected their depth of learning. Similarly, learning was connected to reasoning as the way students worked through concepts related to data literacy was dependent on their learning and depth of learning. Additionally, depth of learning was found to be connected to simplicity as teachers explained students' depth of learning was typically just a basic learning of data literacy and not in-depth.

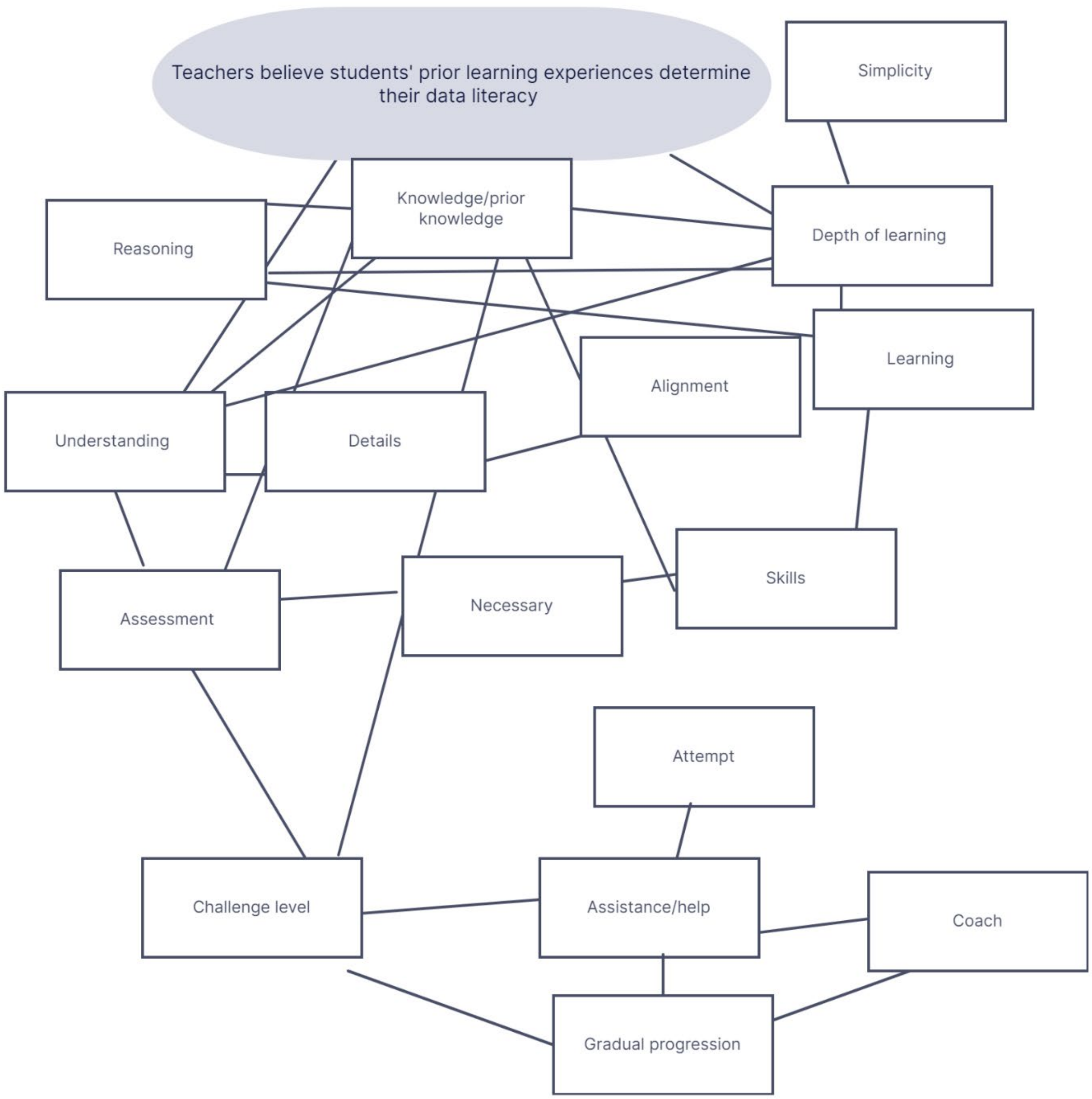
Extending on learning as a category that revealed teachers believe students' prior learning experiences determine their data literacy, skills were revealed as a category, which was connected to learning, knowledge/prior knowledge, and necessary. Teachers explained students' skills in how they work through concepts related to data literacy was dependent on their knowledge/prior knowledge and learning. Nonetheless, teachers, such as Teacher 8, emphasized skills as necessary for students to work through concepts related to data literacy.

In addition to necessary being connected to skills, it was also found to be connected to assessment as teachers discussed the need to use assessments to check for students' data literacy understanding. Thus, assessment was found to also be connected to knowledge/prior knowledge and challenge level as teachers expressed their ideas of using assessments to evaluate students' knowledge/prior knowledge, which dictated how rigorous materials would be to have students work through concepts related to data literacy.

Therefore, challenge level was found to be directly connected to knowledge/prior knowledge, assessment, assistance/help, and gradual progression. Students' knowledge/prior knowledge affected the challenge level of concepts related to data literacy and the gradual progression and assistance/help needed. Gradual progress was found to be connected to coach, assistance/help, and challenge level. Thus, the way students gradually progressed through working with concepts related to data literacy was based on the challenge level, training/coaching, and assistance/help. Lastly, assistance/help was found to be connected to challenge level, coach, gradual progression, and attempt. This is because the challenge level of concepts related to data literacy was dependent on the assistance/help, coaching, and gradual progression students needed to be successful. Attempt was connected to assistance/help as teachers explained how they tried to help students work through concepts related to data literacy when they struggled. Figure 8 demonstrates the relationship of the categories used to discover the theme teachers believe students' prior learning experiences determine their data literacy for RQ 3. The subsequent section will discuss the connection of each category used to reveal teachers believe students' prior learning experiences determine their data literacy in detail for RQ 3.

Figure 8

Connection of categories used to reveal teachers believe students' prior learning experiences determine their data literacy for RQ 3.



Knowledge/prior knowledge. Knowledge/prior knowledge was indicated when teachers specified students knowing how to work through concepts with data literacy. Some described this based on prior knowledge. This category was revealed using the codes previous encounters, know how, know, background, and middle school. Teacher 5 stressed the importance of knowledge and skills in student data literacy in science. For example, she emphasized students ". . . being able to do it themselves…" and knowledge in math to work through concepts related to data literacy. Similarly, Teacher 5 emphasized knowledge by stating "…making sure you know how to take it from a science perspective…" as she explained how students work through data literacy concepts. Comparably, Teacher 3 explained how her students worked through data literacy by first focusing on "…vocabulary that they may not have encountered in middle school…." Likewise, Teacher 1 explained how he would see if students "…know how to graph…" as a way to advance students' data literacy.

Understanding. Connected directly to knowledge/prior knowledge, understanding was indicated when teachers described the importance of students absorbing science data literacy information and how they checked for students' understanding as they worked through concepts related to data literacy. Teachers had broad perspectives of what constituted as data literacy in their science classes. Some viewed it more from a quantitative lens while others, such as Teachers 6 and 7 had a wide range of what data literacy could be in their science classes. For example, Teacher 7 explained that students need an "…aptitude for science…" to do well in her Chemistry class. She explained how it was important to understand the content by emphasizing how students "…absorb the materials" and explained how "It's not just something you know that you can absorb, walk in and pick up." Likewise, she stated, "…you got to understand where and what" as she explained the importance of students understanding data in the periodic table.

Comparably, Teacher 8 also emphasized understanding through absorption as she explained the importance of a common progression within the district that addresses "…how the children are getting the information and able to absorb it…"

Assessments. Assessments were indicated when teachers described how they used assessments to understand how students work through concepts related to data literacy. Extending on the focus of understanding the way students work through concepts related to data literacy, Teacher 5 explained how she implemented assessments in her class to "…make sure everybody understands it." Moreover, Teachers 2 and 8 emphasized gaining insight on students' understanding by asking reflective questions, such as analyzing graphs and asking "…how is that happening…" as Teacher 8 described.

Reasoning. Reasoning was indicated when teachers described how students reason and worked through data literacy problems. It was also indicated when teachers described how they reasoned through data literacy needs. For example, Teacher 4 described how PLCs were implemented to address students' data literacy needs by allowing teachers to analyze data and "…figure out which questions are being missed more…" to determine best instructional approaches.

Extending on reasoning as a category, Teacher 8 emphasized reasoning for test taking preparation. For example, she explained that questions presented to students in a similar way that they were taught helped prepare "…them for how the test makers want them to be thinking." Nonetheless, teachers, such as Teachers 1, 5, and 8, indicated that reasoning was based on knowledge/prior knowledge, learning, and depth of learning. Likewise, reasoning was also indicated when teachers discussed their thoughts as they answered interview questions. For example, when Teacher 1 was asked about item 14, he explained how he had "…never really thought of data literacy…" and stated, "I just have never thought of the actual term data literacy." These findings imply that teachers' past experiences with data literacy likely affects their own data literacy and the way they approach it in the classroom through their previous learning, which has shaped their reasoning of data literacy in science.

Depth of learning. Reasoning was found to be connected to depth of learning since students' thinking was influenced by learning and depth of learning as they worked through concepts connected to data literacy. Depth of learning was indicated when teachers described what was needed to improve students' performance as they work through concepts related to data literacy. For example, Teacher 4 explained how teachers were "…still left with questions about how in-depth to teach certain things" as she explained how the science standards were broad and could be revised to support students' data literacy needs. Moreover, Teacher 3 explained how learning activities centered on communicating data improved and said that there is a "…huge growth…" in students' learning as they work on communicating data sources through lab reports in her class.

Simplicity. Simplicity was indicated when participants described students working through basic science data literacy concepts. For instance, Teacher 1 explained how students' knowledge is typically limited to only learning "…basic concepts…" and gave an example of students understanding that "…a mixture is a solution," which revealed simplicity as a category. During his example, he had students analyze an image, which was displayed on a promethean board to categorize types of solutions. Thus, this was included as a form of data literacy in the present study as images were used as a data source for students to analyze and interpret information connected to scientific concepts. Teacher 1's activity, which required analysis of data depicted in images, was similar to Teacher 4's review activity where she used quizzes depicted on the promethean board that included images of cellular transport and required students to determine the type of transport illustrated based on data presented in the images.

Details. Details were indicated when teachers described how students worked through concepts related to data literacy and areas to focus on to improve data literacy. Although students only understood "…basic concepts…" as described by Teacher 1, teachers emphasized a deeper focus in working through concepts related to data literacy, which led to the development of details as a category. Teacher 1 described how focusing on data sources and "…areas that…generate data…" allows for teachers to "…improve data literacy in those areas." Similarly, Teacher 2 explained how the science curriculum could be improved to support data literacy "…if the curriculum focused or targeted specific things about data."

Alignment. Alignment was indicated when teachers emphasized standards being used to address data literacy. For example, Teacher 4 stated that the curriculum could be improved by having "…clearer standards and…concepts that go with the standards." She further stated, "A lot of times the standards are too vague, and you don't know exactly what to teach so if they would minimize or like break it down…." Similarly, Teacher 5 stressed the importance of students being able to examine data sources carefully and "…pick apart…" necessary information needed to answer questions. Likewise, Teacher 6 explained when students were "…most engaged…" in "Just picking up information and conveying it…." Moreover, Teacher 8 explained how she believed "…there needs to be a clear cut" standard. Thus, she stressed alignment with details making these categories connected to reveal the theme teachers believe students' prior learning experiences determine their data literacy. Comparably, Teacher 7 explained, "…we look at the standards, uh, you have those personalized learning targets in there."

Extending on the topic of standards connected to alignment, Teacher 3 stated, "When we transferred over from the GPS standards to the GSE standards, and they brought in the science methods, a lot of those science methods incorporate the data literacy in them already. Thus, this reiterated the need for alignment and detailed understanding to improve how students work through concepts related to data literacy.

Skills. Skills were indicated when teachers described the skills students needed as they worked through concepts related to data literacy and the skills students obtained by working through data literacy concepts. For example, Teacher 6 explained she wanted her students to "…be able to have an investigative approach to come to a conclusion." She explained how students often lack such skills when they work through concepts related to data literacy in her Forensics class. Consequently, Teacher 6 explained how she focused on this to advance students' data literacy. Likewise, Teacher 2 stated, "…you roll out specific skills" as she explained the science curriculum being specifically designed to support data literacy. She also explained how skills often get lost when students enter middle and high school and stated that there is a greater focus on rigor rather than skills at these grade levels.

Challenge level. Challenge level was indicated as teachers described how students worked through different levels of complex materials that challenged the way they work through concepts related to data literacy. Similar to Teacher 6, Teacher 7 described how her students often struggle when working with concepts related to data literacy. She said, "…they struggle a little bit…" and explained how students had a "…hard time remembering things…" due to students being "...adverse to homework…." She further explained how students struggle when working through concepts related to data literacy. For example, Teacher 7 said, "…some of them struggle with locating different data points on the periodic table…." Consequently, she emphasized students having knowledge and an understanding of data in the periodic table to be able to locate necessary information needed for students to work through concepts related to data literacy. Teacher 2 explained how the science curriculum in high school is rigorous. She stated, "…at the high school level it's so rigorous…."

Gradual Progression. Gradual progression was indicated when teachers explained how students progressed through concepts related to data literacy. For example, Teacher 3 described how she gave her students easier work in the beginning and then gradually progressed to more challenging materials to increase their confidence. She stated that "Starting with easier articles at first" was needed to "…build up their confidence so that they know what they are doing…." Teacher 3 explained how she used gradual progression when teaching challenging concepts by implementing collaboration. She said, "…if they're trying to analyze or interpret an acceleration time graph and get back to the distance time graph or anything like that, then that's where they may have to rely on their teammates." This was similar to how she incorporated group work as a way to assist students as they worked through challenging concepts related to data literacy. For example, in response to item 3, Teacher 3 said, "…if you're looking at a college level reading article, then I'll allow them to work in pairs or even in groups of threes so that way they can bounce ideas off of each other…." Drawing on the topic of gradual progression, Teacher 7 explained how she implemented drawings in the beginning to advance students' data literacy. She stated, "…during the first part of the course, I had them draw out atoms that are displayed in the back of the room…."

Assistance/help. Assistance/help was found to be directly connected to gradual progression as teachers explained how they used gradual progression to assist students as they work through concepts related to data literacy. Thus, assistance/help was indicated when teachers described how students needed assistance. For example, Teacher 1 explained how he believed

PLCs were helpful and stated, “Teacher interactions have been very helpful to me.” He elaborated on how PLCs are used to discuss data of students’ performance and pacing within the curriculum. He explained how PLCs “…address deficiencies in certain standards.” Moreover, connected directly to gradual progression and assistance, coach was also found as a category as teachers described the training students needed to advance in how they worked through concepts related to data literacy. For example, Teacher 4 stated “…training students to do better…” was necessary to ensure they are “…actually being able to analyze…” and “…transition them from just getting data to actually using data…” Thus, she alluded to the category necessary, which was indicated when teachers described what students needed to do well as they work through concepts related to data literacy. Teacher 3 stated, “…I don't feel like we as a school have honestly dove into that as much as we should” as she described how PLCs were used to address students’ data literacy needs. Nonetheless, teacher 2 explained how she tried to help and train students to work through data literacy as she stated, “…me trying to help or train them if they didn't pick up on certain things” Thus, this led to the development of attempt as a category, which indicated when teachers explained how they tried to help students and thus connected directly to the category assistance/help.

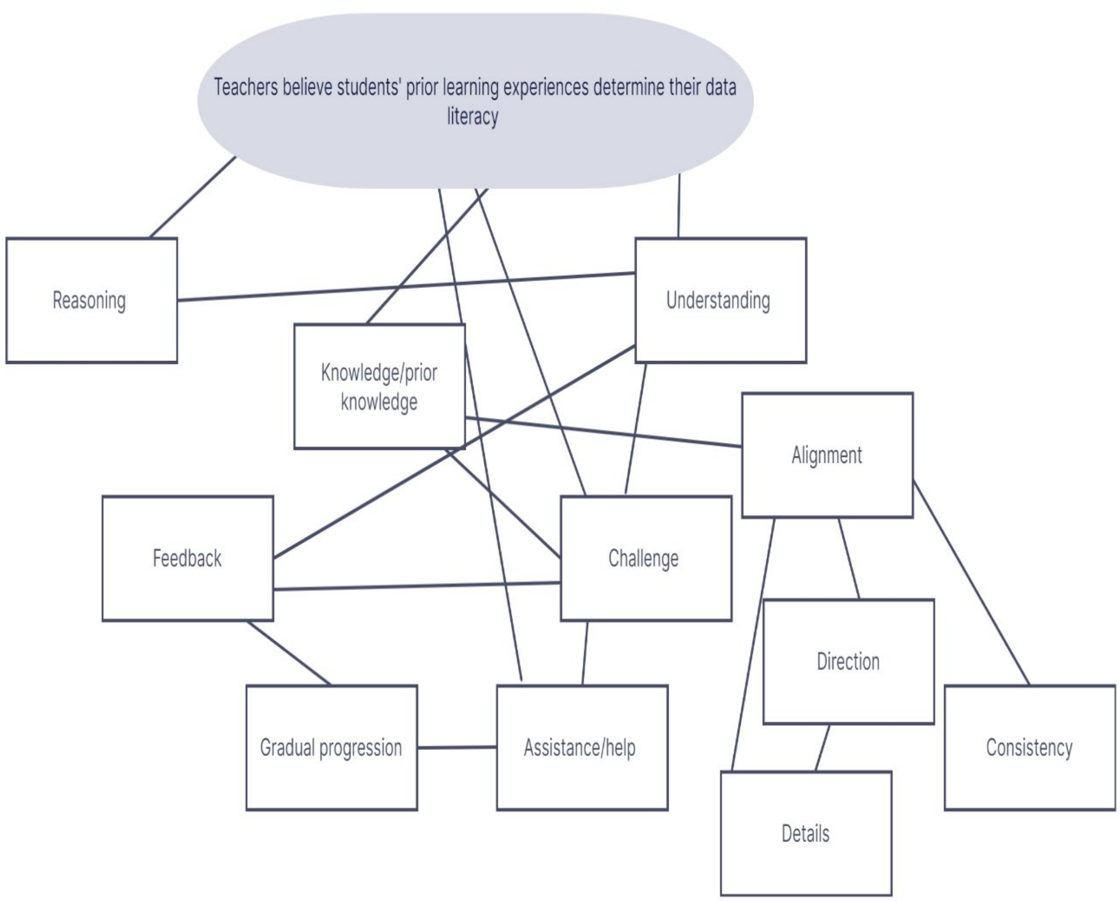
The categories that led to the development of teachers believe students' prior learning experiences determine their data literacy suggest that teachers must take into account each students’ previous learning and knowledge, which influence the way they work through and reason through concepts related to data literacy. Moreover, teachers emphasized how using assessments to gain insight on students’ prior knowledge and understanding was necessary to determine the appropriate challenge level of data literacy materials that align to each learner's needs and assistance required. These findings imply that students’ past experiences substantially influence the way students work through data literacy concepts in their high school science classes, which could lead to potential future research targeting data literacy learning in lower grades and professional learning for teachers serving students in theses lower grades to help advance their data literacy before students reach high school science classes.

RQ 4. Like RQs 1, 2, and 3, teachers believe students' prior learning experiences determine their data literacy was identified for RQ 4, which indicated that such past experiences impacted the way strategies were implemented to scaffold and foster data literacy. The following categories were used to reveal this theme: Knowledge/prior knowledge, reasoning, understanding, challenge, feedback, gradual progression, and assistance/help.

Reasoning was found to be connected to understanding as the way an individual reasoned was based on their understanding. Likewise, understanding was found to be connected to challenge and feedback as teachers described how students' past experiences affected their understanding, which was obtained through feedback and such understanding dictated the level of rigor implemented to foster data literacy. Moreover, teachers indicated that gradual progression was a strategy implemented based on student feedback of their understanding and influenced the assistance/help needed. Therefore, gradual progression was found to be directly connected to feedback and assistance/help. Furthermore, alignment was found to be connected to consistency, details, and knowledge/prior knowledge as alignment indicated standard-based instruction and understanding. Thus, ensuring standard-based instruction was implemented influenced knowledge/prior knowledge. Nonetheless, teachers indicated how they focused on a section of a data literacy lesson in science to foster data literacy learning, which led to the development of details as a category. This was connected to direction and alignment. Additionally, direction was indicated when teachers incorporated predictions as a way to foster data literacy. However, incorporating such predictions were dependent on previous learning aligned to state standards. Furthermore, consistency was found to be connected to alignment as standards help provide consistency in instructional practices to foster data literacy. Lastly, reasoning, knowledge/prior knowledge, challenge, understanding, and assistance/help were all found to be directly connected to the theme teachers believe students' prior learning experiences determine their data literacy skills. Figure 9 demonstrates the relationship of the categories used to reveal this theme.

Figure 9

Categories that revealed teachers believe students' prior learning experiences determine their data literacy theme for RQ 4.



Knowledge/prior knowledge. Knowledge/prior knowledge was indicated when teachers described how students' knowledge influenced how they used strategies to foster data literacy. For example, Teacher 3 stated, "I'll even have the kids discuss the words before-hand to see what prior knowledge they have, and one example was the word 'conductor' when we were teaching Physical Science electricity, and that was on our worksheet, and the kids were like, 'Oh those are the people in front of an orchestra.' Yes, that is a conductor. However, in a science class we have another word, you know, another definition for conductor."

Knowledge/prior knowledge was referenced many times in the classroom observations. For example, Teacher 1 referenced a question students completed the previous day as they engaged in calculations. Likewise, Teacher 2 provided assistance and referred to previous examples they had worked through in class related to x and y axes. Similarly, she asked questions that connected to students' prior knowledge as students completed the station activity, such as "How does this connect to what we covered earlier this week?" and "Do you remember what we learned about in our ecosystem unit?" Comparably, Teacher 3 stated that she believed the metric system was important prior knowledge needed before carrying out investigations that required students to use the metric system to obtain, evaluate, and communicate sources of data related to speed, velocity, distance, acceleration, and time (SP1). Thus, her classroom observation lesson led to standard SB1 later that week.

Reasoning. Reasoning was indicated when teachers described their thought process of the strategies they used to foster data literacy. For example, Teacher 1 explained his views of using labs to promote kinesthetic learning by stating, "I think labs are to get them engaged."

Moreover, reasoning was identified in the observations when teachers encouraged or implemented activities that required students to use reasoning as a strategy to foster data literacy.

For example, Teacher 1 instructed his students to use their cellphones to figure out the density of it. Likewise, he instructed students to "Be thinking about what you are going to do with the paperclips" and explained to students that they need to "Think about how you can measure volume." Similarly, student reasoning was revealed in document analyses. For example, Teacher 4's activity asked students to think about what "…will happen to the cell membrane of an egg when soaked in sugar or syrup."

Understanding. Understanding was indicated when teachers described how they emphasized understanding to improve students' data literacy. For example, Teacher 3 stated, "They're going to at least be reading the purpose to understand why the research was conducted…." Similarly, Teacher 2 explained how she had her students "…create their own questions" to develop understanding of data represented in visuals. Moreover, she emphasized "…making sense out of…" data and "digging into…" it for a deeper understanding. Furthermore, Teacher 7 stressed understanding and explained, "…if you do not understand the theory, then when it comes to problem solving, to me, you're just manipulating numbers. You do not understand exactly what you're doing." She further stated, "…just doing a bunch of word problems and not understanding it, what's the overall point?" and also asked, "How can we say we thoroughly educated them when…they really don't understand what any of this stuff means?" Comparably, Teacher 8 explained that "The application in the long run helps them with understanding."

Like the interviews revealed, teachers also used questioning to check for student understanding in classroom observations. For example, Teacher 1 included a variety of verbal and written questions. One written question included the following: "Problem 6: A flask that weighs 345.8g is filled with 225 ml of carbon tetrachloride The weight of the flask and carbon tetrachloride is found to be 703.55 g. Calculate the density g/ml." Although Teacher 1 asked a variety of questions, he quickly answered questions he asked leaving little time to check for students' understanding.

Similarly, Teacher 2 had a question projected on the board, which was titled "Interpreting graphs in science" at the beginning of class. Students were required to match descriptions with graphs illustrated. Moreover, like Teacher 1, Teacher 2 asked simple, lower level questions, such as "What's happening in number A?" and "What's going on in number B?" However, students engaged in conversations by answering her questions unlike Teacher 1. As students completed the station activity, Teacher 2 asked questions for understanding, such as "How do you think this relates to changing populations?" Furthermore, Teacher 2 asked lots of questions to check for students' understanding such as "What is the type of transport we used yesterday in the lab?" and "What are the two types of transports?" Nonetheless, most of the review questions asked at the beginning of the observation were lower level recall questions. Furthermore, Teacher 6 asked students questions to assess their understanding of using data sources to solve cases.

Like Teacher 8's emphasis on application for understanding, Teacher 3's assessment required students to apply the calculations they learned from conducting the rocket lab to calculating "…the height of fireworks." Similarly, Teacher 4's activity included 10 items, which addressed students' understanding of an osmosis lab. These questions were subdivided into analyzation, conclusion, and extension questions. Although Teacher 6 did not provide an assessment, it was evident that the ten questions included in the data literacy activity she provided checked for students' data literacy understanding.

Likewise, questions were included in document analyses. However, the challenge level of these questions varied. For example, only one question in Teacher 1's assessment asked 'why' as all other questions were lower level and required students to interpret visuals. Nonetheless, Teacher 3's assessment appeared to gradually progress from simple to more complex thus linking the categories understanding and gradual progression,

Challenge. Challenge was indicated when teachers described the difficulty of the strategies they used to foster data literacy. For example, Teacher 1 explained how he implemented labs as they were "…kinda like college…" as they provided "…hands-on…" learning. However, he stated, "…that can be difficult because someone might not want to go outside for a little bit. It's a struggle." Nonetheless, challenge was also included as a topic when teachers described how they differentiated learning. For example, Teacher 2 explained how she implemented tier 2 learning activities to foster data literacy for students who experience more challenges in their learning while Teacher 3 stated, "I'll group the kids sometime even in their labs based on their levels." Teacher 2 explained how she used quizzes as "They're a little more…not as rigorous, a little more, I guess, basic" and explained how progress learning was "…more difficult…."

Taking the topic of challenge in a different direction, this category was also indicated when teachers described challenges they experienced in teaching data literacy. For example, when asked about item 8, Teacher 4 replied, "So this question is kind of hard because of the environment itself…."

Extending on this topic, challenge was indicated among teacher observations. Some implemented more rigorous, challenging strategies; whereas, others challenge level targeted lower depths of learning. For example, Teacher 1 asked a variety of questions to check for understanding. However, these questions were basic, low DOK levels. For instance, he asked students, "What does it classify as?" "H2O is a compound, so is CO2. What is O2?" and "What is air?" in reference to images depicted on the promethean board. Nonetheless, students seemed to need additional support as compared to some of the other classes observed. This was evident throughout the observation as he modeled how to calculate densities, yet students still needed step-by-step explanations of how to calculate densities. Comparably, Teacher 7 explained how she wanted her students to go back to the periodic table because she recognized many of them were struggling with interpreting it.

Feedback. Feedback was indicated when teachers described how they used assessments as a strategy to gauge where students are and offer feedback. For example, Teacher 7 stated, "I grade it and give it back to them. Tell them to put that back into their binder. Save it because those are good study notes…." Similarly, Teacher 8 described how she asked simple questions "…to get a temperature…" of students' understanding. Moreover, Teacher 4 explained how she used a ticket out the door as a way "…to get feedback on how they're doing or how they understand it." Similarly, Teacher 8 stated, "…I usually start with getting a temperature of what they see, right? So I want the initial feedback to see are they even starting on the right track or is it far back left because that's going to change the approach you take…."

Additionally, feedback was also revealed in classroom observations. For example, Teacher 2 asked questions for understanding and waited for students' responses to give feedback. For instance, one student responded to her question and stated that there was a change in the graph. She replied, "De-acceleration, a change. This is very important. You are going to see this later and see how these lines can tell you about changes in the ecosystem. The lines tell you a lot." Similarly, one student held up a plastic graduated cylinder, which led Teacher 1 to provide feedback and recommend that he use a glass graduated cylinder due to its transparency. Likewise, he circulated around the room and asked to check students' numbers on the back of their sheet for the densities so he could see if they were in the right range. Teacher 1 also explained that he wanted to know if they did it right and if they didn't, why. Like Teacher 1, Teacher 2 had her students discuss and share their responses to an activator projected on the board as a way to provide feedback before students engaged in a station activity. Once students wrote down their answers, she had a student share her response and then the teacher facilitated a class discussion to provide group feedback on interpretation of graphs.

All questions in Teacher 2's activity checked for students' understanding. However, the assessment she provided included only multiple choice items unlike Teachers 1, 3, and 6. Thus, limited data was provided on students' thought processes, which impacted how feedback was administered. Nonetheless, Teacher 2's activity and Teacher 5's assessment allowed data related to students' thinking to be obtained so that effective feedback can be given. For example, item 3 on page 7 asked, "In general, how has the popularity of this event changed over the years since 1993? Tell how you know." Thus, this question required students to provide a short constructed response and explain their thinking, which allowed the teacher to ensure students' understanding. This also provided an opportunity to address misconceptions. Likewise, Teacher 4's and 6's activity included short constructed responses, which allowed better detection of students' understanding. Nonetheless, like Teacher 2, Teacher 4's assessment consisted of only multiple choice items, and Teacher 6 did not provide an assessment.

Gradual Progression. Gradual progression was indicated when teachers described how they elicited student feedback to determine a starting point of instruction and used this information to gradually progress to foster data literacy. Thus, teachers explained how they slowly moved forward in using data in science as a way to foster learning. For example, Teacher 8 explained how she determined "…their starting place…" as a way to gauge instruction, which was similar to Teacher 4's response and emphasis on student feedback. For example, Teacher 3 stated, "You have to build that confidence with them with easier stuff as a stepping stone to get up to doing the harder items. And once you do get up…so, with the harder items, you're definitely going to want to put them in a group to discuss and throw ideas at each other." Teacher 8 explained, "So, if you understand this, if this were in another, you know, scenario, what would we expect?" as a way she fostered data literacy in Biology.

Taking the view of gradual progression in a different direction, Teacher 2 suggested a curriculum that started in elementary school and gradually progressed to middle and high school. For example, in her response to item 14, she stated, "…so if we had a curriculum that started in elementary that focused on data then the middle school a step further, make it more specific because I feel like it kind of gets lost in the mix…."

Expanding on the incorporation of gradual progression as a strategy to foster data literacy, Teacher 3 implemented a metric lab in her physics class during her classroom observation. She explained how she had her students complete this lab at the beginning of the semester to help them get familiar with the metric system before they progress in physics calculations using the metric system. Similarly, Teacher 2 explained how she implemented collaborative discussions as a way to gradually progress to difficult concepts and independent learning. This was also evident in her classroom observations as she had students work together to analyze data sources related to population dynamics at different stations around the room. Likewise, Teacher 1 implemented gradual release during his observation as he initially modeled how to complete the lab sheet aligned to the density lab by instructing and modeling how to calculate densities. After illustrating calculations, students work in pairs to complete the lab, which was followed by individual assessments the following day. Thus, he progressed from whole group, small group, to independent learning as a strategy to foster data literacy. Similarly, during Teacher 7's observation, one student asked a question about noble gasses, and the teacher responded by telling students not to work ahead and to focus on the basics, which was electron configuration.

Like interviews and observations, gradual progression was also identified in document analyses. For example, Teacher 3's lab gradually progressed from step-by-step to organizing data to determine relationships and apply learning to other situations. For example, item 4 asked, "What is the acceleration of the rocket during its flight?" However, item 8 asked, "Now again, taking into account the variables which you do not have data for, what equation could be used to determine the maximum height achieved by the rocket?" and the last item stated, "Explain how you could use this method to calculate the height of fireworks." Thus, there was a progression in the lab assessment in rigor. Similarly, Teacher 7 provided a clear progression in the activity and assessment she provided as her activities required students to organize information of elements into a graphic organizer and unscramble words; whereas, her assessment required comparison and an understanding of rules related to orbitals.

Assistance/help. Assistance/help was indicated when teachers described strategies that helped kids progress in data literacy. For example, Teacher 3 stated, how asking why and how questions would "…also help the kids whenever they go to write their own…lab report at the end…." Moreover, teacher 6 stated, "…we want to steer them away from jumping to conclusions…" as she described strategies she used to foster data literacy. Additionally, Teacher 3 explained how she used active learning by having students extrapolate their own data form labs and described how it helped "…the kids understand the difference between instantaneous velocity or speed versus average velocity or speed, so it all ties back to the formulas I've taught them in class….” Likewise, Teacher 3 also explained how she grouped her students “…in order to assist with each other, so that way you don’t have all of your gifted kids together in one group.”

Comparably, this category was reiterated in the classroom observations. For example, Teacher 1 stated to the entire class that if they needed an explanation of how to calculate the volume of the paperclips, then they needed to come to him. Likewise, Teacher 2 asked probing questions in reference to graphs to foster data literacy. She also stated, “…I am here to help, but I won't tell you the answer, but I will help guide you through it.” Similarly, Teacher 3 provided direct instruction to break down the problems as she explained to one student, “One foot is twelve inches.” She circled the room and provided direct assistance for students that needed additional help. For example, she corrected one student’s work and stated, “This needs to be grams and this needs to be milligrams so leave the numbers and just change the units. Okay, so now this is going to cross out.”

Physical science teachers appeared to actively assist/help students more than life science teachers. For example, when Teachers 1 and 3 implemented a lab, they circled the room and offered one-on-one and small group assistance as a strategy to foster data literacy. Teacher 3 provided assistance for approximately 80% of the duration of the observation. The assistance was whole group, small group, and one-on-one. She used feedback, questioning, and modeling to implement this.

Direction. Direction was indicated when teachers described how they had their students analyze trends and make predictions. For example, Teacher 2 explained how she had students determine “What predictions can we make about the data?” Similarly, Teacher 3 explained how she had her students obtain their own data and then “…analyze it by looking at trend lines….”

However, this category was not as prevalent in classroom observations. Nonetheless, it was identified in document analyses. For example, item 14 in Teacher 2's assessment asked, "Based on the data, in order to increase plant growth, what might you suggest?" Thus, these questions required students to make a prediction to identify a proposed solution. Likewise, Teacher 4's lab activity required students to formulate a hypothesis prior to implementing the osmosis lab. Comparably, Teacher 6's activity required students to make predictions of events that will take place in upcoming episodes.

Details. Details were indicated when teachers described how they had their students focus on particular data literacy components to develop conclusions. For example, Teacher 6 stated, "…we want to steer them away from jumping to conclusions, so we want them to focus…have an open mind and focus on the case…" as she explained how she wanted her students to assess all data sources.

Details were found to be connected to alignment. For example, Teacher 4 explained how the curriculum could be improved by "providing more resources to the teachers up front." She also explained that there was a need for "…clearer standards and…concepts that go with the standards a lot of times the standards are too vague, and you don't know exactly what to teach…." Similarly, Teacher 8 stated, "So there needs to be a clear cut like, in every like, standard."

Alignment. Alignment was indicated when teachers described how they used the standards to guide their instructional strategies. For example, Teacher 8 was not able to answer item 7 but then stated, "I will go by the standards to see what the standards expect and try to find resources…that match that, but outside of that, I don't do that." Additionally, when replying to item 9, Teacher 7 stated, "…we use state standards. Okay? The state has uh, standards that they have set forth." Taking the use of standards in a different direction, Teacher 1 explained how he needed to work on scaffolding but how he used the standards to build on concepts and students' prior learning.

Moreover, alignment was revealed in classroom observations. For example, Teacher 1 had his students perform a lab using a lab sheet, which specified the standard being addressed. Likewise, Teachers 5 and 8 had the standards being addressed written on their board. Furthermore, Teacher 2 had standards written at the back of her room on a whiteboard. However, the standard and date posted did not align to the lesson of population dynamics being addressed. Like interviews and observations, alignment was revealed in document analyses. For example, Teacher 1 provided students with a lab sheet to complete their lab, which indicated standard SPS 5.a. being addressed. The standard written on the sheet included "Obtain, evaluate, and communicate information to compare and contrast the phases of matter as they relate to atomic and molecular motion. Ask questions to compare and contrast models depicting the particle arrangement and motion in solids, liquids, gasses, and plasmas. The lesson observed did not address this standard. However, it still required students to obtain, compare, and contrast data sources. Teacher 2's activity and assessment did not explicitly address science standards like Teacher 1. Nonetheless, it was evident that she used this activity to guide the students into the population dynamic lesson, which required students to analyze and interpret population growth curve graphs. Thus, she used this activity to prepare students in analysis and interpretation, and she used the 15 item multiple choice quizzes as a way to assess her students' understanding. Consequently, there was a clear alignment between the activity and assessment she provided. Furthermore, Teacher 4 provided an activity, which explicitly included the standard SB 1.d at the top of the document.

Additionally, Teacher 3 explained how data literacy was embedded in the science standards and if teachers were doing what they are supposed to be doing, then it should be included regularly. She stated, “When we transferred over from the GPS standards to the GSE standards, and they brought in the science methods, a lot of those science methods incorporate the data literacy in them already. So, if the teachers are teaching the standards like we're supposed to, then it's already incorporated into our classrooms. It's not something that needs to be extra. This was opposed to Teacher 2’s view of standards in the science curriculum. For example, when asked about item 14, she stated, “I feel like it kind of gets lost in the mix because it's not a specific standard that they’re forced to focus on. I don't even know if in middle school…data is even taught because if it's not a standard, it gets lost.” Nonetheless, there were variations across other teachers' descriptions of alignment. Thus, no clear difference was detected between teachers' conceptions of data literacy regarding standards. Nonetheless, physical science teachers placed greater emphasis in data literacy than life science teachers. Teacher 4 was unsure of what data literacy was, and teacher 5 suggests that life science was not so “heavy in data literacy” as some of the other sciences.

A need for consistency. A need for consistency was indicated when teachers described a need for uniform instruction among teachers to foster data literacy. For example, Teacher 8 explained how “Even within the district…” there needed to be “…a consistent way of…” how to present data literacy in science.

The overarching theme of teachers believe students' prior learning experiences determine their data literacy suggest that the way teachers scaffold and foster data literacy was dependent on students’ past experiences, and determining past experiences was viewed as essential to choosing instructional approaches aligned to state standards. Many teachers expressed how students' data literacy was basic, which helps explain the lower level questioning identified among teachers used to check for students' understanding. Moreover, students' knowledge, which was highly influenced from their past experiences, dictated how assistance was provided and their thinking process of working through data literacy. Nonetheless, there were differences identified among physical science and life science teachers. For example, assistance/help was prevalent more among physical life science teachers. These teachers also had more student-centered activities administered in their observations and illustrated in document analyses, which suggest that assistance/help was a way teachers facilitate learning in their classroom using this approach.

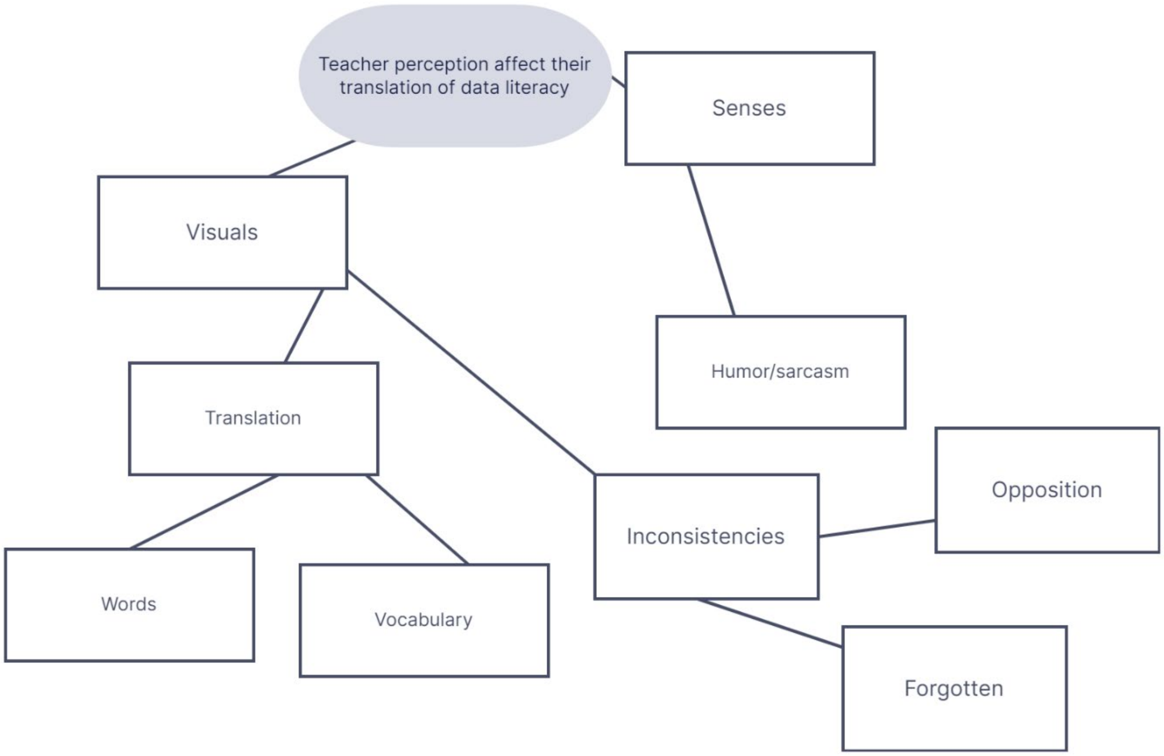
These findings assert that targeting data literacy early in students' education would be beneficial to advance students' data literacy using different strategies to foster learning. Thus, this suggestion is similar to Teacher 2's interview explanation as she explained how data literacy was often lost once students progressed to high school. Additionally, the findings imply that physical science teachers likely offer approaches on ways to implement instructional designs using a student-centered approach and highlight strategies to assist students in their data literacy learning. Consequently, common collaborative planning within the department rather than by subject may be an avenue the school would like to consider in the future to advance students' data literacy in science.

RQ 1 Subtheme: Teacher Perception Affect Their Translation of Data Literacy. The subtheme teacher perception affect their translation of data literacy was identified after developing the categories senses, visuals, humor/sarcasm, translation, words, vocabulary, conflicting, opposition, inconsistencies, and forgotten. Senses were designated when teachers indicated one of the five senses when describing what they knew about data literacy in science.

This was connected to visuals as most teachers suggested data literacy involved some use of data and recognition of patterns. Likewise, senses were also found to be connected to humor/sarcasm as teachers' sense of data literacy was revealed through some form of humor. Words and vocabulary shared similarities as teachers, such as Teacher 3, indicated vocabulary was needed to understand information displayed in science articles and readings. Consequently, these categories were found to be connected to translation as teachers described their conceptions of data literacy as including words and science vocabulary. However, many of the translations were inconsistent among the teachers. Therefore, translation was found to be connected with inconsistencies as some had opposing views, while others, such as Teacher 8, suggested data literacy was often forgotten. All of the categories helped reveal the subtheme teacher perception affect their translation of data literacy as there were varying views, which was likely due to teachers sensing data literacy in diverse ways and varying in their interpretation and translation of what is meant by data literacy in science. Figure 10 displays the connections of categories used to reveal the subtheme teacher perception affect their translation of data literacy for RQ 1.

Figure 10

Connection of categories used to reveal the subtheme teacher perception affect their translation of data literacy for RQ 1.



Senses. Senses were indicated as teachers described data literacy using the three senses hearing, seeing, and feeling. The category 'sense' was identified from the initial codes: Listen, see, look, feel, and watching. For example, Teacher 5 mentioned feeling when she said, "…I feel like even test taking skills could count as data…" in response to item 1. Likewise, Teacher 8 explained her views of data literacy in item 15 by stating "…I feel like it's the foundation for a lot of things."

Visuals. Visuals were indicated when teachers described illustrations of displaying data. This category was identified to be connected to senses and developed based on the initial codes charts, tables, graphs, x and y axes, diagrams, data tables, and literacy tables. Many of the teachers stressed these sources of visuals as they explained their conceptions of data literacy in regards to their knowledge and definition of it (items 1 and 15). For example, Teacher 8 discussed what she knew about data literacy by explaining, "…I know that data literacy is how students understand information that is presented to them…" and gave examples including, "…pictures, diagrams, flow charts…." Likewise, Teacher 5 explained that "Data literacy is them being able to read charts and graphs…" in response to item 15. Similarly, Teacher 2's definition of data literacy included, "…reading and interpreting tables, charts, diagrams."

Humor/sarcasm. Humor/sarcasm was indicated when teachers expressed comedy, laughter, or smiled when responding to data literacy questions. Like visuals, humor/sarcasm was a category identified to be connected to senses. Teacher 1 chuckled when asked about item 15 and stated, "You can tell I'm sarcastic." He also laughed after stating he was tempted to Google a definition for data literacy. Likewise, Teacher 8 laughed after responding with, "I think that's it," in regards to being asked item 18.

Translation. Translation was indicated when teachers explained data literacy as a form of translating data sources through means of interpretation and communication. Taking a connection to perception in a different direction, translation was identified as a category using the initial codes interpret, explain, communicate, read, and say. For example, Teacher 7 replied "…being able to communicate in such a way that demonstrates that you have an understanding of the data…" in response to item 15. Additionally, Teacher 3 described her use of reading as she explained what she knew about data literacy and said, "I utilize articles or any type of reading." Correspondingly, Teacher 6 described the importance of listening to "…what the students are saying…" in response to item 18. Interpretation was also emphasized by many teachers throughout the interview as they explained what data literacy was to them and described what they knew about it. For example, Teacher 1 explained his definition of data literacy as being

"The ability to interpret data." He also explained the importance of understanding the concepts and theories behind data generated. Specifically, Teacher 1 said, "If they don't know what solubility is, then they can't interpret it." Likewise, Teacher 4 explained how her definition of data literacy centered on taking information and "…being able to interpret or understand it…" Moreover, Teacher 2 explained that "It's vital that they know how to read data like the charts, tables, and interpret it and to use it."

Taking the view of data literacy in a different direction, Teacher 7 described how interpretation varied and explained how resources may be useful by stating, "…because my interpretation might be different…." This view of interpretation was similar to Teacher 6 who stated, "…my interpretation of data and how two people can look at evidence and see two totally different things…." All teachers revealed their conceptions of data literacy as being centered on translating data sources in science.

Words. Words were indicated when teachers described sources of data and stated passages could be data as they described data literacy. Extending on the category translation, the category 'words' were identified and found to be connected to translation. Teacher 5 described what she knew about data literacy by explaining it to involve picking "…apart passages for context clues…" Similarly, Teacher 4 described her definition of data literacy as being able to "…see any piece of evidence, so it could be a passage, it could be an article…" and "…being able to interpret or understand it…by explaining." Fifty percent of the teachers emphasized this category suggesting that teachers' conceptions of data literacy involves text and readings as a source of data in science.

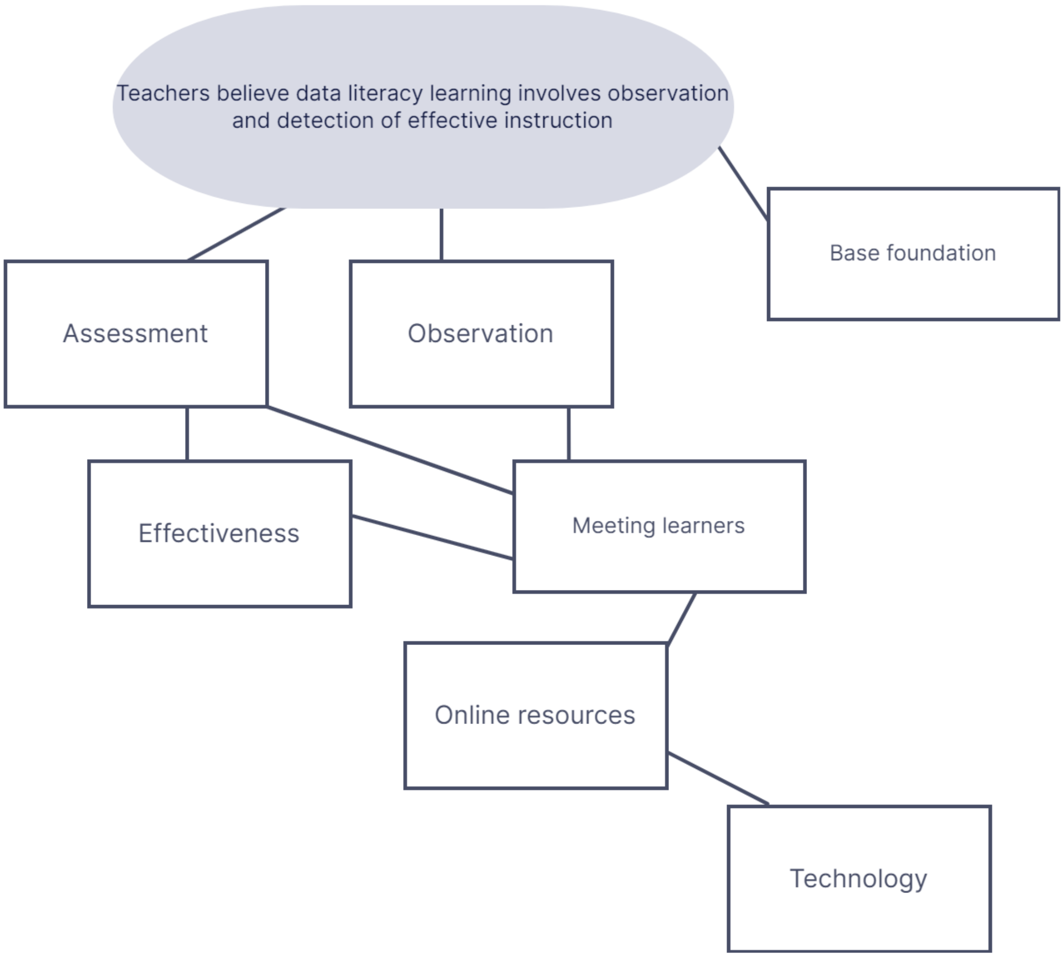
These findings imply that teachers' conceptions of data literacy is dependent on views of senses used to facilitate data literacy in science and ways data sources are communicated as a variety of visuals and methods of interpretations were described. Likewise, the findings indicated that some teachers believed data literacy could be expressed in a variety of ways. These discoveries connect to the literature in that there is not a single agreed upon understanding of data literacy making it open for interpretation, which will be different based on individual perceptions.

RQ 1 Subtheme: Teachers Believe Data Literacy Learning Involves Observation and Detection of Effective Instruction

Also connected to teacher perception affect translation of data literacy, the subtheme teachers believe data literacy learning involves observation and detection of effective instruction was identified after developing the categories assessment, observation, base foundation, effectiveness, meeting learners, online resources, and technology for RQ 1. Figure 11 demonstrates the connection of categories used to reveal the subtheme teachers believe data literacy learning involves observation and detection of effective instruction.

Figure 11

Connection of categories used to reveal teachers believe data literacy learning involves observation and detection of effective instruction as a subtheme for RQ 1.



Assessments. Assessments were indicated when teachers described data literacy as using data sources to determine students' data learning. Teacher 5 described test taking skills as a form of data literacy. Teachers suggested it was essential to understand the base foundation students have of data literacy. Consequently, teachers emphasized using assessments to detect students who need additional help in data literacy and determine their instructional effectiveness in teaching data literacy in science.

Connected to assessments, Teacher 6 suggested that much of data literacy in sciences was being observant and indicated she assessed students and determined her effectiveness using approaches centered on observational skills. She also emphasized the importance of being observant to meet the learner where they are in her explanation of what she knew about data literacy. Moreover, Teacher 6 described her definition of data literacy as being "…the data that you gather from the students to determine whether or not you're effective, whether or not you're getting through them, the materials getting through to them; it can be whatever you want it to be, whether it's test scores or information the students are sharing or just being observant and noticing what they're focusing on to see if whatever you are doing is working." Likewise, she explained that she believed data could be "…Whatever you want it to be…" in her response to item 15. Similarly, Teacher 3 responded to item 15 and stated, "I use that data to help understand whether they understood the material…" Thus, this data revealed the category assessments.

Technology. Technology was indicated when teachers described videos as a way to show students' data literacy from real-life cases. For example, Teacher 7 suggested teachers' conceptions of data literacy could be improved by giving students online resources, while Teacher 6's knowledge and definition of data literacy centered on using technology, such as videos, for students to obtain data for interpretation.

Observation. Observation was indicated when teachers described data literacy as being a form of observation for sources of data. This category was developed using the codes observe, evidence, and notice. Teacher 4 described her definition of data literacy as "…being able to read, or observe, see any piece of evidence…." Although most of the teachers discussed observations related to their conceptions of data literacy, Teacher 6 emphasized this the most. For instance, Teacher 6 stated in her response to item 15 that data literacy is "…just being observant and noticing what they're focusing on to see if whatever you are doing is working." Additionally, Teacher 6 emphasized in her response to item 18 listening and observing to what "…the students are saying or observing…" was necessary in science data literacy.

Meeting learners. Meeting learners was indicated when teachers described the importance of teachers feeding off of students in data literacy in science. Connected to observations, the category meeting learners was identified using the codes feeding off and information to guide instruction. For example, Teacher 6 described her conception of data literacy as "…listening to your students and kind of feeding off of what they are giving you." Likewise, Teacher 3 explained how she obtained information of her students' current knowledge and skills to guide instruction. She responded to item 1, "I use that data to help understand whether they understood the material that was supposed to be given to them or not."

Base foundation. Base foundation was indicated when teachers described their conception of data literacy as being foundational for scientific learning. Extending on the idea of meeting learners where they are at in their data literacy, the category 'base foundation' was discovered using the codes foundation and start. For example, when asked by Teacher 8 to share her definition of data literacy, she said, "…I feel like it's the foundation for a lot of things."

Effectiveness. Effectiveness was indicated when teachers described how data literacy could be used to determine one' own effectiveness in teaching. This category was identified to be connected to the categories assessment and meeting learners. This category arose as teachers discussed data literacy as using sources of data and determining their effectiveness. For example, Teacher 6 said data literacy could be "…the data that you gather from the students to determine whether or not you're effective…." Likewise, Teacher 3 responded to item 1 and described how she used "…data to help understand whether they understood the material…."

Online resources. Online resources were indicated when teachers described a need for online modules for teachers to access data literacy resources. Connected to meeting learners, the categories 'online resources and technology' were identified using codes such as modules and videos. The category online resources arose as Teacher 7 replied to item 18 and suggested an online resource that houses clear data literacy expectations and materials for teachers to use. Additionally, Teacher 6 explained that they were "…watching some videos right now…" as she described what she knew about data literacy.

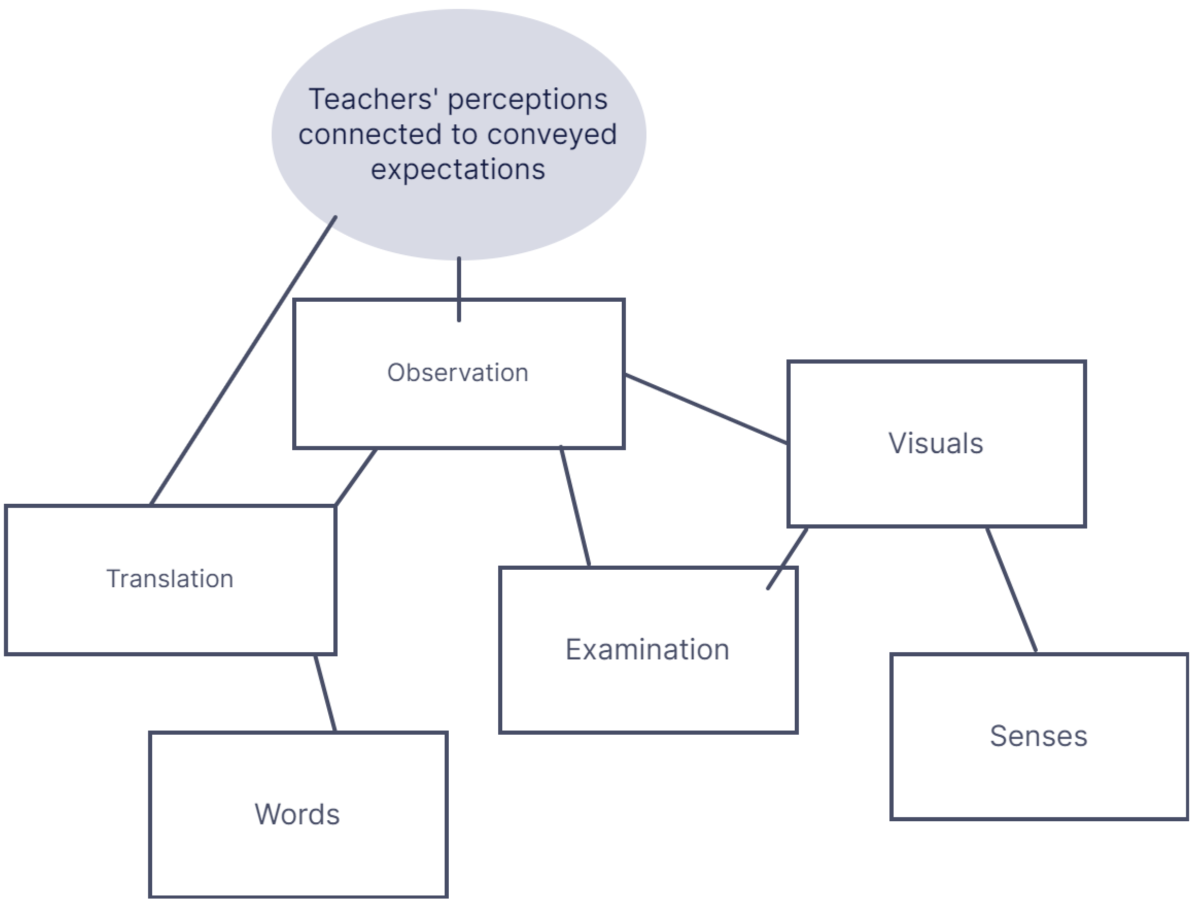
The findings associated with the categories discovered and the subtheme teachers believe data literacy learning involves observation and detection of effective instruction explains how teachers' conceptions of data literacy centered on observing students' data literacy and using different resources to detect effective instructional approaches. Teachers 4 and 6 viewed observations as a component of data literacy. Moreover, Teacher 3's conceptions of data literacy emphasized detection through effective instructional approaches including the use of different assessments, which was also emphasized by Teacher 6 through the data collection form of observations. The category base foundation was discovered in Teacher 8's response to data literacy, which was identified by Teachers 3 and 6 as they described their conceptions of data literacy involving using data from assessments to meet the learner's needs. Consequently, online resources were identified to be connected to meeting learners, and this category was discovered when Teacher 7 discussed resources she felt teachers needed as she added to additional information of her conception of data literacy in item 18. Lastly, technology was developed as a category as video was coded to identify it. Both online resources and technology had few codes associated with their categories. However, they were included because they stood out to the researcher during the analysis process.

The overall findings illustrate how past experiences affect students' learning, which will require teachers to meet the students where they are academically. These discoveries help answer RQ 1 by explaining how teachers' conceptions of data literacy in science is central to students' past learning experiences, which are detected through assessments that can also be used to monitor effectiveness as teachers try to meet their students' data literacy needs. Nonetheless, Teacher 7 revealed that teachers' data literacy needs needed to be met by providing additional online resources, which further reiterates the need for additional data literacy support for teachers.

RQ 2 Subtheme: Teachers Perceptions Connected to Conveyed Expectations. The following categories aided in revealing the subtheme teacher perception affect their translation of data literacy connected to conveyed expectations: Observation, translation, examination, visuals, senses, and words. Observation was found to be directly connected to this subtheme as teachers perceived observations affected the way they conveyed their expectations. Similarly, translation was directly connected to perceptions connected to conveyed expectations, observations, and words. This is because teachers translated their expectations based on their observations of students' learning and individual perceptions. Likewise, several teachers, such as Teachers 3, 4, and 5 revealed the category words, which was indicated by codes such as passage, Lexile, context clues, and articles. Nonetheless, the way teachers translated their expectations were different in some aspects leading to the connection to individual perception. Comparably, examination, which was directly connected to observations, individuals, and translation, was discovered when teachers discussed student analysis, picking apart information, and asking deeper questions for in-depth understanding. In addition to visuals being connected to examination, it was also found to be connected to observations and senses as teachers emphasized visuals in their expectations based on their observations, which incorporated senses. Figure 12 demonstrates the connections of each category used to reveal the subtheme teacher perception affect their translation of data literacy connected to conveyed expectations for RQ 2.

Figure 12

Connection of each category used to reveal the subtheme teacher perception affect their translation of data literacy connected to conveyed expectations for RQ 2.



Observation. Observation was indicated when several teachers emphasized an expectation of observational skills they expect their students to possess. Teacher 6 expressed how her expectations of data literacy knowledge and skills centered on observations more so than the other teachers. For example, when responding to item 2 and describing data literacy knowledge and skills Teacher 6 expected her students to possess she stated, " . . . we talk about observation as being 90% of Forensics anyways." She further elaborated on her expectations of observations and said, "I would want them to have a better understanding of how that applies to the criminal justice system." Likewise, when asked to provide an example of students engaged with data and how she knew they were engaged (Item 16), she explained how students pay attention to sources of evidence. Teacher 6 provided an example of how she had her students observe the Steven Avery case and collect evidence as they explored this case as a class. As she elaborated on how she knew the students were engaged with data, she stated, "My whole goal is to teach them to be observant, and so I think that's probably the time they were most engaged, and I just felt it because they were explaining material to me in a way that I had not thought of it and sharing with the class in a way that I know the class have not thought of it, and then we used it from there um, to kind of expand on a longer discussion about it." Similarly, when responding to item 17 to explain a time students encountered challenges with working with data in science, she stated, "…I think that's 90% of our problem is we're all driven by what's happening next and making sure that we're getting there on time and not focusing on what's going on in front of us." Similarly, Teacher 4 responded to item 17 and described how students struggled with identifying data sources presented to them in scenarios. When asked what was needed for students to overcome this challenge, she replied, "Better observation skills."

Examination. Examination was indicated when teachers emphasized their expectations of students being able to analyze and pick apart data as they ask questions. For example, Teacher 3 described how she implemented an effective lesson that engaged students, which centered on being able to analyze data sources. This activity required students to analyze data in graphs to extend their knowledge through application. Specifically, Teacher 3 responded to item 16 and described how she incorporated a "…chart or graph…" and explained how the students "…analyze it a little bit further and say, 'Okay if we only went to 10, what would happen if we went to 15?" Therefore, asking questions was a way she described student engagement with data. This was similar to Teacher 8's response to item 16 as she replied, "…asking questions lets me know that they're engaged…."

However, this was somewhat contradictory to Teacher 4's response to item 16 as she indicated that students "…didn't have as many questions doing that as they do with science concepts." Nonetheless, Teacher 4 described an activity that engaged students with data that involved cell phone data usage and not science concepts. Therefore, this likely contributed to the different views toward asking questions as a way to detect student engagement with data in their classes.

Visuals. Visuals were indicated as teachers described their expectations of representing data. As teachers emphasized examination, they described use of many visuals, such as graphs, tables, and diagrams. For example, Teacher 8 stated, "So afterwards, I would hope that they're able to read and interpret graphs, like with population trends." Likewise, Teacher 1 revealed visuals to display data when he explained a lab he implemented that engaged students in data literacy. He explained, "…you can graph that as distance versus time because that's what speed is" in reference to the data students obtain from conducting the lab. Similarly, Teacher 2 explained how she used tables to engage students in discussions by asking, "What does the table tell you?" Comparably, Teacher 7 emphasized data displayed in the periodic table. She described her expectations of data literacy to include "…being able to take data off of the periodic table."

Teachers also explained how they posed questions to have their students further analyze data related to science concepts. For example, in Teacher 8's response to item 16, she described how she will "…point to a structure and say 'What is…what's going on here?" as a way to determine students' engagement and see if they can answer such questions.

Senses. Senses were indicated as teachers described how they used different senses, such as sight and hearing, to monitor students' data literacy knowledge and skills. For example, Teacher 3 explained how she used eyesight to monitor students' learning as they engage with data. She responded to item 16 and stated, "…I can actually see them doing the process in order to get their own data…." Additionally, Teacher 4 explained how she saw students highly engage with data sources as they completed an activity, which required them to graph their own cell phone usage data. She explained that she knew students were engaged with data as she observed them.

In addition to teachers using their senses to monitor students' data literacy in reaching their expectations of engagement, data suggest that students also use their senses to engage in data sources. Teacher 6 emphasized observations as a form of data literacy knowledge and skills she expected her students to possess. She explained how taking the time to listen and see was essential in data collection and evaluation for Forensics. She further elaborated on this topic when she responded to item 16 as she described how her students were engaged in working with data sources related to real-life cases that were being explored in the class. Similarly, Teacher 7 described how students used hearing to collaborate with other students in her Chemistry class. For example, Teacher 7 described how one student "…heard another student that was like, 'Yeah we got it, we got it!" and then sought clarification from this student.

Translation. Translation was indicated as teachers emphasized interpreting data sources. Extending on this topic, Teacher 8 described how she monitored students' engagement by allowing students to see what she sees. She further explained that "First, you got to put it in front of them," and described how simply verbally explaining it was ineffective. Teacher 8 described how she expected students to be proficient in analyzing, interpreting, and communicating data sources, such as graphs that demonstrate science concepts connected to data at the completion of her course. She further explained that the ability to make predictions was a higher learning achievement.

Words. Words were indicated when teachers described how they expected their students to use passes and construct their own explanation. For example, Teacher 4 responded to item 17 and described her expectations of students being able to "…read a scenario…" and how she expected students to "…construct their own explanation." However, she noticed that students were not able to complete this task and struggled with identifying the problem presented to them in a scenario. Consequently, she suggested that "Better observation skills" would likely help them be able to communicate and identify data sources. Likewise, Teacher 7 described the importance of students being able to read the data in the periodic table as a foundation for reaching data literacy proficiency in Chemistry. She stated, "That's the important thing, so that's the first piece of data that I have high expectations for."

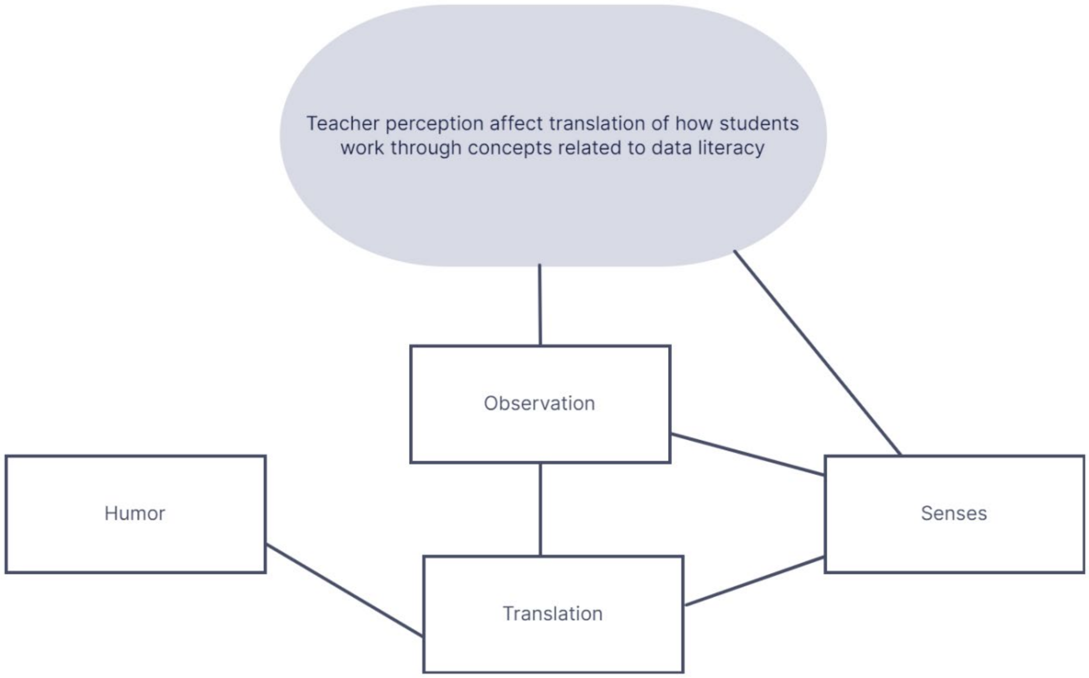
The subtheme revealed from these categories suggests that teachers' expectations of students' data literacy knowledge and skills varied, which was likely affected by the way they interpreted sensory information, which is influenced by interests, beliefs, expectations, and experiences. These findings are similar to the literature, which suggested conceptions of data literacy varied, and therefore, likely affect expectations of data literacy due to differences in perceptions influencing conveyed expectations of students' data literacy knowledge and skills.

RQ 3 Subtheme: Teacher Perception Affect Translation of How Students Work through Concepts Related to Data Literacy. Like RQ1 and RQ 2, perception was found to influence the way data literacy was communicated for RQ 3. Thus, this subtheme connects to teachers believe students' prior learning experiences determine their data literacy as perception helps explain how these differences and emphasis in past experiences affecting how students work through concepts related to data literacy varied based on individual teacher perception, which was revealed by the categories observation, senses, humor, and translation.

Observation was found to be connected directly to the subtheme perception and the categories senses and translation. This is because the way in which observations are made are influenced by one’s perception, which is directed by their senses as this is the foundation of perception. Thus, sense was also found to be directly connected to the subtheme perception. Additionally, translation was found to be directly connected to observation, humor, and senses. This is because the way in which teachers translated how students worked through concepts was dependent on their observations and senses used as a way to evaluate how students work through concepts related to data literacy. Likewise, humor was found to be connected to translation as some teachers expressed comical attitudes as they explained how students worked through concepts related to data literacy. Figure 13 represents the connection of these categories used to reveal the subtheme teacher perception affect their translation of data literacy of how students work through concepts related to data literacy.

Figure 13

Connection of categories used to reveal the subtheme teacher perception affect their translation of data literacy of how students work through concepts related to data literacy for RQ 3.



Observation. Observations indicated how teachers observed students working through concepts related to data literacy and how observations were an important part of data literacy in science. For example, Teacher 4 explained her observations of how students work through concepts related to data literacy by stating, “I observed so far that…they're having a hard time so far.” Moreover, Teacher 6 said, “I told them that's what I wanted them all to be, is observant and you know, functioning adults whether they go into criminal justice or not.” Thus, she explained how she focused on improving students' observational skills to advance how they work through concepts related to data literacy.

Senses. Senses were indicated when teachers describe how students use their senses to work through concepts related to data literacy. Teachers also indicated how they used their senses to determine students’ data literacy. For example, Teacher 7 described how she used her sight to "…see if they really have it…" in reference to students understanding data in the periodic table in her Chemistry class. Similarly Teacher 8 explained how she felt how students work through data literacy as she replied to item 11, "I feel like they can grapple with it, think about it, and apply it in different contexts…." Teacher 3 stated, "I feel like the new standards…have incorporated data literacy pretty well…." Likewise, Teacher 2 described her sense of feeling by stating, "I felt like they were engaged in that and they had a discussion about that" as she described a time students were engaged when working through concepts related to data literacy.

Translation. Student translation was indicated when teachers described how students interpret and explain data literacy concepts as they work through data literacy. For example, Teacher 4 described how she had her students engaged in data where they are "…able to analyze that data by explaining it…." Similarly, Teacher 3 described how her students worked through concepts related to data literacy by "…analyzing it and writing about it…."

Moreover, teacher translation was indicated when teachers described communicating data literacy to students. For example, Teacher 7 explained, "…in order to discuss it, you had to read" as she described the importance of reading in science. This was similar to Teacher 3 emphasis on implementation of reading and discussions as she explained how students use article readings and work collaboratively as they work through concepts related to data literacy. She also described how she could "…actually see them doing the process in order to get their own data…." Additionally, Teacher 6 described how she had to translate the importance of the investigative process when obtaining data to form a case. She stated, "…I have to explain how important it is to keep an open mind and investigate the case…." Comparably, Teacher 2 replied, "Kind of what you see when you think and then kind of feeding off of each other…" as she described how students worked through concepts related to data literacy in her Biology class. Furthermore, Teacher 8 stated, “First, they could see exactly what I could see” as she described how she saw her students working through interpreting and communicating data displayed in graphs.

Humor. Humor was indicated as teachers expressed comical attitudes as they communicated how students worked through concepts related to data literacy in science. For example, Teacher 1 explained how they “…get a little silly with it…” as he explained how students performed labs to understand concepts related to data literacy in his Physics class. Moreover, he also laughed as he responded to several of the items in the interview, such as in his reply to items 12 and 14.

These categories aided in discovering the subtheme teacher perception affect their translation of data literacy of how students work through data literacy because each teachers' observation varied based on their senses and the way they perceived information, which affected their interpretation of how students' work through concepts related to data literacy. Thus, the way teachers translate their senses of how students worked through concepts related to data literacy was based on their understanding, which is formed from sense making leading to perception. Nonetheless, perception was identified to be a subtheme of teachers believe students' prior learning experiences determine their data literacy as teachers still emphasized students' past experiences as they described how they perceived students working through concepts related to data literacy in their classes. These findings suggest that teachers view how students worked through concepts related to data literacy based on the way they sensed and perceived this in their class. Consequently, this helps explain the varying views teachers shared of how students worked through concepts related to data literacy and offers an avenue for future research to hone in on teachers' senses and how these senses are communicated based on their perceptions. Nonetheless, this also implies that if teachers' had limited conceptions of data literacy in science, then their perceptions will likely be influenced, which will affect interpretation of data literacy.

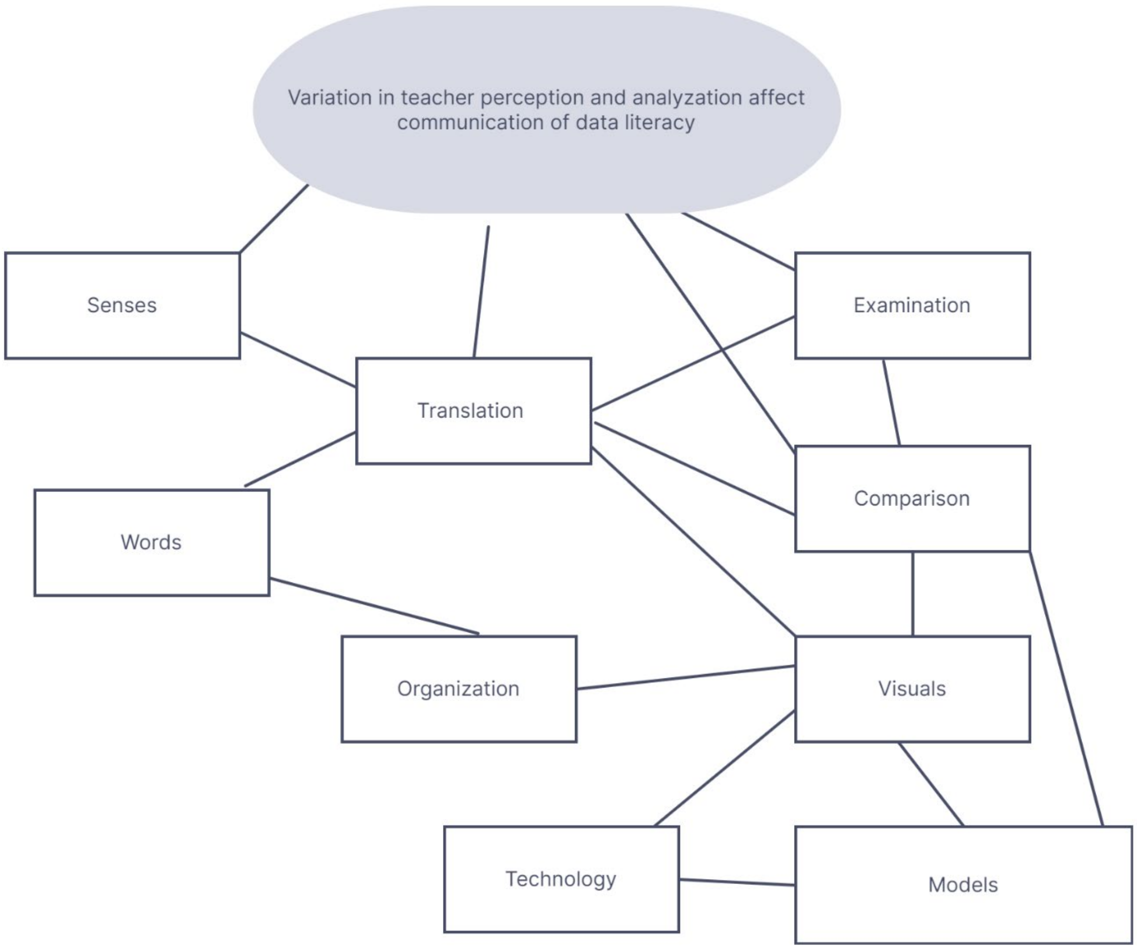
Subtheme: Perception and Analyzation Affecting Communication of Data Literacy

The following categories were used to reveal the subtheme perceptions and analysis affecting communication of data literacy: Translation, examination, senses, words, comparison, visuals, models, technology, and organization.

Translation was found to be directly connected to senses, words, examination, comparison, and visuals. This is because the way data was translated was based on one's examination of it, comparison of it, use of visuals, and individual senses. Likewise, several teachers, such as Teachers 3 and 7, emphasized words as a heavy portion of data literacy and thus important in the translation process. Similarly, words were identified to be directly connected to organization as teachers emphasized vocabulary as a way to stay organized and foster data literacy. Comparably, organization was also found to be connected to visuals as teachers described how they used visuals, such as tables, graphs, and graphic organizers, to allow their students to arrange data and concepts related to data literacy as a way to foster learning in science. Moreover, visuals were also found to be connected to models and technology as teachers described how they used a variety of visuals and models, such as illustrations and demonstrations to foster data literacy. Additionally, technology was used among participants to model the visuals, which also allowed a comparison. Thus, comparison was found to be connected to visuals, models, and translation. Some teachers, such as Teacher 2's and 5's documents heavily relied on using visuals as a way to make comparisons to translate data literacy information. Lastly, senses, translation, examination, and comparison were found to be directly related to the subtheme. Figure 14 demonstrates the connection of these categories used to reveal the subtheme perceptions and analysis affecting communication of data literacy.

Figure 14

Connection of categories used to reveal variation in teacher perceptions and analyzation affect communication of data literacy subtheme for RQ 4.



Translation. Translation was indicated when teachers described strategies used to foster students' communication of data in science. For example, Teacher 5 explained how she wanted her students to "…hopefully learn how to read…" graphs after repeated exposure. Nonetheless, Teacher 7 explained how communication of data sources was challenging for her students. Specifically, she stated, "They do not read with accuracy…."

Moreover, translation was identified during classroom observations as teachers explained data literacy concepts. For instance, Teacher 1 explained to students to think about what they can do with 10 small paper clips. Thus, translation was connected to understanding as teachers emphasized and implemented translation as a way to target students' understanding. Likewise, teachers incorporated student translation as a way to foster data literacy. For example, Teacher 4 had her students write a conclusion on a graph they created. For example one conclusion stated, "In conclusion, I believe that if I don't use my phone, my EOC score will go up because I will be able to focus on my school work and be able to learn more without having my phone distracting me." Furthermore, Teacher 5 explained how dispersion patterns give scientists more data about how species behave. All teachers revealed this category as they explained data literacy and how to interpret data related to the concepts being learned in the class. Likewise, there was a connection between translation and visuals as teachers used visuals to explain data literacy, such as the graphic organizer Teacher 4 used and the periodic table Teacher 7 had her students analyze to understand electron configuration. Additionally, visuals were used to assist students in interpreting data. For example, Teacher 2 used visuals to explain population dynamics and then implemented a station activity where students used tables and graphs to interpret data sources.

Similar to interviews and observations, translation was predominant in document analyses. For example, Teacher 1 had his students create graphs to describe their data. Afterwards, students completed analysis questions, which included, "1. Explain what is happening to the water molecules in the flat area of your graph." and "2. Explain what is happening to the water molecules in the sloped area of your graph." Thus, there was a clear connection between the categories visuals and translation as students' visuals, such as graphs and tables, were used to aid in the interpretation and analyses of data. These findings were similar to

Teacher 3's activity in the conclusion section. For example, item 5 stated, "Explain how you could use this method to calculate the height of fireworks." Likewise, Teacher 4's activity required students to discuss, describe, and explain concepts related to an osmosis lab. For example, item 3 in the conclusion section stated, "Explain the role cellular transport has in maintaining homeostasis." Additionally, after students unscrambled words in Teacher 7's activity, they had to "Write down one point discussed in class about the word." Comparably, her assessments required students to translate information of elements in the periodic table.

Examination/ways to use data. Examination/ways to use data was indicated when teachers explained how they had their students analyze data sources to foster data literacy. For example, Teacher 3 stated, "I'll find different current articles or even lab reports from medical journals, scientific journals, physics journals, etc. that can be used in the classroom for my students to analyze…." Similarly, Teacher 7 emphasized examination and explained how her student often did not do such as she explained how students "…group all of the gasses into that rather than actually looking at them."

Like interviews, examination was revealed in classroom observations. For example, Teacher 2 had her students complete a review activity, which required them to analyze data sources. She stated, "You will see images in this form and you will have to analyze it to determine where molecules are moving and whether or not energy is needed." Students analyzed images of different cell parts and answered questions.

Additionally, examination was prevalent among document analyses. For example, most of the questions included in Teacher 2's activity required examination by analyzing visuals, such as graphs and tables. For instance, item 2 on page 2 of the activity asked, "In what year did the greatest number of people take part in this event, and in what year did the fewest take the plunge?" This was similar to Teachers 1 and 3's activities. However, their activities required students to obtain their own data sources. Teacher 5 and 8 supplied the same document, which required students to analyze graphs connected to a population dynamic lesson. However, compared to the other teachers, Teachers 5 and 8's documents required less analysis. Nonetheless, Teacher 4's activity included an analysis section, which consisted of three questions related to examining and interpreting data from an osmosis lab. Likewise, Teachers 5 and 8 provided guided notes, which also required students to analyze graphs and answer questions associated with the graphs.

Senses. Senses were indicated when teachers described their senses as they explained strategies they used to foster data literacy. For example, Teacher 2 said "I feel…" as she explained her views of viewing collaborative strategies in the classroom. Moreover, teachers described how they used their sight as a way to monitor students and identify students that need additional assistance to foster data literacy learning.

Words. Words were indicated when teachers described how they implemented vocabulary and readings to foster data literacy. For example, Teacher 3 stated, "I'll find different current articles or even lab reports from medical journals, scientific journals, physics journals, etc.…they can use their Chromebooks to research some of the vocabulary." Similarly, Teacher 1 stated, "I'm thinking of word problems like Physics." Likewise, Teacher 7 said that she has her students "…take all of their vocabulary words that we talked about, and I will scramble them, scramble them up on a piece of paper, and it's their job to unscramble it." Moreover, Teacher 7 explained how she went "…a little old school on certain things…" and described how she made students "…use their textbook."

Overall, Teachers 3, 4, 5, and 7 emphasized vocabulary in their observations. For example, Teacher 4 explained to students that knowing the vocabulary words would enhance performance while Teacher 5 took out a vocabulary sheet that they had previously received related to biomagnification.

Although Teachers 1 and 3 were both physical science teachers, they had different views of what data literacy was and ways to foster data literacy in science. For example, Teacher 3 believed data literacy heavily relied on reading. She emphasized reading scientific articles and having her students write lab reports as a strategy to foster data literacy; whereas, Teacher 3 did not view writing as a component of data literacy in science as he stated, "…we do those literacy writing assignments, but that's not data literacy. That's trying to get the students to learn how to write."

Nonetheless, like interviews, vocabulary was also revealed in observations and document analyses. For example, although not explicitly stated, it was evident that students had to know the vocabulary associated with heating curves and phases of matter to complete the lab activity and assessment. For example, students needed to know vocabulary words, such as condensation, vaporization, and molecular motion to answer questions associated with a graph on the assessment. Similarly, students had to know terms such as apex, acceleration, and velocity to complete the activity document supplied by Teacher 3. Moreover, Teachers 5 and 8 had their students complete guided notes using the same document. The guided notes required students to fill in missing words. Similarly, Teacher 7's assessment required students to fill in the blank, Likewise, her activity required students to unscramble words as she described in her interview. For example, students had to unscramble "Mtoa" and place the correct word on their sheet.

Comparison. Comparison was indicated when teachers described how they had their students compare data sources. For example, Teacher 2 explained how she had her students analyze Biology EOC data to determine "…how we compare to the state." Similarly, Teacher 5 described how she would implement labs and how "…some people still get different data," which "…gives them an opportunity to compare…to read what they have and then compare it to somebody else."

Correspondingly, comparison was discovered in classroom observations. For example, Teacher 4's data literacy lesson was focused on a comparison of the number of molecules/ percentage of solutes to determine the type of cell transport and an analysis of images that demonstrate different cellular transports. Likewise, Teacher 5 explained the similarities and differences among clump, uniform, and random dispersion patterns in her population dynamic lesson. She also explained population density and the differences between high population density and low density using two images of snails. Moreover, Teacher 6 had her students watch a video, which focused Comparative drawings of individuals as evidence using facial feature differences.

Similar to interviews and observations, document analyses revealed comparison. For example, Teacher 3 provided an assessment, which required students to determine "…the relationship between the initial velocity and the apex of the rocket?" Likewise, questions on Teacher 1's assessment required students to compare data points represented in graphs. Moreover, a question in Teacher 3's metric lab worksheet asked, "Which set of units was easier to use when making measurements, especially for values that were not whole inches or centimeters?" Comparably, Teacher 2's data literacy activity required students to compare data sources represented in tables and graphs, which mirrored her data literacy assessment. Furthermore, Teacher 4's assessment required students to compare molecules that were in and outside of the cell to determine the movement of molecules across the membrane. For example, one item asked, “Consider the size of the sugar and water molecules in Model 1. Which molecules in the diagram in Model 1 are able to move through the selectively permeable membrane?” Moreover, teacher 5 had her students use visuals to compare population densities and graphs in her data literacy activity.

Visuals. Visuals were indicated when teachers described how they had their students use visuals to interpret data related to concepts. For example, Teacher 1 stated, “Water is heated up, and students measure the temperature until it boils then they graphed that….” Similarly, Teacher 4 explained how her school focused on visuals by explaining that they believed “…all content levels across the board should be able to use a graphic organizer that's pretty much the same all the way around.” She explained that use of such graphic organizers were termed ‘window notes’ at her school. This was something I also noticed while conducting my observation in her classroom at her school. Specifically, the principal stated over the intercom that he would like to come around and see teachers who were implementing window notes. Additionally, Teacher 5 stated the source of data she used was usually “…just a picture….”

Moreover, visuals were revealed in classroom observations. For example, Teacher 1 displayed images and had students classify examples depicted in each picture. Likewise, Teacher 2 presented graphs and had her students analyze each for interpretation. For example, she pointed to the S-shaped curve graph, which was a logistic curve graph, and she asked the class, “What is happening here?” One student in the front replied, “It's steady and then it spikes and then it goes flat.” Furthermore, Teacher 4 had her students use a cell transport graphic organizer while they completed two open-book assessments. Like Teacher 4, Teacher 5 had her students analyze images as data sources. For example, at the beginning of her class, she had an image displayed and asked the students, “What is being represented in this picture?” The image included two examples of wolves, deer, and producers with one image that represented the removal of a keystone species, which were the wolves. She also used a graph as a visual and had her students answer questions related to it. It was evident that visuals were used for translation. For example, Teacher 8 pointed to a graph illustrating pepsin enzymatic activity at different pH levels.

Like interviews and observations, a variety of visuals were revealed in document analyses. For example, Teacher 1 provided a data literacy activity, which required students to obtain and display their data in a table. Afterwards, they used this information to create a graph of data from three different time points and temperatures. Similarly, Teacher 3's activity included three tables for students to record the data they obtain from a lab. They obtained and interpreted the data obtained. Thus, visuals were used as an organizer for translation. Comparably, Teacher 2's activity and assessment was composed of 27 visuals for students to analyze and interpret. Although fewer, Teacher 4 included one visual for each document. The visual in the activity was a data table for students to record their data from a lab; whereas, the visual for the assessment she provided was a model cell with different molecules in and out of the cell. Comparably, Teachers 5 and 8 provided the same guiding notes to their students, which included graphs as visuals related to a population dynamic lab. Moreover, Teacher 5 had her students complete drawings during notetaking. For example, the guided notes required drawings of clump, uniform, and random population distribution patterns. Similarly, Teacher 7 provided an ion graphic organizer as a data literacy activity she implemented in her Chemistry class. She also included a visual of isotopes in her data literacy assessment.

There was a clear connection among visuals and translation among the interviews, observations, and document analyses. For example, Teacher 1 provided an assessment for the document analyses, which required students to analyze a graph and interpret information in the graph by answering ten questions associated with it. Although these questions checked for students' understanding, they were simple questions that required students to determine from six different labeled points. Thus, these questions required students to pick from six options but did not address the 'why' and 'how' of students' understanding. For example, three other questions on the assessment required students to know what happens during a phase change, and interpret a graph representing the boiling point of a substance. Nonetheless, the 13 item assessment did include one 'why' question. For example, item 12 required students to determine "which best explains why the temperature is NOT increasing between lines AB and CD?" The other two questions required students to analyze three graphs and answer questions associated with heating curves and phases of matter. All questions were multiple choice and thus did not provide detailed information on students' thought process as the analysis questions included in Teacher 1's activity.

Model. Model was indicated when teachers described how they used illustrations as a strategy to foster data literacy. Teacher 1 explained how he incorporated showing students graphs using a PowerPoint presentation. He stated, "I try to teach them to do that with PowerPoints and then showing them the graphs." Moreover, he stated. "Doing some type of demonstrations…" was a way he used strategies to foster data literacy. Furthermore, he stated, "Showing them how to, you know, give them one point then having them calculate another point on the graph." Likewise, Teacher 3 explained how she had her students read relevant articles from Journal databases as a way to model how lab reports should be "skeletonized." Similarly, Teacher 6 stated, "I show them a case…" as she described how she fostered data literacy in Forensics.

Teachers that emphasized modeling in their interviews also revealed this topic during the classroom observation. For example, Teacher 1 described how he used modeling as an initial strategy to foster data literacy in his interview, and this was evident in his classroom instruction as he modeled how to apply the density formula before having students begin the density lab. Moreover, Teacher 3 identified students struggling with multi-step conversion problems so she explained, "I will show you how to work through them and I will show you how I would read the problem so that you can understand when we get to other problems." Similarly, she modeled to her class how to write numbers in scientific notation. Comparably, Teacher 4 demonstrated how a cell was composed of bilayer phospholipids. Like Teacher 4 who incorporated images as ways to model topics and solve problems, Teacher 5 modeled biomagnification by showing students an image illustrating how biomagnification occurs in a food chain.

Such as the findings for interviews and observations, the category model was revealed among teachers' documents. Most of the models included graphs and tables. Thus, there was a clear connection between these two categories. Nonetheless, some Teachers, such as Teacher 3, had her students model a rocket lab and obtain data for interpretation after placing data in tables for visualization. Likewise, Teacher 5 had her students use visuals as a way to model population densities in her data literacy activity.

Technology. Technology was indicated when teachers described a type of technology they used as a way to foster data literacy. For example, Teacher 1 described how he taught students how to complete labs using PowerPoints. He specifically stated, "I try to teach them to do that with PowerPoints…." Teachers 2 and 8 explained how they used resources from progress learning as a way to foster data literacy. Moreover, Teacher 8 indicated that she sometimes goes "…online to see what resources…are available for teachers…."

Expanding the application of technology as a strategy to foster students' data literacy, Teacher 1 used a variety of technology in his classroom observation. For example, at the beginning of class, he used the promethean board to project a question. Afterwards, he had students join quizzes as a way to review classification of substances that were depicted in images. Students joined the quizzes using their Chromebooks or cell phones. Similarly, Teacher 4 had her students join a quiz review using a QR code, which was projected on the promethean board, and students used their Chromebooks to participate.

All teachers incorporated some form of technology in their class, but most technology incorporated were basic, such as a promethean board, Chromebooks, an electronic pen to use on the promethean board, Google slides/PowerPoint presentations, and cellphones. Teachers' incorporation of technology varied in the observations. For example, Teacher 7 used limited technology; whereas, Teachers 4 and 6 used some form of technology throughout their entire observations.

Like interviews and observations, technology was revealed in document analyses. For example, Teacher 6's data literacy activity aligned to the Avery case, which she discussed in interviews and addressed in her observation. This document consisted of ten questions aligned to an episode of the Avery case.

Organization. Organization was indicated as teachers describe how they had their students unscramble words as a data literacy strategy. For example, Teacher 7 stated, "Once they unscramble it, and then they have to write a sentence with the word that's applicable to what we discussed, so I figured that's two things: One, it helps them spell the word correctly. Two, it makes them search the meaning of the word, making sure they know what they are talking about." Additionally, Teacher 7 stressed the importance of students staying organized as she explained how she "…insists that all of them stay organized" as a means to foster and scaffold data literacy.

Organization was also depicted in classroom observations. For example, Teacher 3 passed around a yellow piece of cardstock explaining how students would use this sheet to write down formulas. She encouraged her students to keep the paper in their binder and stated they will need it for quizzes and tests. Organization was found to be connected to visuals as teachers supplied documents where students used visuals, such as data tables, to organize their data sources and answer questions related to the data presented. For example, Teacher 3 provided an activity where students obtain and display their data in a table and then answer questions related to the data displayed. This was similar to the data literacy lab activity Teacher 1 provided. Similarly, Teacher 3's assessment had students rank their launch velocity and then use this information to interpret their data sources. Thus, this demonstrated a connection of organization, visualization, and translation. Moreover, Teacher 3's question presented in her lab assessment appeared to be organized from simplest questions that gradually progressed to more challenging questions. Thus, this also illustrates a connection among organization, gradual progression, and challenge.

Extending on the topic of organization, Teachers 5 and 8 provided guided notes as a way to help students organize their Biology notes. Similarly, Teacher 7 provided a graphic organizer as a visual and a way for students to organize their knowledge of characteristics of elements in the periodic table.

The overarching theme variation in teacher perceptions and analyzation affect communication of data literacy was identified to be closely connected to past experiences. This is because students' and teachers' perceptions will be affected based on past experiences. Thus, communication of data literacy is influenced based on individual perceptions and shaped by past experiences, individual knowledge, and individual beliefs. This subtheme asserts that people analyze and communicate data differently as a result of individual perceived variations. Moreover, these findings relate to RQ 3, which found that teachers view how students worked through concepts related to data literacy based on the way they sensed and perceived this in their class. Thus, perceived difference in how students work through data literacy affects how and what strategies teachers use to foster data literacy.

These findings suggest that since perception affects analysis and communication of data literacy, teachers' past experiences will influence perceptions. Thus, teachers' perception will be influenced if they have limited data literacy experiences. Consequently, these findings suggest that like the theme of past experiences affecting students' data literacy, teachers' past experiences influenced the way they perceive and translate data sources. Consequently, this suggests that, like students, exposing teachers to data literacy early in their teacher preparation will likely help advance students' data literacy.

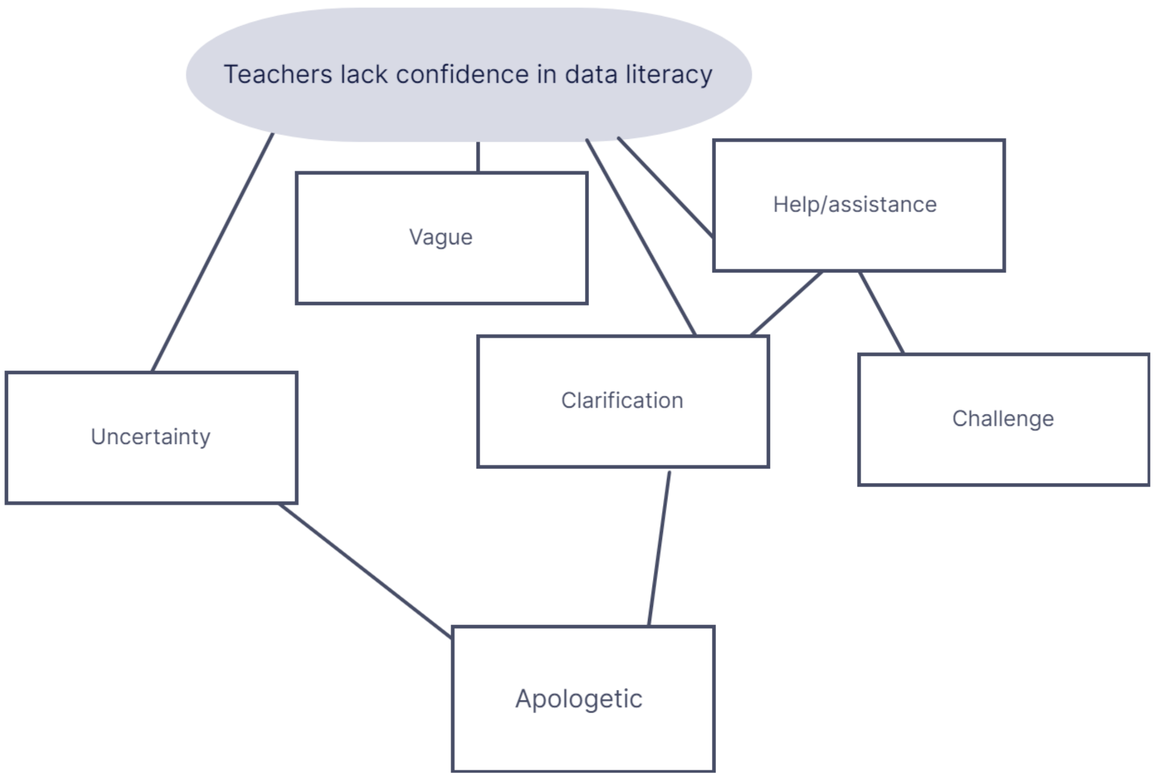
Teachers Lack Confidence with Data Literacy

Words such as um, uh, and ah were coded individually in the present study and used to reveal lack of confidence across all RQs. These words were an indication of teachers lack confidence rather than used as filler words in the interview findings. For example, when Teacher 1 was asked what he knew about data literacy, he replied, "Um, data literacy?" and asked for an explanation of what it was after indicating that he did not know and was tempted to Google it. Thus, the researcher determined that um was an indication of lack of confidence. Similarly, when Teacher 8 was asked approximately how much time she allocated for data literacy, she replied, "…I would say probably every um…eee, at least every lecture or a few times a week." She then further explained how she incorporated it often but was not sure exactly what was meant by data literacy. Thus, um was coded as an indication of lack of confidence. Comparably, Teacher 4 used uh in her response as she described her definition of data literacy and then indicated that she was not quite sure what data literacy was and that she would like to know more. Thus, uh was used as a coded to reveal lack of confidence. The researcher's choice to code these types of words and use them to reveal lack of confidence is similar to Smith and Clark (1993) research, which found people to use words such as uh and um more often when they displayed a weaker feeling of knowledge in a given area being addressed.

RQ 1. Categories were combined based on connectedness, which led to the development of the theme of teachers lack confidence with data literacy. This theme was revealed with categories uncertainty, vagueness, clarification, apologetic, assistance/help, and challenge. These categories had several similarities, which resulted in the development of lack of confidence as a theme. For example, teachers did not have a direct answer when asked about the meaning of data literacy. Many were vague in their explanation of data literacy, and all expressed some level of uncertainty when responding to the prompt. Likewise, teachers needed clarification on several questions that were asked, and some, such as Teachers 1 and 2, needed an explanation of what data literacy was before responding to the first item in the interview. Consequently, this led to the development of assistance/help as a category and apologetic as Teacher 2 stated she was sorry several times when asking for clarification, and Teacher 1 expressed he felt like he was not helping much. Figure 15 demonstrates the relationships of the categories used to reveal teachers lack confidence with data literacy for RQ 1.

Figure 15

Connection of categories used to reveal teachers lack of confidence with data literacy for RQ 1.



Uncertainty. Uncertainty was indicated when teachers were undecided about data literacy questions. Teachers' use of words such as uh, um, and guess as well as uncomfortable body language were coded as uncertainty, which was prominent among teachers suggesting a lack of confidence. However, lack of confidence did not appear to be directly connected to years of experience. For example, Teacher 6 who had 6 years of experience teaching high school science indicated that she was uncertain of what data literacy was and that she would like to know more about it in her response to item 18 in the interview. Similarly, Teacher 2 who had 1 year of experience stated that she did not "….n S E know anything about it" until I further explained what I meant by data literacy to her after asking item 1 in the interview. Nonetheless, Teacher 3 who had 16 years of experience in high school science and Teacher 6 who was in her first year of teaching high school science displayed overall more confidence compared to the other teachers. Their body language, responses, and limited need for clarification led to inferences in exhibiting greater confidence in their conceptions of data literacy.

In contrast, Teacher 7, who was in her second year of teaching, indicated that she did not know "…a great deal…" about data literacy and further stated "I don't know a lot about it…" in her response to item 1 in the interview. Likewise, Teacher 1, who was in his third year of teaching high school science, appeared to display uncomfortable body language as he made limited eye contact and had his arms crossed after I asked item 1 in the interview.

Vagueness. Vagueness was indicated when teachers were indistinct in their responses. For example, words such as not really, basically, pretty much, and quite were coded as vague. For instance, Teacher 3 explained how she "basically" used "…data to help understand whether they understood the material that was supposed to be given to them or not." Similarly, when Teacher 6 was asked if there was any additional information she would like to share to provide a clear depiction of her conception of data literacy she was vague by replying, "Um, not really." Likewise, Teacher 1 described how interpreting charts and graphs was "…pretty much data literacy."

Clarification. Clarification was indicated when teachers needed questions repeated, further explained, or simplified. For example, when asked about item 1 in the interview, Teacher 1 replied, "Can you repeat that one more time?" Likewise, Teacher 2 said, "Okay. What was the question one more time?" when responding to item 1 in the interview to which she apologized for asking for clarification.

Apologetic. Apologetic was indicated when a teacher was remorseful for seeking clarification or indicating uncertainty. For example, Teacher 2 said, "Oh, I'm sorry" when she asked for clarification on item 1 of the interview. Moreover, she said “I'm sorry I said data table or chart? Umm…interesting, I guess” as she responded to her definition of data literacy. This indicated that she was apologetic for her uncertainty and need for clarification.

Assistance/help. Assistance/help was indicated when teachers suggested they needed help answering a question in the interview. For example, when Teacher 1 was asked for his definition of data literacy he replied, “I’m tempted to Google it,” which further implied that he lacked confidence.

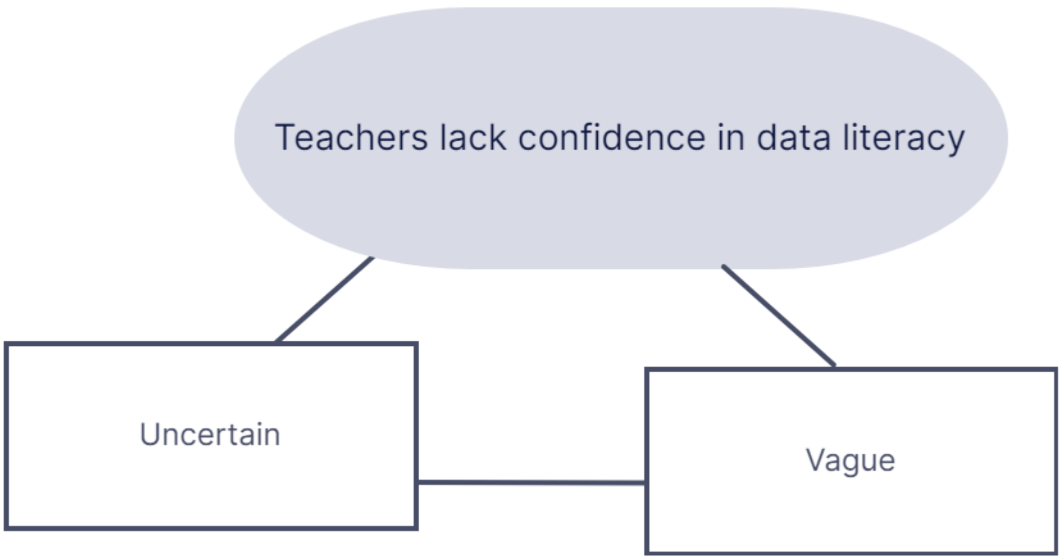
Challenge level. Challenge level was indicated when teachers discussed rigor with data literacy. For example, Teacher 1 explained how Forensics was “…supposed to be a rigorous class” but how such learning was dependent on mathematical knowledge. He also stated, “I can’t remember all the math,” suggesting that mathematical understanding of data literacy was challenging for teachers, which may also contribute to teachers lack confidence towards data literacy.

These findings assert that teachers’ overall conceptions of data literacy were limited, which led to a lack of confidence in discussing their knowledge and views of data literacy in science. These findings imply that teachers lack confidence in data literacy likely impacts instructional approaches and students’ learning of data literacy in science.

RQ 2. The categories uncertainty and vagueness revealed teachers lack confidence as they described their expectations of data literacy for RQ 2. Uncertainty and vagueness were found to be connected with each other as teachers indicated uncertainty or responded with indistinct explanations describing their expectations of data literacy knowledge and skills they expect their students to possess. Figure 16 illustrates the connection among the categories used to reveal the theme teachers lack confidence in data literacy for RQ 2.

Figure 16

Connection of categories used to reveal teachers lack confidence in data literacy for RQ 2.



Uncertainty. The category uncertainty arose as teachers indicated that they did not know, guessed, and used words such as uh and um. Uncertainty in teachers' expectations of data literacy was identified more among less experienced teachers compared to teachers with longer experiences, such as Teachers 3 and 4. Nonetheless, some teachers still indicated that they did not know and appeared to lack confidence during the interview as was the case for Teacher 2. For example, she replied to item 2 and said, "I guess, that's it. I mean, they leave my room looking at it differently and asking any other questions, and kind of analyzing questions, better I guess." However, Teacher 2 was able to provide some type of response for each item asked in the interview; whereas, Teacher 8 indicated she had not explored a time students explored data literacy and also reminded me of her limited experience. Similarly, Teacher 5 stated, "I don't know," in his response to being asked item 16 in the interview, which suggested she had limited experience of observing students engaged in data related to science in her classes.

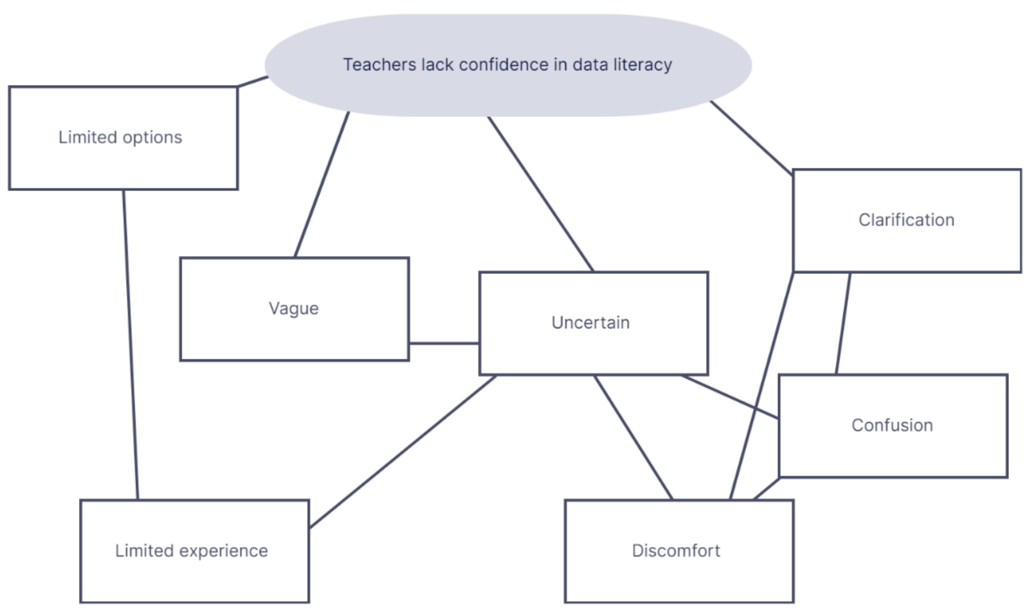
Vagueness. Vagueness arose as teachers were unspecific in their explanations. For example, Teacher 6 explained how she had her students share information "…to kind of expand on a longer discussion about it" as she described a time students were highly engaged in data literacy in her Forensics class. Likewise, Teacher 8 was vague in her explanation as she explained, "…I quickly kind of learned not to have high expectations…" Similarly, Teacher 5 was indistinct in her explanation of her expectation of data literacy as she stated, "The expectation of when they get here is kind of to be able to read in general and go ahead and pick apart context clues…." Therefore, these findings assert that teachers, especially teachers with little experience, lacked confidence in their expectations of data literacy. These implications suggest that teachers' lack of confidence in their expectation of data literacy likely affects students' data literacy, especially when such learning expectations are indistinct.

RQ 3. Like the findings of RQ 1 and 2, lack of confidence was also found to be a theme to help answer RQ 3. The following categories were used to reveal the lack of confidence theme for RQ 3: Limited options, vague, uncertain, limited experience, clarification, confusion, and uncomfortable. These categories shared common relationships in many ways. For example, vague and uncertain was found to be directly connected as teachers expressed uncertainty in describing how students worked through concepts related to data literacy in their classes. Consequently, much of the responses were vague. Thus, both of these categories also connected directly to the theme of lack of confidence. Additionally, confusion and discomfort were also found to be connected directly to uncertainty as some teachers expressed confusion when responding to items, which also resulted in uncomfortable behavior documented during the interview. Thus, confusion and discomfort were also directly connected. Clarification was revealed when teachers needed questions repeated or rephrased before they could respond.

Clarification was connected directly to confusion and discomfort because some teachers expressed uncomfortable behavior and appeared to be confused when they asked for clarification. Thus, clarification was also found to be directly connected to the theme of lack of confidence. Furthermore, connected directly to uncertainty was limited experience, which was connected to limited options. Limited experiences were connected directly to uncertainty as some teachers expressed uncertainty and reminded me that they had limited experiences in their responses. Lastly, limited options were revealed as teachers described constraints due to resources, which also contributed to limited experiences leading to lack of confidence.
Figure 17 represents the connection of categories used to reveal the theme lack of confidence for RQ 3.

Figure 17

Connection of categories used to reveal teachers lack confidence in data literacy theme for RQ 3.



Uncertainty. Uncertainty was indicated when teachers were uncertain about how students work through data literacy. Codes used to reveal this category included, not sure, uh, I guess, don’t know/don’t think, um, I don’t actually remember, maybe, I don’t really know, left with questions, and body language such as looking to the side of the classroom and appearing nervous. Teacher 2 expressed uncertainty multiple times in the interview. For example, when asked questions in the interview, Teacher 2 made little eye contact, spoke to herself as if she had to about many of the questions because she was uncertain, and looked to the side of the room when responding. Likewise, when teacher 5 was asked about previous experiences with how her students performed or worked through concepts related to data literacy, she replied, “I don’t remember actually.” Similarly, when teacher 1 was asked item 10, he stated, “I don't really know how to answer that,” indicating he was uncertain of the support, training, and resources teachers needed to be effective in teaching data literacy. He also indicated that incentives may help students be more engaged, but then stated, “I don't know,” following his suggestion. Moreover, ‘um’ was categorized as a single code in the analysis. All teachers expressed this code in the dataset, but certain teachers, such as Teacher 8, expressed this more frequently. Lastly, Teacher 4 expressed uncertainty on how to teach students data literacy to advance the way they work through concepts related to data literacy by stating, “…we’re still left with questions about how in-depth to teach certain things.’

Limited experience. Limited experience was indicated when teachers had little to no exposure to questions being addressed. For example, connecting limited experience with uncertainty, Teacher 5 replied, “I don’t know if we have done that yet,” when asked to provide a time when students were engaged working with data in her science class. Teachers 5, 6, 7, and 8 reminded me of their limited experiences throughout the interview when responding to items.

Discomfort. Discomfort was indicated when teachers state they were uncomfortable or when body language was identified to exhibit some form of discomfort. Teacher 1 stated, “I am making myself uncomfortable….” Moreover, Teachers 3 and 5 expressed some level of discomfort in their body language by crossing their arms. Similarly, Teachers 2 and 5 made little eye contact.

Clarification. Clarification was indicated when teachers needed questions repeated, rephrased, or further explained. For example, Teachers 2, 4, 5, and 7 requested questions to be repeated, while Teacher 4 also requested clarification. For instance, when asked about item 4, Teacher 4 replied, “Say it one more time.” Similarly, when teacher 2 was asked item 3, she replied, “How do they work through concepts related to….” Likewise, Teacher 4 needed clarity on item 3 as she asked, “Are you talking about standard based concepts?”

Limited options. Limited options were indicated when participants described only one way to get students to understand data literacy. For example, Teacher 1 stated, “The only way I have figured out how to get them to understand it is to just show them a curve, explain what is going on…” as he described how students worked through concepts related to data literacy in his class. Likewise, Teacher 7 explained how students were adverse to homework and how that limited her options in the way she taught data literacy and how students worked through concepts related to data literacy in science. For example, she explained that “…the only time…” students “…see certain data points…is in class….” Thus, this limited data literacy experience.

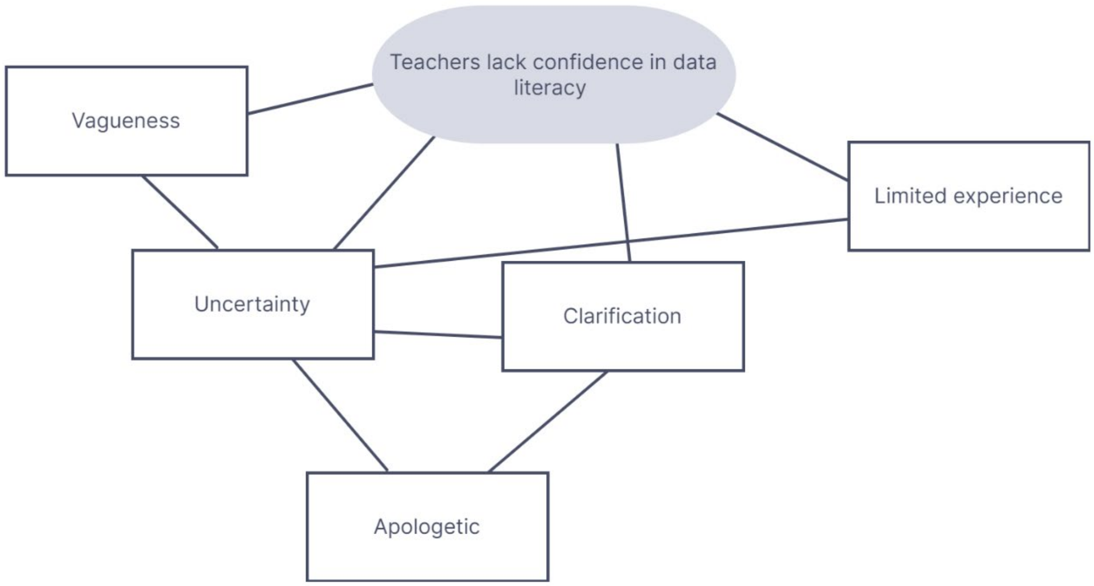
Vague. Vagueness was indicated when participants were unclear in their responses. The codes used to reveal this category were kinda/kind of, fairly, and teachers mumbling when responding to interview questions. For example, Teacher 1 described a lab to be “…fairly long…” as he explained a time students were engaged when working with data literacy in his class. Moreover, Teacher 1 indicated vagueness when he replied to item 16 by stating “That kinda stood out in my mind for when you said engaged because they got engaged." Likewise, he also mumbled when he initially responded to item 3.

These findings indicate that teachers lacked confidence in responding to items that addressed their conception of how students work through concepts related to data literacy suggesting that this lack of confidence may be due to limited knowledge, understanding and experiences with how students work through concepts related to data literacy in their science classes. Thus, this implies that teachers would likely benefit from training and resources that target increasing teachers' experiences, options, clarity, confidence, and certainty in data literacy in science to aid in their understanding of how students work through concepts related to data literacy in their science classes.

RQ 4. Like the other RQs, lack of confidence was revealed among teachers' conceptions as they explained strategies they used to foster data literacy. The categories used to reveal teachers lack confidence in their conceptions and strategies used to foster data literacy included uncertainty, clarification, apologetic, vagueness, and limited experience. Clarification and apologetic was found to be connected to uncertainty and clarification as teachers were apologetic for needed clarification or when they did not understand a question being asked. Figure 18 demonstrates the connection of these categories.

Figure 18

Connection of categories used to reveal teachers lack confidence in data literacy for RQ 4.



Uncertainty. Uncertainty was indicated when teachers were unsure in their responses. For example, Teacher 4 demonstrated uncertainty by using “um” multiple times in her response to item 4. Specifically, she stated, “Um, images mostly, so taking um, picture…taking sometimes passages um, usually just those two things….” Similarly, Teacher 6 indicated uncertainty when replying to item 4 as she used six ‘ums’ in her response. Likewise, Teacher 8 said ‘um’ five times when responding to item 4. Similarly, Teacher 2 indicated uncertainty by replying to item 5, “Gosh, I can't think of like, a technique, um….”

Clarification. Clarification was indicated when teachers needed questions illuminated or repeated. For example, Teacher 8 replied, “Can you clarify what you mean by data literacy strategies?” when asked about strategies she used to foster data literacy. Similarly, Teacher 1 needed clarification when asked item 8 as he replied, “Scaffolding, like how do you build upon things?” Likewise, Teachers 1, 2, 3, 4, 7, and 8 needed clarification on item 7, which addressed incorporating the local context in data literacy in science. For example, Teacher 7 replied, “Can you explain it for me?" when asked item 7. All participants needed clarification on the terminology, local context excluding Teachers 5 and 6.

Apologetic. Apologetic was indicated when teachers were uncertain or needed additional clarification. For example, when asked about item 5, Teacher 2 stated, "Can you read it one more time? Sorry."

Vagueness. Vagueness was indicated when teachers were unclear in their explanations. For example, Teacher 3 was vague as she explained how she used labs as she stated in her explanation, "…so that way they kind of know how to function…or not how to function, but how to skeletonize their reports." Similarly, Teacher 7 was vague in the number of worksheets she used as she indicated they used "…quite a few worksheets."

Limited experience. Limited experience was indicated when teachers describe how they did not understand questions asked in the interview. For instance, Teacher 4 stated, "Um, but scaffold…I don't really…I don't think I really do that." Likewise, Teacher 1 also had a limited response to describing how he scaffolded and indicated that he struggled in this area. Teacher 8 was not able to reply to item 7. After clarification was sought, she stated, "Hmm, so, honestly, I haven't used any of those."

Overall, lack of confidence was identified more among life science teachers than physical science teachers. This was evident in interviews and classroom observations. Nonetheless, each teacher indicated some level of lack of confidence in their interviews.

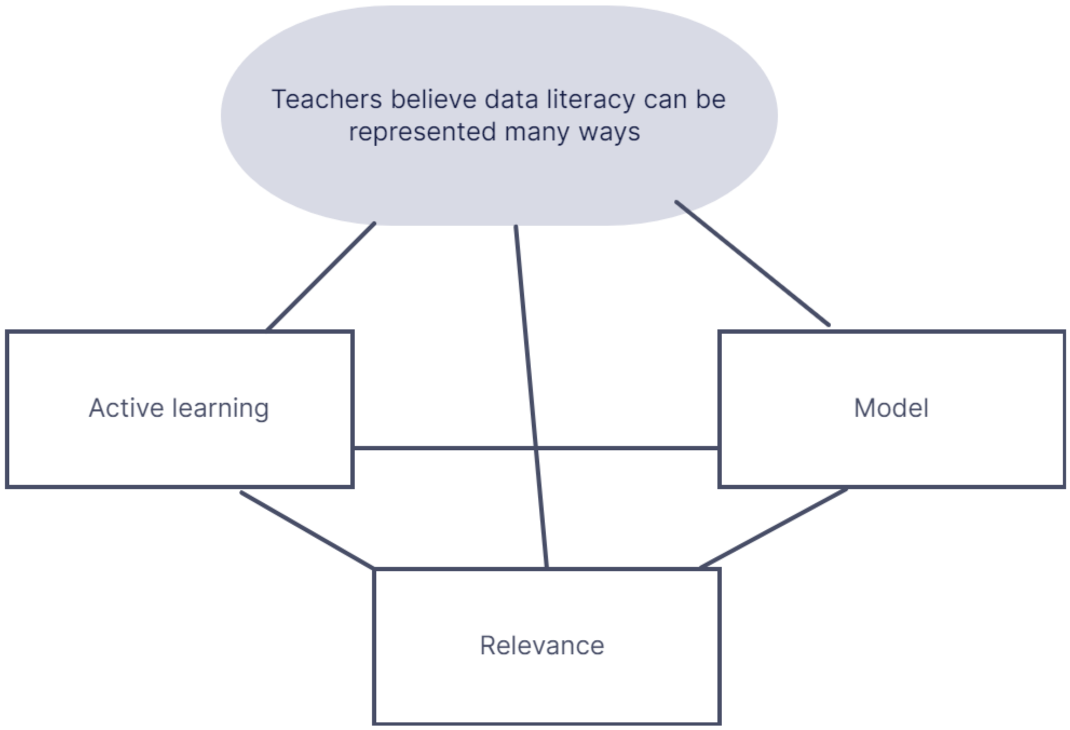
These findings assert that teachers' lack confidence in strategies used to foster data literacy, which suggest that effective instructional approaches and students' data literacy learning may be negatively impacted. Consequently, training centered on data literacy instructional approaches in science will likely be beneficial in targeting confidence to improve teachers' use of strategies to foster data literacy. Moreover, the findings suggest that collaboration among physical and life science teachers may help improve life science confidence since they appeared to lack confidence more. One reason for this may be similar to what Teacher 5 alluded to in her interview as she explained how she believed life science does not use data literacy as much as some of the harder physical science classes. Consequently, discussions on conceptions of data literacy and strategies used to foster data literacy among all science teachers may target improving confidence to advance instructional approaches and students' data literacy learning in science.

Teachers believe Data Literacy can be Represented Many Ways

RQ 1. The theme teachers believe data can be represented many ways was discovered from the categories active learning, model, and relevance for RQ 1. In their responses, teachers described their knowledge of data literacy by using demonstrations, such as modeling, in their classes. They also explained how active learning, such as students conducting labs and obtaining data, was what they knew about data literacy in science. Nonetheless, prior to conducting the lab, teachers emphasized using illustrations, such as modeling, to ensure student understanding. Likewise, teachers expressed the importance of connecting data sources to something that relates to students. Consequently, these categories led to the development of teachers' ideas of representing data literacy as a theme. Figure 19 displays the connection among the categories used to discover the theme teachers believe data literacy can be represented many ways for RQ 1.

Figure 19

Categories connected to reveal teachers believe data literacy can be represented many ways for RQ 1.



Model. Model was developed as a category as teachers described their conceptions of data literacy by using demonstrations and illustrations. For instance, when Teacher 1 was asked to share what he knew about data literacy, he described how he included data in his class through use of demonstrations. For example, he stated, "We demonstrate half-life by graphing half-life and using a twizzle that they cut in half (small chuckle) you know, they take a twizzler and fold it over and over until they can't fold it anymore to illustrate half-life or Carbon 14…." Thus, there was a clear connection between models and active learning.

Active learning. Active learning was identified as teachers described students' learning by doing as they responded to questions that addressed their conceptions of data literacy in science. For example, Teacher 1 described having students do simple labs as he explained his knowledge of data literacy in science. Likewise, Teacher 7 described her definition of data literacy as "…being able to look at data that is relevant to whatever course you're taking and being able to communicate in such a way that demonstrates that you have an understanding of the data that has been set before you."

Relevance. Relevance was indicated when teachers emphasized connecting data to other courses and in a way that students can relate. Likewise, several teachers stressed active learning and modeling as they described their conception and definition of data literacy. Therefore, these findings imply that teachers' conceptions of data literacy in science centered on making connections. Teachers described connections with data literacy in science by discussing modeling, use of active learning activities, and materials that included real-life situations. These findings assert that teachers' conceptions of data literacy in science is centered on making connections to students to help improve their data literacy learning.

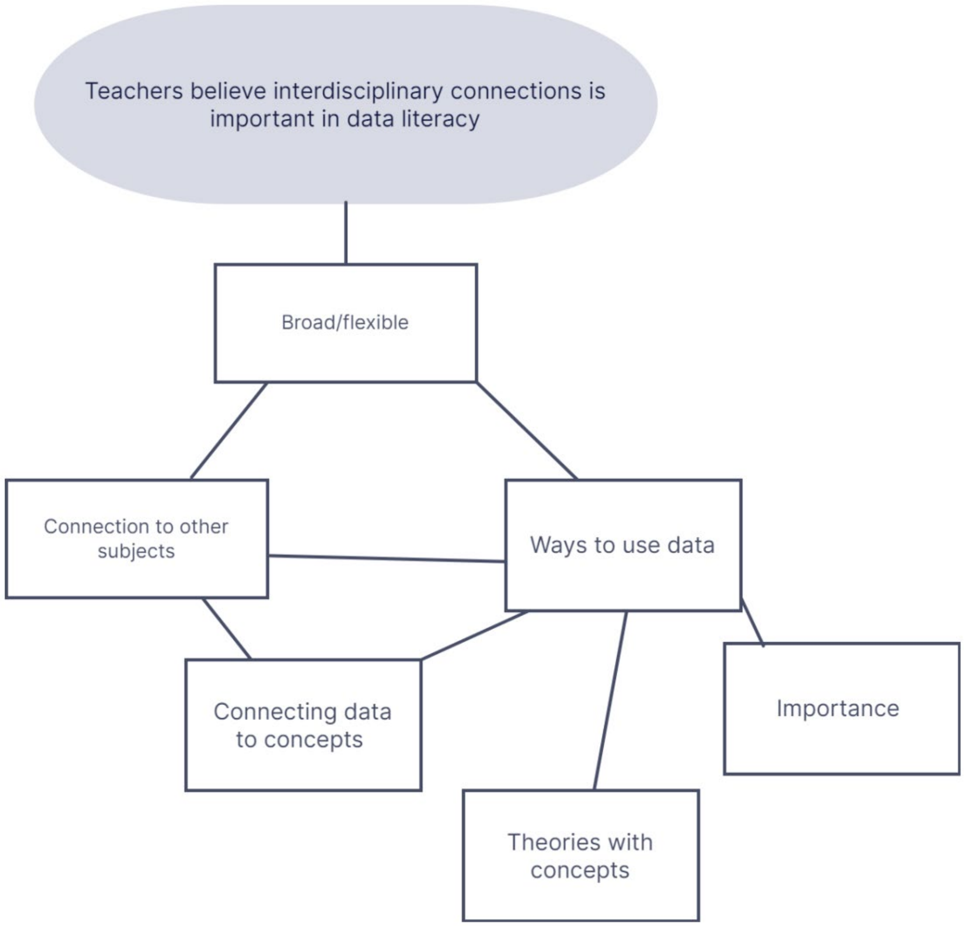
Furthermore, teachers viewed data literacy as being flexible and applicable to different situations and subjects. For example, Teacher 7 stated that her definition of data literacy was using data "…relevant to whatever course you're taking." Likewise, Teacher 6 said data literacy could be "…whatever you want it to be," and Teacher 5 said her knowledge of data literacy was "…literacy in general just…knowing their vocab words and knowing how to read and pick apart passages for context clues…." This was similar to Teacher 3's response that stated, "I utilize articles or any type of reading" as she described her knowledge of data literacy.

Overall, years of experience did not seem to influence teachers' views of connecting concepts with data literacy. This theme was identified mostly among Teachers 1, 3, 5, 6, 7, and 8 who all but Teacher 3 had limited years of experience. Nonetheless, these findings were prevalent among six of the eight teachers, which revealed their conceptions of data literacy centered on involving a combination of disciplines by using data in different ways, which was deemed important in the formation of ideas related to data literacy. Moreover, teachers' conceptions of data literacy suggested data should be connected to different concepts, and Teacher 1 stressed the importance of using data to connect theories with concepts so that students develop a deeper understanding. These implications assert that teachers view data literacy as being applicable to other subjects and concepts, which led to the subtheme 'interdisciplinary.'

RQ 1 Subtheme: Teachers Believe Interdisciplinary Connections is Important in Data Literacy. Teachers believe interdisciplinary connections is important in data literacy was derived from the following categories: Connecting to other subjects, ways to use data, connecting data to concepts, importance, and broad/flexible. Connecting to others was revealed when teachers described using data literacy to improve other subjects, such as mathematics and readings. Consequently, this category was found to be connected to ways to use data as teachers had varying views of data literacy in science and how it could be implemented. Some, for instance, suggested data literacy should be connected by understanding what is behind the data generated and the theories that associate with the concepts being learned. Although not all stressed the importance of understanding theories behind concepts, many teachers explained the importance of data literacy, which was connected to ways to use data. All of these categories were found to be connected to the category broad/flexible as teachers had a wide range of conceptions of data literacy. Figure 20 demonstrates the connection of each category used to reveal the subtheme teachers believe interdisciplinary connections is important in data literacy for RQ 1.

Figure 20

Connection of categories used to reveal the subtheme teachers believe interdisciplinary connections is important in data literacy for RQ 1.



Connection to other subjects. Connection to other subjects was indicated when teachers mentioned other subjects as they replied to data literacy questions. For example, Teacher 1 indicated that graphing was part of his knowledge of students' data literacy and said, "They need to be able to learn and interpret charts with x and y axes just like they learned in algebra or geometry or whatever…but that depends on how well they performed in regular math." Likewise, his response to item 15 was similar as he stated, "I mean, it's like compared to English, okay? They read a book, but do they understand what it's about, right? Can they answer questions about the plot?" Similarly, Teacher 3 emphasized having students read and use articles by stating, "…I utilize articles or any type of reading."

Connecting data to concepts. Connecting data to concepts was indicated when teachers described using data sources to connect to specific scientific concepts. For example, Teacher 1 explained how he had his students "…demonstrate half-life by graphing half-life…" Moreover, Teacher 1 also explained how he connected data to solubility concepts in physical science by "…graphing solubility curves…" which also led to a focus on understanding theories behind concepts.

Theories with concepts. Theories with concepts was indicated when teachers explained how data literacy in science connects data with science concepts. For example, Teacher 1 stressed the importance of conceptual understanding by "understanding what's behind the data that is generated." Likewise, Teacher 7 also stressed the importance of understanding theories in her Chemistry class for students to do well in data literacy connected to science concepts.

Ways to use data. Ways to use data was indicated when teachers described varying ways to implement data usage in their science classes. For example, Teacher 3 explained that students need to be able to utilize "…information to understand or create…" their own findings. Likewise, Teacher 2 explained that students need to be able to "…infer from a data table, diagram, or literacy chart" in her explanation of data literacy.

Importance. Importance was indicated when teachers described the necessity of data literacy in science. For example, Teacher 6 stated, "I think the most important thing is…to be patient and listen to what um, the students are saying or observing" as she responded to item 18. Likewise, Teacher 2 said, "…I know about it, especially in science. It's vital that they know how to read data like the charts, tables, and interpret it and to use it."

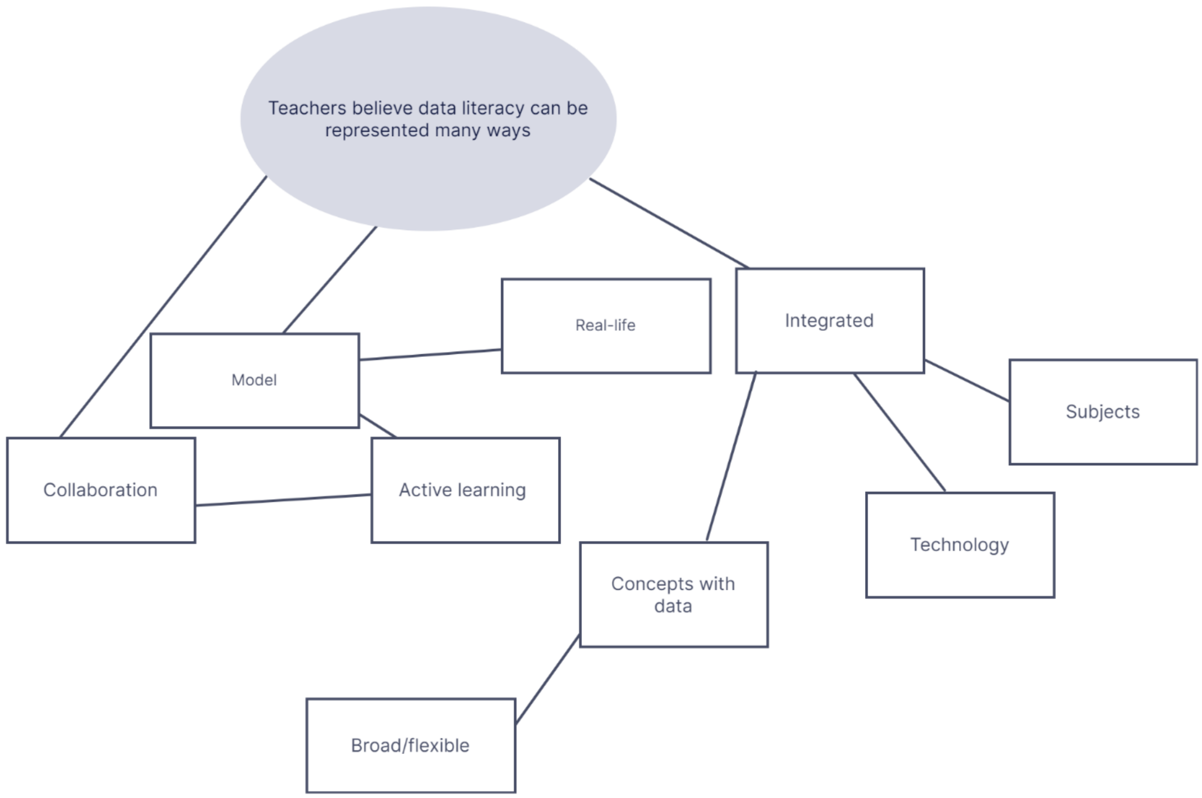
Broad/flexible. Broad/flexible was indicated when teachers described how data literacy can be applied to a variety of subjects and concepts. For example, Teacher 6 said data literacy "…can be whatever you want it to be…." Similarly, Teacher 5's conception of data literacy was broad as she explained "I feel like even test taking skills could count as data…."

These findings imply that teachers' views of data literacy are interconnected with other subjects, indicating teachers' view of data literacy in a flexible way to connect data sources with concepts in different areas. Although not as prominent among the teachers as teachers lack confidence in data literacy and teachers believe students' prior learning experiences determine their data literacy skills, several of the teachers described interdisciplinary connections as they explained their knowledge and definition of data literacy.

RQ 2. Similar to RQ 1, teachers believe data literacy can be represented many ways was discovered as a theme for RQ 2. The categories models, active learning, collaboration, concepts with data, broad/flexible, real-life, integrated subjects, and technology revealed the theme teachers believe data literacy can be represented many ways and helped understand teachers' expectations of knowledge and skills they expect their students to possess. Figure 21 demonstrates the connection among the categories used to reveal teachers believe data literacy can be represented many ways RQ 2.

Figure 21

Connection among the categories used to reveal teachers believe data literacy can be represented many ways RQ 2.



Model. Model was revealed as a category when teachers explained how they expected their students to illustrate, show, or use models in their data literacy learning. For example, Teacher 4 described how she expected her students to be able to create illustrations of data sources on their own. She stated, "I would expect them to be able to create a graph, whether it is a pie chart or a line graph, or a bar graph…." Therefore, her expectations centered on models. She also explained how she showed students "…how to find data sources." This was similar to Teacher 1's explanation of how students typically cannot reach expectations until he demonstrated as a whole class.

Active learning. Active learning was indicated when teachers described learning by doing in their expectations of data literacy. Many of the teachers described how they used active learning to address a time where students struggled with working with data, which was a question asked in item 17 of the interview. For example, Teacher 7 described how students struggled with knowing how to read and interpret data sources in the periodic table. Consequently, she had her students “delve” into the content and actively search for information to develop a deeper understanding and help address misconceptions. Moreover, Teacher 1 described how he had his students complete activities, such as labs, to obtain their own data. For example, he implemented a motion lab in his physics course and explained how students asked different questions and then completed a lab to answer their questions related to speed and distance traveled. He explained how this data literacy activity engaged the students and how most participated including those that typically did not. He further explained how he wanted students to “…get up out of their seats…” and “…get involved….”

Collaboration. Collaboration was indicated when teachers described how they used group work to have students meet their expectations of data literacy in science. For example, Teachers 1, 2, 3 and 7 described how they implemented collaboration as they had their students engage in active learning to learn data literacy in science. Teacher 1 stated, “…it helped get them involved because it needed to be done in a group,” and further stated, “It was teamwork.” Additionally, Teacher 7 stated, “And it's amazing how sometimes when they're working in groups, they can teach each other.” This was similar to Teacher 2’s explanation of a time students were engaged in data literacy in her class as she stated, “…they just got in groups and had a discussion about what they wrote down….” Similarly, Teacher 3 explained how her students engaged in data literacy to meet her expectations by “…discussing it with their teammates to make sure they are using the right formula.” For example, Teacher 7 described how students were struggling with understanding and interpreting data sources in the periodic table and how she allowed students to work in groups to address the challenges they had with this. Moreover, she explained how peer-teaching yielded amazing student learning results at times. Likewise, Teacher 2 emphasized discussions in her class.

Concepts with data. Concepts with data were found to be connected to active learning as teachers described ways they actively had their students engage in data to connect such data to concepts being learned in the classroom. For example, Teacher 1 described how he embedded the concept of motion while students engaged in a data literacy activity. He stated, "I got some engaged with uh, uh the concept of motion in physics…." Likewise, Teacher 8 emphasized students' data literacy in reading and interpreting graphs related to enzymatic activity concepts and population dynamic concepts in Biology. For example, when students enter her class, she explained how she "…would hope that they're able to read and interpret graphs, like with population trends." She elaborated and stated, "I would expect after this class to be able to say the population has stabilized, the population has increased. The population has decreased based on the information presented…." Some teachers indicated that students experience less challenges when analyzing and interpreting data sources compared to data sources related to science concepts. For example, Teacher 4 responded to item 16 and explained how students "…didn't have as many questions doing that as they do with science concepts" in reference to a cell phone data usage activity.

Real-life. Real-life application was another category that arose in the interview as teachers described their expectations of data literacy knowledge and skills and activities they found to be effective in engaging students in data literacy. For example, Teacher 4 described how she had her students use their own phones to analyze the time they spent on it and then they were required to graph this data and write a conclusion on their findings. She explained how she used this activity to help students understand how to read, interpret, and create graphs to something that is relevant to them before she progressed to science concepts. Similarly, Teacher 6 described having her students explore a real-life case, which was “Stephen Avery who was wrongfully convicted…” to engage students in data literacy in Forensics.

Challenge level. Challenge level was indicated when teachers described the rigor of their instruction. For example, Teacher 7 explained her expectations of data literacy by stating she expected students “…to be able to, with ease and comfort, tell me how Chemistry relates to their world….” Furthermore, Teacher 1 described how he had his students obtain their own data so that they can connect to it, which also relates to active learning.

Integration. Integration was indicated when teachers described their expectations by integrating other subjects and skills. For example, Teacher 3 expanded views of representation of data literacy by describing integration of reading and understanding the authors’ meaning. Specifically, she stated, “I expect them to be able to utilize that Lexile to analyze what the article reading is and interpret what the author’s trying to say to get the point across as far as how that article connected into the science we are learning.”

Subjects. Subjects were connected to integration and were revealed when teachers described other subjects as they explained their expectations of students’ data literacy in science. For example, Teacher 5 explained how students' data literacy and ability to “…pick apart passages…” were dependent on what they learned in ELA.

Technology. Technology was indicated when teachers described how they used technology to have students meet their expectations of data literacy. For example, Teacher 4 embedded technology by having students “…come up with a conclusion as to whether or not they thought their cell phone usage or screen time was affecting their grades.” Comparably, Teacher 2 described how students struggled in meeting expectations of data literacy in Biology as she stated, "What they do on green dots popped up and time and time again it will come up, and I will have to help them." Correspondingly, Teacher 6 described her expectations of students' data literacy as she implemented videos in her class for students to obtain and evaluate data. She explained how they "…watched a video about Stephen Avery…" and how "…if they speak up during the video…" she would "…pause it" and incorporate class discussions.

Broad/flexible. Broad/flexible was indicated when teachers had a wide range of views of representing data literacy. It was evident that teachers had a broad view of representing data literacy related to their expectations of students' data literacy knowledge and skills. Consequently, this led to the development of the category broad/flexible. For example, Teacher 5 described her expectations of students' data literacy knowledge and skills as expecting "…them to leave with knowing how to read charts and graphs, and anything that has data on it and understanding that they don't necessarily have to know the graph is telling them or what it's telling them just be able to read it and pick out what they need."

These findings assert that teachers have a wide range of views and expectations of connecting data literacy. Nonetheless, the findings suggested that representation was necessary for their expectations of students' data literacy knowledge and skills to be met. Therefore, the theme representation helps explain why teachers emphasize integrating models, active learning, collaboration, and real-life situations to help meet their expectations.

RQ 3. Teachers believe data literacy can be represented many ways was discovered for RQ 3 using the following categories: Model, visuals, technology, resources, words, perfect world, relevance, application, dynamic, collaboration, surprising, self-belief, other subjects, comparison, active learning, concepts with data, ways to use data, broad/flexible, and objectivity.

Model was directly connected to teachers believe data literacy can be represented many ways theme and visuals because teachers described how they used different visuals, such as graphs, to demonstrate ways to represent and communicate data in their science classes. Thus, visuals were also connected to teachers believe data literacy can be represented many ways theme, relevance, and technology. Teachers, such as Teacher 6, described how she used technology as a way to have students visualize data sources and many suggested that visuals were effective in displaying real-life content. Thus, relevance was also connected to application, dynamic, and collaboration as teachers explained how data literacy should be embedded with real-life situations through application, and should be continuously evolving. Likewise, teachers emphasized collaboration as a way to incorporate relevant data representation in their class, which was also connected to active learning, surprising, and self-belief. This is because teachers described how they implemented collaboration when they engaged students in active learning to increase their confidence, and Teacher 7 explained how the students' data literacy learning through collaboration was surprising.

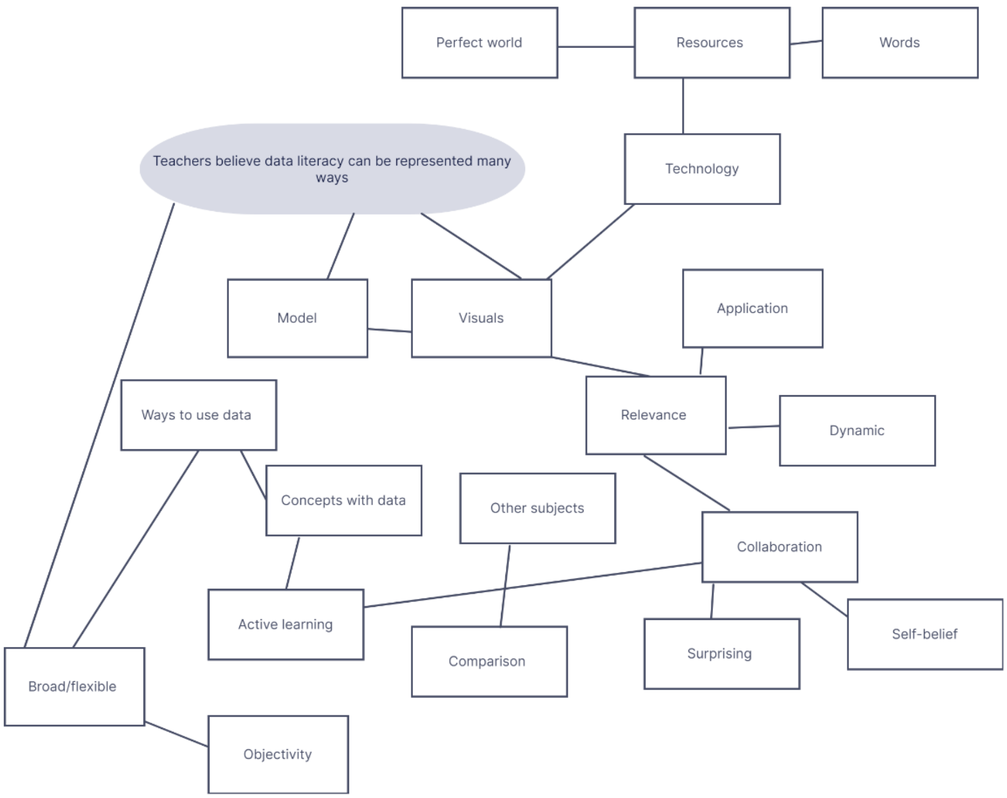
Extending on the connection of active learning, comparison and concepts with data were found to be connected to this category because teachers described how they had their students engage in active learning to connect concepts with data and stressed comparison for understanding. Moreover, comparison was also connected to other subjects as teachers compared how students worked through concepts related to data literacy through comparison with other subjects, such as math and ELA.

Additionally, concepts with data were found to be directly connected to ways to use data as teachers described a variety of easy concepts that could be represented using data in their science classes. Thus, ways to use data were found to be directly connected to broad/flexible, and this category was found to be connected to teachers believe data literacy can be represented many ways theme and objectivity. Teachers had broad views on how data could be represented as they described how students worked through concepts related to data literacy and the importance of keeping an open-mind.

Returning to the category of technology, this was found to be connected to resources, which was found to be directly connected to words and perfect world. This is because teachers described a variety of resources that they use or needed to represent data literacy, but some indicated that actually receiving such resources was unlikely. Nonetheless, teachers, such as Teachers 3 and 7, stressed data literacy resources that involved reading, which was a code used to represent words and thus explains its connection to resources. Figure 22 demonstrates the relationship of the categories used to reveal teachers believe data literacy can be represented many ways theme for RQ 3.

Figure 22

Connection of categories used to discover teachers believe data literacy can be represented many ways theme for RQ 3.



Modeling. Model was indicated when teachers described demonstrating or showing students data literacy and ways students were assessed. For example, Teacher 1 explained how students worked through data literacy concepts in science after he implemented modeling. Moreover, Teacher 4 described how it was challenging for her students to work through different concepts related to data literacy. Nonetheless, unlike Teacher 1 who had positive views towards using modeling before students perform or work through different concepts related to data, Teacher 4 described how modeling resulted in students copying. She stated, "So, if I model it then, they copy it, but whether or not if I would not have modeled it, I don't think they would be able to." This was similar to Teacher 7's views of demonstrations. She stated, "…you can't just have a demonstration on the board to get the point…" as she described students learning electron notation.

Nonetheless, Teacher 6 described a component of modeling and explained how she had her students present specific cases they learned about in class. She explained how such opportunities helped students in their communication skills, which she deemed important. She stated, "I told them today how important it is for them to um, to present and to learn how to talk to adults…." Thus, Teacher 6 combined a component of modeling with verbal communication as a way for her students to work through concepts related to data literacy.

Visuals. Visuals were indicated when teachers explained how students performed or worked through concepts related to data literacy. Many explained that students struggled with these, which they detected in different forms of assessments. Teacher 2 described how she had her students use graphs as a source of visuals and work in groups to determine what the graphs represented related to concepts connected to data literacy. She explained how students evaluated the graphs and then "…they just got in groups and had a discussion about what they wrote down…." Similarly, Teacher 3 explained how she had her students work in groups to complete labs and obtain data and then represent the data through use of different visuals. For instance, she said, "…once they all have their own data, they then utilize that data to create a graph, or to create a chart…."

Collaboration. Collaboration was indicated as teachers described how students worked through data literacy problems and how teachers could address data literacy needs. For example, Teacher 2 emphasized collaboration, especially when students begin working through data literacy in science. She explained how group discussions were a common way of how she had her students perform or work through different concepts with data literacy; whereas, Teacher 3 described how students were uncertain when students work with challenging data sources, such as college level articles. She explained how she incorporated collaboration as students worked through science concepts with data literacy if they are engaging in more challenging materials.

Extending on collaboration, teacher 2 suggested teacher collaboration could be advantageous to "…have more people bring to the table examples…" in PLCs to address data literacy needs. She also suggested that such opportunities provide variation in ways to address data literacy needs. Similarly, Teacher 4 explained how PLCs targeted students' data literacy "by getting together…" to "…compare results…" and determine best instructional strategies. Like Teachers 2 and 3, Teacher 6 described how she incorporated discussions in her class because students typically jump to conclusions when working with concepts related to data literacy. She explained how she used these discussions to emphasize observing all sources of evidence before making conclusions. She further explained how students, "…tend to trip themselves up on focusing on things…jumping to conclusions." Additionally, she explained how she used class discussions as a form of assessments to monitor how students perform or work through concepts related to data literacy. For example, when asked how she assessed students' data literacy, she stated "I also grade them kind of based on discussions we have in class." Moreover, Teacher 3 described how she implemented collaboration as students engage in difficult science data literacy articles. This was similar to Teacher 2's description of pairing students to work through difficult, wordy problems to advance students' data literacy. For example, she stated, she would have students "…pair up with somebody and let's tackle this one. You know, two brains are better than one, and it builds confidence, and it helps them to troubleshoot off of each other." Likewise, Teacher 3 emphasized students collaborating ideas as they engage in more challenging concepts related to data literacy. For example, she stated, “So, with the harder items, you're definitely going to want to put them in a group to discuss and throw ideas at each other.”

Self-belief. Self-belief was indicated when teachers described students’ confidence as they worked through data literacy concepts. For example, Teacher 2 described how she had her students engage in group discussions to increase their confidence. Teacher 2 described how she had her students engage in repetitive practice and suggested it increased their confidence. For example, as she explained how she advanced students’ data literacy, she stated, “The more they practice and have conversations about it, I feel like the more confident they become….”

Surprising. Surprising was indicated when teachers described unexpected results or observations as students worked through data literacy. For example, Teacher 1 explained how he unexpectedly got students engaged in a motion lab in his Physics class. He stated, “…surprisingly, I got some engaged with uh, uh the concept of motion in physics….” Furthermore, Teacher 7 described how it was “…amazing how sometimes when they're working in groups, they can teach each other.”

Relevance. Relevance was indicated when teachers described how they related data to students. For instance, Teacher 1 stressed the importance of students working collaboratively to complete tasks. He explained how collaborative labs helped “…with going out in the real-world….” Comparably, Teacher 6 stated that she wanted her students to “…understand how that applies in life” when explaining the importance of being observant to advance data literacy. Moreover, she described how students tend to lack good observation skills as they work through data literacy in science. Correspondingly, Teacher 8 stated, “I try to give them real-world applications like, in the scenario that we give” as she described how she advances students' data literacy” and elaborated “Like, extrapolating that data and expanding it to real-life scenarios.”

Teacher 2 explained how if they "…had data already available," they could be more effective in teaching data literacy. She also explained how she "…would love to use data that is specific to them," which suggests that she values relevance in science data literacy.

Dynamic. Dynamic was specified when teachers indicated they believed the curriculum should be constantly evolving. For example, Teacher 6 stated, "I think the best design is to be constantly changing, to be evolving with issues as new issues arise." Thus, dynamic and relevance was found to be connected as she emphasized this in her response. She further elaborated on the importance of the curriculum connected to students' lives by stating, "I think you need to respond to what's going on in the community, and, and talk about those kinds of issues."

Active. Active learning was indicated when teachers described active ways that students worked through data literacy. Teacher 1 emphasized students working with data through active learning and being able to use learning relevant to students' lives to make predictions. For example, he described how he had his students complete a physics lab, which required them to determine time and distance traveling different ways. He had his students work in groups to complete the lab.

Comparison. Comparison was indicated when teachers described how students compared data as they worked through science concepts. Teachers 1 and 5 emphasized active learning through labs. For example, when Teacher 5 was asked how she advanced students' data literacy, she replied, "…give them a lab that they would get data from." She explained how she would have students follow directions for a lab and then compare their data with others in the class. Thus, this was a way she included active learning, comparison, and collaboration in her class to advance students' data literacy.

Concepts with Data. Concepts with data were discovered as teachers provided examples of concepts addressed in their class when describing how students worked through data literacy and how it was implemented in their class. For example, Teacher 1 described how he connected data literacy to "…the concept of motion in Physics…" by having students complete a lab. Thus, he connected active learning with concepts with data. Moreover, Teacher 8 emphasized how she would like to know "…how to present data…" as she taught active and passive transport. Thus, this connected concepts with data supporting the overarching theme, representation. Teacher 8 explained how students worked through concepts related to data literacy by first analyzing the information presented to them and then asking reflective questions that targets understanding. For example, she explained the steps she sees students take when working through such problems by asking themselves, "…how is this happening…" and "…how can I see things increasing, decreasing, when they stop…"

Other subjects. Teachers 5 recognized how data literacy was connected to other subjects and prior learning. For example, Teacher 5 replied, "…being able to do it themselves because not everybody has a strong math background" as she explained the support and training needed for teachers to be effective in teaching students' data literacy. Moreover, Teacher 4 explained how commonality among teachers and contents could help advance students' data literacy. For instance, she stated, "…if other teachers or other contents were also using the same scenarios or situations" and "…trying to get students to think beyond…" students' data literacy could be advanced. She also suggested questions that centered on 'how' and 'why' to facilitate data literacy learning. Like Teacher 2 and 3 who emphasized collaboration through discussions, Teacher 4 suggested, "…the conversations in the classroom would be a root to helping students get a little better."

Resources. Resources were indicated when teachers described how the curriculum could be improved to support students' data literacy. For example, Teacher 4 stated, "Maybe providing more resources to the teachers up front" when she described what could be improved to address data literacy needs. As Teacher 1 responded to questions, it was evident that he used a premade science curriculum for his Physical Science classes. For example, he explained the need for students to have more labs to allow students to work through data literacy concepts, and suggested that the current curriculum did not have this. Moreover, Teacher 1 emphasized extrinsic motivation through rewarding students with different incentives to increase engagement. He explained how he believed resources, such as funding, should be set aside for incentives. For example, Teacher 1 asked, "Can we reward students? Can you motivate students to get involved with rewards?" He further stated, "I am becoming dangerously close to criticizing the fact that it is all about EOCs. It doesn't really motivate me. We need a kind of budget to reward students…."

Additionally, Teacher 1 stressed the importance of having updated lab equipment to prepare students for post-secondary education and careers. He explained how lab equipment that science teachers had access to were outdated. He said, "That's one way is to have newer equipment" as he described resources teachers need to be effective in teaching students' data literacy. Thus, these implications suggest that how students work through concepts related to data literacy could be improved by updated resources. Similarly, Teacher 3 described funding allocated to high school science was needed to adequately prepare students. Likewise, Teacher 6 stated that she wanted her students to be "…functioning adults whether they go into criminal justice or not" and suggested that observation skills were essential. She elaborated and said,

"…there's a lot of careers that would focus on this, and I want them to be able to be observant…."

Likewise, Teacher 2 explained that she believed science teachers needed more resources and "different variations" as she explained what teachers needed to be effective in teaching data literacy. Teacher 3 explained how resources were limited at the high school levels, which negatively impacts preparing students for their future. She said, "…the high school gets left behind to where we want access to certain things, but we're not given that access…." This focus of preparing students for their future was similar to Teacher1's views and emphasis on updated lab equipment.

Taking the views of needed resources in a different direction, Teacher 4 said, "There needs to be something to help transition them from just getting data to actually using data…." However, she explained how she was uncertain of what was needed to achieve this. Specifically, she said, "I don't know what kind of training that would be." Teachers 1, 2, 7, and 8 emphasized readily available premade data as a resource needed for teachers to be effective in teaching students data literacy. For example Teacher 8 explained how a place that she could specifically go and "obtain data pertaining to" different science concepts would be beneficial.

Perfect world. Perfect world was indicated when teachers described ideal resources they would like to have to advance students' data literacy as they work through concepts related to data literacy. For example, Teacher 1 said, "I wish we had more labs" in his response to how students work through concepts related to data literacy in his class.

Technology. Technology was indicated when teachers described how students performed or worked through data literacy with the integration of technology. For example, Teacher 6 stated, “We watched a video about Stephen Avery who was wrongfully convicted…” as she explained a time that students worked through data literacy in her class and were highly engaged. Teacher 4 explained how she had her students analyze the amount of time they spent on their phones. She used this activity to teach students how to create graphs. Thus, she used technology as a way to integrate visuals in her Biology class. Nonetheless, overall, teachers did not emphasize use of technology to advance students’ data literacy as discussed in the literature. In fact, Teacher 7 suggested such technology was overused. Specifically, she said, “…everything should not be computer based.” She argued that Googling information did not promote learning as using notes and books. She said, “When they have to search for things, it sharpens their minds…” and emphasized having students read for data literacy understanding. For example, Teacher 7 stated, “…reading is fundamental.” Nonetheless, Teacher 7 suggested that an online module of resources would be beneficial in teaching data literacy as it would offer a common place for teachers to access materials aligned to standards.

Words. Words were indicated when teachers described vocabulary, articles, and reading in their explanation of how students worked through concepts related to data literacy. Teacher 3 stated, “If it's college level vocabulary, then they don't know those definitions yet, so they can work together to figure out what that word is actually meaning in that sentence to analyze it scientifically to the classroom.” She stressed the importance of students knowing the vocabulary before engaging in scientific data literacy. Specifically, she stated, “…they have to understand what the vocabulary of the article is before they can actually conduct a scientific analysis.” She viewed vocabulary in a broad way and suggested that it was needed before science data literacy could be achieved. In her responses, she emphasized analysis as students worked through concepts related to data literacy. Nonetheless, she also explained how analysis was important for the teachers to determine what students' have learned. Specifically, she explained how she assessed students' data literacy "…through the analysis of what they gained…."

Broad/flexible. Broad/flexible was indicated when teachers viewed data literacy to include a wide range of learnings. Teacher 2 stated, "…in high school, it is very broad. It's kind of everything about data." This was similar to Teacher 6's explanation of what she knew about data literacy as she said she believed "It can be anything you want it to be…." Moreover, based on teachers' explanation of how students worked through concepts related to data literacy, it was evident that many viewed it in a broad spectrum and flexible to the content being studied. For example, Teacher 4 explained that it could be anything that requires students to interpret information, which was similar to Teacher 5's description in how students worked though concepts related to data literacy as she explained how students "…picked apart passages…."

Objectivity. Objectivity was indicated when teachers described keeping an open mind when students work through concepts related to data literacy. For example, Teacher 6 stated, "I have to explain how important it is to keep an open mind and investigate the case thoroughly" as she described how students worked through concepts related to data literacy in her Forensics class.

The overarching theme teachers believe data literacy could be represented many ways suggest that teachers believe data should be presented through demonstrations, such as models and visuals, which can be integrated in a variety of ways. Nonetheless, teachers stressed the importance of relating data to students, especially in the application of data literacy. Moreover, teachers believe that the way students worked through concepts related to data literacy varied and improved when representation of data included collaboration, comparison, active learning, and connecting concepts with data. However, limited resources were cited as a constraint in how students worked through data literacy, which impacted the way data were portrayed in the class.

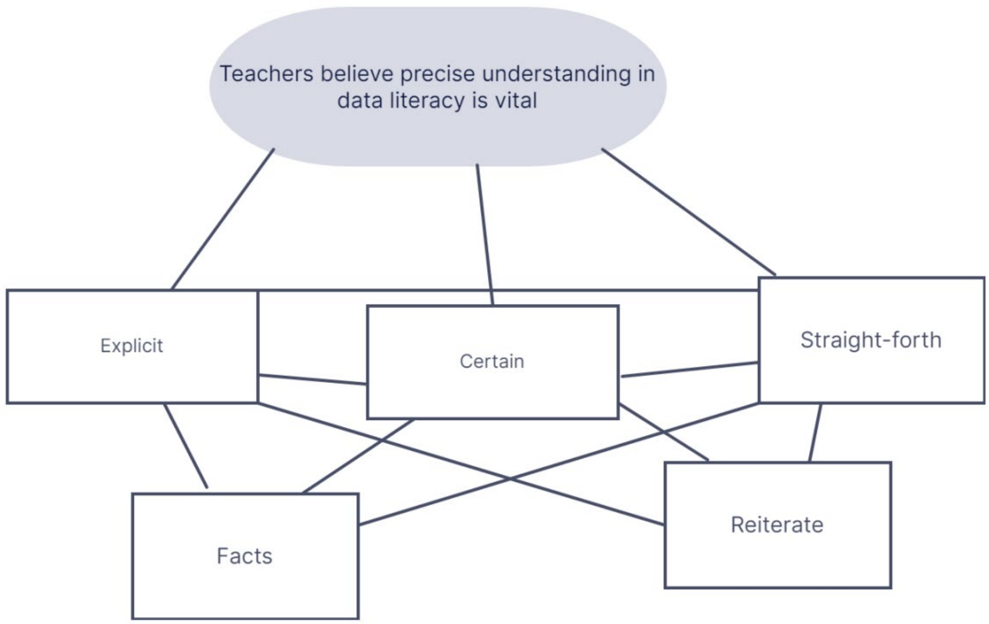
These findings suggest that teachers have a broad spectrum of how data can be represented in their classes, which implies that such differences likely lead to diverse conceptions of how students work through concepts related to data literacy. Consequently, these implications suggest that clearer communication and distinct training could aid in teachers having a more uniform view of data representation in their classes and a better understanding of how they can teach concepts related to data literacy, which will affect how students work through concepts related to data literacy in their science class.

Teachers Believe Precise Data Literacy Understanding is Vital

RQ 1. The theme teachers believe discrete understanding of data literacy is needed was identified after developing the categories explicit, facts, certain, straight-forth, and reiterate. Nearly all teachers suggested that data literacy involved interpretation using data, which resulted in explicit and facts being connected. Explicit was found to be connected to facts as teachers, such as Teacher 7 stated she would like to know exactly what they teach students since the standards are broad. Moreover, facts were found to be connected to certain and straight-forth as teachers indicated a need for discrete understanding of data literacy, which was reiterated many times. Figure 23 displays the connection of categories used to reveal teachers believe precise data literacy understanding is vital for RQ 1.

Figure 23

Connection of categories used to reveal teachers believe precise understanding in data literacy is needed for RQ 1.



Explicit. Explicit was indicated when teachers explained how it would be beneficial to know exactly what data literacy concepts need to be taught. For example, Teacher 7 responded to item 18 and described how teachers would benefit from direct resources that help them know exactly what needs to be taught as it relates to science data literacy in her Chemistry class. Specifically, she stated, “Tell us exactly what they're looking for rather than having us just you know, if we were all looking for one central thing.” Although Teacher 7 acknowledged she had little experience with data literacy in science, she stated, “…it's beginning to become clearer exactly what some of this terminology means” as she responded to item 1 and described what she knew about data literacy in her science classes.

Certain. Certain was indicated when teachers provided definitive responses. Similar to explicit, the category certain was identified in the dataset, which used the code 'definitely.’ For example, Teacher 2 stated, “It definitely makes me think about it a lot more,” as she described her conception of data literacy and responded to item 18 in the interview. Comparable to the category certain, facts was a category identified in the dataset after using the codes information, answering, and findings.

Facts. Facts were indicated when teachers described their conceptions of data literacy being factual information. For example, Teacher 3 explained her definition of data literacy in item 15 as she described that it involved, "…Information to understand or create your own findings at the end of your research." Likewise, Teacher 1 described his definition to be how students "…interpret the data, what the data means, and then apply it towards answering certain questions about it." Similarly, Teacher 6 stated that her definition of data literacy included, "…information the students are sharing or just being observant and noticing what they're focusing on to see if whatever you are doing is working."

Straight forth. Straight-forth was detected when Teachers responded with closed-ended responses. The straight-forth category arose as teachers were able to clearly communicate their data literacy conception/understanding. For example, some teachers were straight forth in their response to item 18 as they believed their response to the other items in the interviews accurately conveyed their conceptions of data literacy. For example, Teachers 3's response was 'no' to item 18. Similarly, Teacher 3 was able to provide more straight-forth responses explaining her conception of data literacy compared to many of the other teachers, which suggested her conceptions of data literacy were clearer compared to others, such as Teacher 4 who indicated she did not know 100% what data literacy was and Teacher 2 that stated she didn't know anything about it. Thus, overall, teachers were not straight-forth in their conceptions of data literacy except for Teacher 3 as most were uncertain and even then, Teacher 3 expressed some level of uncertainty. Nonetheless, the straight-forth category also revealed that teachers were straight-forth in describing that they were uncertain of what data literacy was in science and a need for better understanding. Therefore, teachers were straight-forth in their recognition of their own conceptions of data literacy as was the case for Teachers 2, 4, and 5.

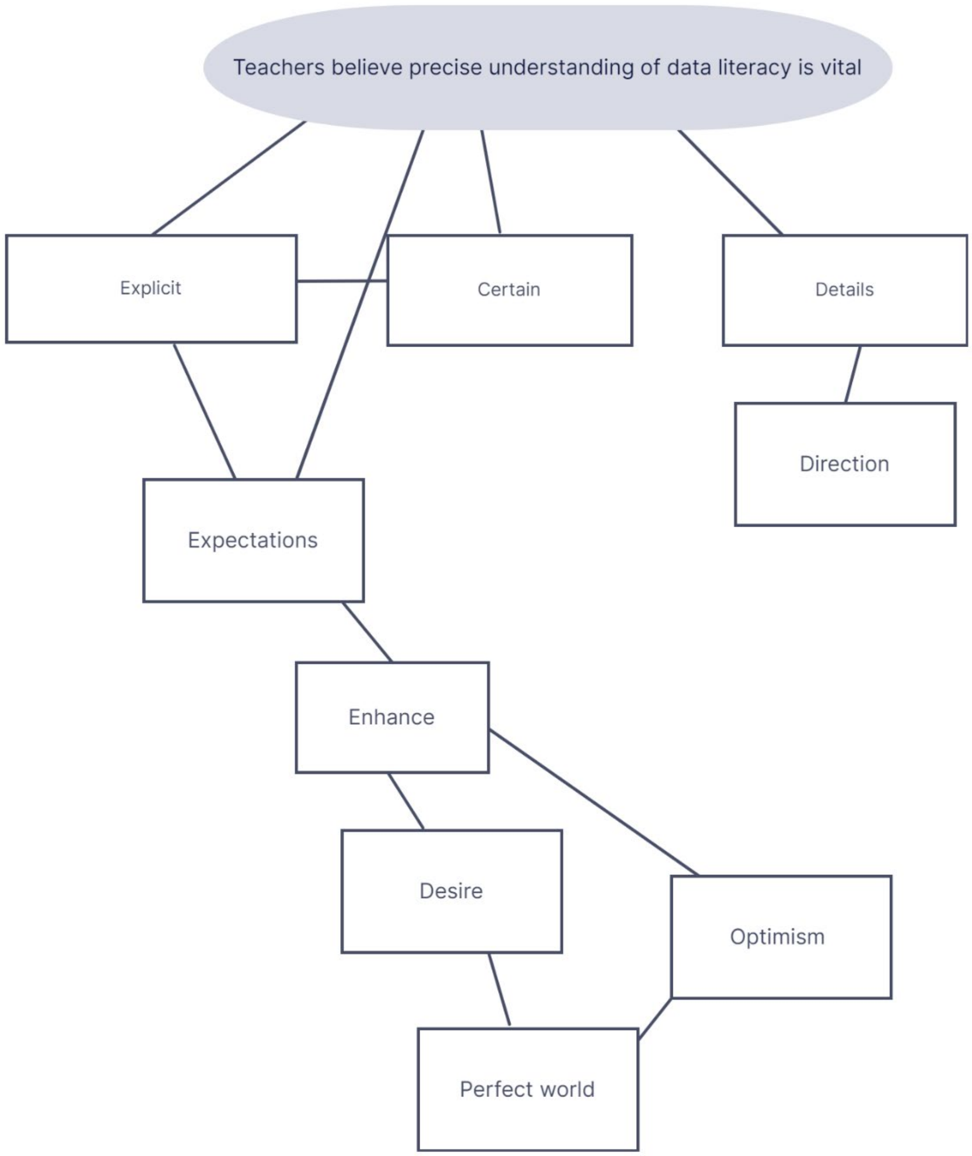
Reiterate. Reiterate was indicated when teachers repeated responses. This category was identified by using the codes again and repeated responses. For example, Teacher 4 repeated her response to her definition of data literacy by stating, "So, again, graphs, pie charts, uh images…being able to interpret those." This category further reveals the need for discrete understanding.

Although teachers discussed data literacy as being able to explain information using data as factual evidence, several teachers expressed that they needed to think about it more and learn about it more. One teacher described how teachers would likely benefit from explicit instruction and resources to help them facilitate data literacy in their science classes. These findings assert that teachers' conceptions of data literacy in science are broad and many recognize a need to make improvements. Teachers' conceptions of data literacy was subjective, and most teachers indicated that data literacy could be anything ranging from words to data displayed in visuals. Nonetheless, teachers viewed data literacy as being factual and thus discrete by taking sources of evidence as facts and relating it to concepts being learned or topics being discussed in class. Thus, these implications suggest that teachers view data literacy as discrete when used in science class, but their definition of data literacy was vague and more relaxed as Teacher 6 stated data literacy can be "…whatever you want it to be." Consequently, the findings assert that teachers recognize a need for precise understanding of data literacy.

RQ 2. Like RQ 1, RQ 2 revealed that some teachers emphasized precise understanding of data literacy as students work through problems related to data literacy in science. The following categories revealed this theme: Explicit, expectations, enhance, desire, perfect world, optimistic, certain, direction, and details. Teachers described discrete knowledge and skills they expected their students to possess. However they explained that these explicit expectations were unlikely and more of ideally what they would like their students to possess. Consequently, explicit was found to be connected to expectations and expectations was found to be connected to enhance and optimism. The latter was found to be also connected to the perfect world, and enhancement was found to be connected to desire, which was connected to the perfect world. Similarly, certain was connected to explicit as teachers described how they expected students to know data literacy and make sure that it is achieved. Moreover, explicit was connected to precise, which was connected to details and direction as teachers emphasized students knowing precise data literacy information by paying attention to details and directions, such as pattern. Figure 24 illustrates the connection among categories used to reveal teachers believe precise understanding of data literacy is vital theme for RQ 2.

Figure 24

Connection among categories used to reveal teachers believe precise understanding of data literacy is vital theme for RQ 2.



Expectations. Expectations were indicated when teachers explained how they had to lower their expectations to meet students' prior learning. Teachers believe that students should have a basic understanding of data literacy knowledge and skills. However, this is not the case for many students. For example, Teacher 8 described how she had to lower her expectations of what she expected students to possess when they entered her classroom. She explained that she had to begin from scratch and find ways to meet the learner where they are and advance their data literacy learning without a foundation of data literacy skills and knowledge. Likewise, Teacher 7 described how she expected students to possess data literacy knowledge and skills as it relates to the periodic table. However, like Teacher 8, she explained that this was not the case. For instance, Teacher 8 stated, “So, I kind of lowered my expectations…” as she described data literacy knowledge and skills she expected her students to possess when they entered her class. Nonetheless, she further stated, “It's my job to get them to this level” and explained that she hoped “…that they’re able to read and interpret graphs…” when students complete her class. Teachers' expectations did not align to reality as they indicated that the majority of students are below proficient in data literacy knowledge and skills.

Enhance. Enhance was indicated when teachers described how they expected their students’ data literacy to improve. For example, Teacher 4 described how she implemented a graphing activity to have her students “…see, over the school year, if that improves their scores or not.”

Explicit. Explicit was indicated when teachers were specific in their responses. For example, Teacher 2 was explicit in her views of what helped develop discrete understanding of data literacy. She stated, “It definitely helps” in reference to small group learning and differentiation. Likewise, Teacher 4 viewed limited screen time as a way to improve students’ data literacy. She stated that she wanted “…to see if over the school year if that improves their scores or not.”

Certain. Certain was indicated when teachers were definite in their responses. For example, when asked if Teacher 3 viewed data literacy knowledge and skills as a holistic view, she indicated, “correct.” Thus, indicated she was certain in her response.

Optimistic. Optimism was indicated when teachers were positive about students meeting their expectations. Some teachers, such as Teacher 5, were optimistic in their views of students’ understanding. She stated, “…hopefully they know it when they get here…” as she explained how she desired students to know how to “pick apart passages” as she described her expectations of students’ data literacy.

Desire. Desire was indicated when teachers described what they wanted their students to gain from their instruction. For example, Teacher 6 described her desire for students' precise data literacy learning by saying, “…when they leave, I want them to understand” and “…be more observant.”

Perfect world. Perfect world was indicated when teachers describe ideal learning expectations of data literacy. For example, Teacher 8 described how in a perfect world, she wanted her students to be able to make conclusions and predictions. She said, “…in an ideal world, can you make…conclusions and predictions based on the trends…” as she described her expectations of students’ data literacy when students complete her course.

Details. Details were indicated when teachers stressed the importance of paying close attention. This aided in the discovery of teachers believe precise understanding of data literacy is vital. For example, Teacher 6 stressed the importance of paying attention and focusing on all details. She further explained how one’s focus could affect observations and thus interpretations and conclusions of data sources. She stated, “We’re all driven by what's happening next and making sure that we're getting there on time and not focusing on what's going on in front of us.”

Likewise Teacher 3 described the importance of details in precise understanding as she explained an activity that highly engaged students in data literacy. She explained how students looked "…in between their data points."

Direction. Direction was indicated when teachers emphasized the importance of precise understanding of trends in data as they described their expectations. For example, Teacher 8 emphasized a directional approach to "…develop conclusions and predictions based on the trends…."

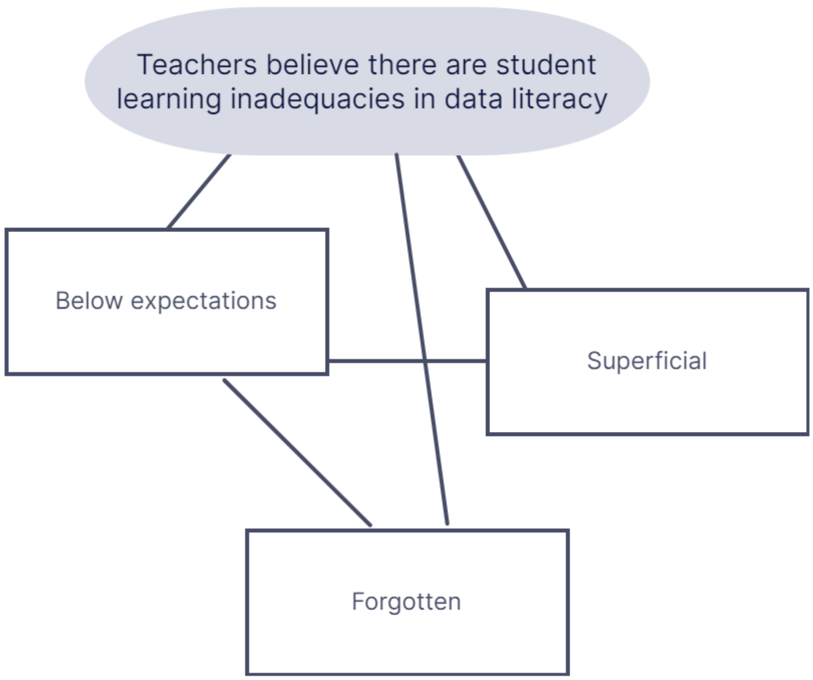
These findings suggest that teachers view a need for students to develop an in-depth, accurate understanding of data literacy with a detailed focused mindset that can be used to gather data sources as evidence to support conclusions and predictions. Teachers explained ways they viewed data would enhance students' data literacy and their desires of data literacy among their students. These implications assert that teachers' expectations of data literacy are not being met and suggest that students' precise understanding of data literacy should be targeted to help reach teachers' expectations.

Teachers believe there are Student Learning Inadequacies in Data Literacy

RQ 2. The categories below expectations, forgotten, and superficial revealed the theme teachers believe there are student learning inadequacies in data literacy. Below expectation was found to be connected to forgotten and superficial as teachers explained students' data literacy as being below their expectations and explained how this is because they have only superficial understanding or have forgotten what they have learned. Thus, superficial and below expectations were found to be closely connected, and all categories were directly connected to views of inadequacies in data literacy. Figure 25 demonstrates the relationship among the categories used to reveal teachers believe there are student learning inadequacies in data literacy for RQ 2.

Figure 25

Relationship among the categories used to reveal teachers believe there are student learning inadequacies in data literacy for RQ 2.



Below expectations. Below expectations were indicated when teachers described students' data literacy as being below their expectations. For example, Teacher 8 stated, "I kind of lowered my expectations…." She further stated, "I kind of lowered my expectations and kind of had the, you know, 'Okay they're starting from scratch. It's my job to get them to this level." Likewise, Teacher 7 described how students' data literacy was below her expectations and was partly because students have forgotten what they learned in middle school. For example, she said, "…in order to get them up to speed, I've had to go back and teach it." Furthermore, Teacher 4 explained how students' data literacy was below expectations when she described how she implemented an activity that requires students to determine how "…much time they spent over a two week period” on their cell phones. She stated, “That should have been a very easy assignment. Uh, what I found throughout that was that they are not able to graph….” Thus, these findings were revealed below expectations and forgotten as categories.

Forgotten. Forgotten was indicated when teachers described how students lost the knowledge they did possess needed to meet their expectations of data literacy in science. For instance, Teacher 7 stated, “Quite a number of them took Physical Science in the 8th grade, and they have uh, lost whatever they did know…” as she explained the data literacy knowledge and skills she expected her students to possess.

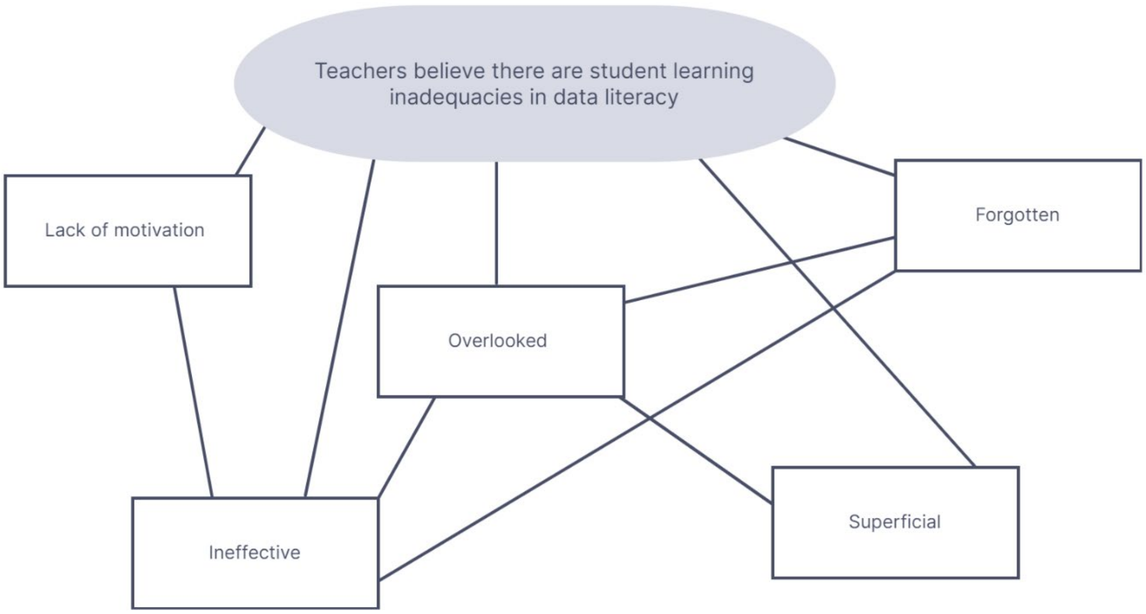
Superficial. Superficial was indicated when teachers described the basic knowledge of data literacy students should possess at the least. For example, Teacher 2 explained her expectations and stated, “I mean, that they can read basic tables, charts, and data.” She explained that her expectations of student data literacy was a basic understanding when they entered her course, and a deeper understanding when they exit her course. Teacher 2 further explained that she wanted students to “…not look at it so basic, such a basic interpretation. I feel like that's how they come to me. It is more basic.” Similarly, Teacher 6 explained that when students enter her class, “they are going to come in with basic knowledge, not a whole lot of specific Forensics knowledge.” Therefore these statements revealed that students only had a superficial understanding of data literacy.

Consequently, these findings assert that students have deficiencies in data literacy and only have superficial knowledge or have forgotten their prior learnings. Consequently, teachers have had to lower their expectations of data literacy in the class making it challenging to meet learners’ needs and learning objectives.

RQ 3. Like RQ 2, the findings from RQ 3 revealed that teachers' views of how students work through concepts related to data literacy were inadequate leading to the theme teachers believe there are student learning inadequacies in data literacy for RQ 3. Categories used to discover this theme included lack of motivation, overlooked, ineffective, forgotten, and superficial. Lack of motivation was found to be directly connected to the theme teachers believe there are student learning inadequacies in data literacy and ineffectiveness. This is because teachers explained how students lacked motivation and how this negatively affected their learning and led to deficiencies in data literacy. Additionally, ineffective was found to be directly connected to the theme of teachers believe there are student learning inadequacies in data literacy and overlooked. This is because teachers described how some instructional strategies will not be effective in facilitating students' learning as they work through concepts related to data literacy and how some instructional strategies used to target students' data literacy needs were overlooked, which led to inadequacies in students' data literacy. Furthermore, overlook was found to also be connected to forgotten and superficial. The latter was revealed as teachers described how students' data literacy learning was only superficial, which then caused deficiencies in data literacy in science. Lastly, forgotten was connected to overlook, ineffective, and the overarching theme, inadequacies in students' data literacy. These connections were made as teachers described how students forgot the data literacy learning they had resulting in ineffective data literacy learning that were forgotten or overlooked leading to deficiencies in data literacy. Figure 26 demonstrates the relationship of the categories used to reveal the theme teachers believe there are student learning inadequacies in data literacy for RQ 3.

Figure 26

Connection of categories used to reveal the theme teachers believe there are student learning inadequacies in data literacy for RQ 3.



Lack of motivation. Lack of motivation was indicated when teachers discussed students unengaged as they worked through concepts related to data literacy. Teacher 1 stressed motivation multiple times. He explained how EOC scores were a focus and how that didn't motivate him. He also elaborated on the need to extrinsically motivate students. Likewise, in his response to item 11, he explained how it was "…hard to get their attention with block scheduling…." He also stated, "I try to motivate them," but explained how it was "…hard time to obtain their attention." Additionally, he explained how he tried to get his students engaged by conducting labs but also stated that some students "… rather do it by themselves." Moreover, he suggested that students' motivation should be targeted to advance their data literacy in science as he suggested lack of motivation was ineffective.

Ineffective. Ineffectiveness was indicated when teachers described strategies that did not improve how students work through concepts in data literacy. For example, Teacher 6 explained how the curriculum should be dynamic or else "…it won't be effective" Other teachers alluded to this category, such as Teacher 7 who described the current science curriculum as being ineffective and a need for practicality, which will be further addressed in the succeeding themes. She stressed a focus on reading and suggested that lack of reading was ineffective and leading to deficiencies in how students work through concepts related to data literacy in science.

Overlooked. Overlooked was indicated when teachers describe how data literacy needs were overlooked as indicated by Teacher 7 who viewed reading as a data literacy need for students to accurately work through concepts related to data literacy. Moreover, Teacher 2 described how data literacy needs were often overlooked as she stated, "…data literacy isn't a standard so we don't give it a lot of attention" in her response to item 12. Similarly, Teacher 3 described how PLCs "…focused right now on achievement…" rather than data literacy.

Superficial. Superficial was indicated when students' data literacy learning and needs were only addressed at the surface. Teacher 3 said, "It's been brushed at the surface, but not enough." Similarly, Teacher 8 stated, "…it's been explored but not to the detail…we have not like, explored that topic as much."

Forgotten. Forgotten was indicated when teachers described the knowledge or learning students have lost by the time they come to their class. For example, Teacher 7 described how she had a student in her Chemistry class that had forgotten the Physical Science concepts she previously learned. As a result, the student was struggling. She stated, "I asked her, 'Do you remember anything we have been going over?' She dropped her head and said, 'No ma'am I don't." Similarly, Teacher 2 described how data literacy was often forgotten at the high school level due to a greater emphasis in rigor rather than skills. For instance, she stated, “I feel like it kind of gets lost in the mix because it's not a specific standard that they’re forced to focus on. I don't even know if in middle school…data is even taught because if it's not a standard, it gets lost.” This contrasted from Teacher 3’s view who stated, “So, if the teachers are actually teaching the standards like we're supposed to, then it's already incorporated into our classrooms. It's not something that needs to be extra.”

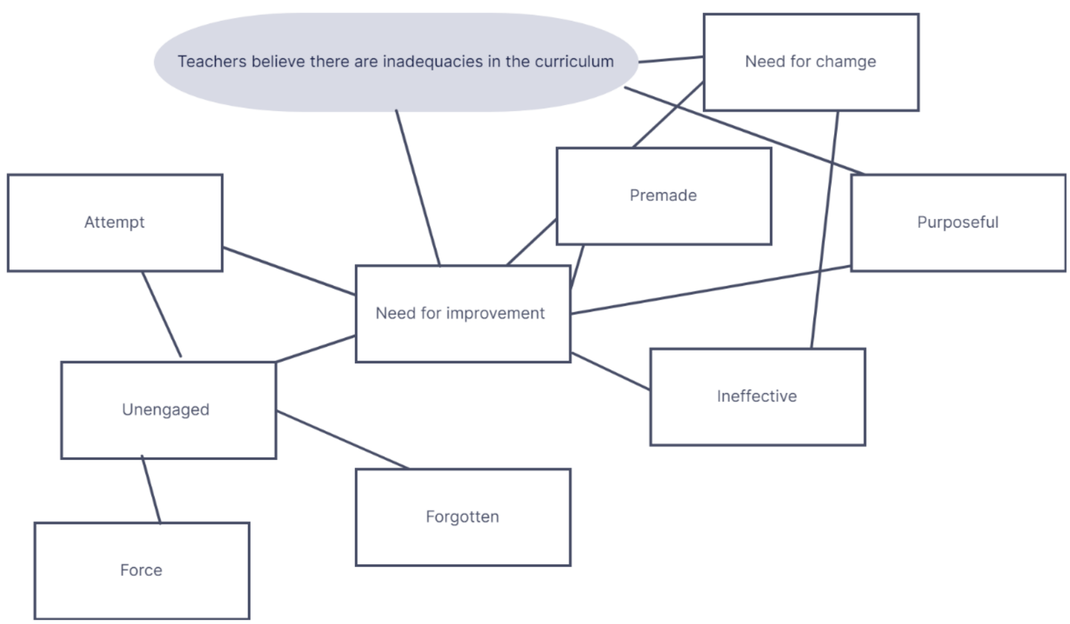
The findings reveal that teachers view students’ data literacy as deficient by the time they come to their class, but the case of these deficiencies varied as some cited that students forgot what they had learned or only learned data literacy at the surface while others cited lack of motivation, ineffective strategies, and data literacy needs as being overlooked as a result of inadequacies in how students’ work through concepts related to data literacy in their science classes. Consequently, these findings suggest that early intervention targeting students’ data literacy needs and motivation would likely improve deficiencies in learning. Nonetheless, considering the proceeding findings of teachers lack confidence with data literacy, teachers’ data literacy conceptions and confidence must be addressed before inadequacies in students’ data literacy in science. Thus, these implications reveal that a strategic plan involving teachers first and then students could likely improve how teachers and students work through concepts related to data literacy in science.

RQ 4. Similar to RQ 3, teachers believe there are inadequacies in the curriculum were revealed for RQ 4. The following categories were used to discover this theme: Attempt, unengaged, force, forgotten, need for improvement, ineffective, premade, need for change, and purposeful.

The category attempt was found to be connected to unengaged and a need for improvement as teachers discussed how they had to force students to complete data literacy tasks and how the current curriculum was ineffective in ways and needed more realistic data as most teachers indicated they used premade data source majority of the time. Thus, Force was found and forgotten were found to be connected to unengaged. Likewise, ineffective was found to be connected to need for improvement, which was also connected to premade and need for change. Furthermore, need for change was found to be connected to purpose as teachers discussed how strategies in the curriculum needed to be revised to promote more purposeful data literacy instruction to foster students' learning. Consequently, need for improvement, need for change, purposeful, and unengaged were all found to be directly connected to the teachers believe there are inadequacies in the curriculum theme for RQ 4. Figure 27 demonstrates the relationship of the categories used to reveal this theme.

Figure 27

Connection of categories used to reveal the theme teachers believe there are inadequacies in the curriculum for RQ 4.



Attempt. Attempt was indicated when teachers explained how they tried to foster data literacy. For example, Teacher 2 stated, “I try to give them some more practice” as a strategy to scaffold and foster data literacy. Similarly, Teacher 1 described ways he tried to engage students in data literacy but explained how some students are still unengaged and do not care to participate.

Comparably, classroom observations revealed that teachers attempted to teach data literacy, but like Teacher 1 indicated, some students were still unengaged. For example, Teachers 5 and 8 had several students sleep through the entire observation.

Unengaged. Unengaged was indicated when teachers describe the lack of engagement when teachers implemented strategies to foster data literacy. For example, Teacher 1 stated, “The lab participation has been kind of poor for my class….” He also explained how he struggled with using strategies to scaffold and foster data literacy as he stated, “I feel like you’re talking about how you differentiate different learning in the class and I haven't learned that.” He further explained, “I got some bored over here because they already got the concepts and that's the classroom differentiation” and explained, “I have seen them where they just won't participate.” Additionally, Teacher 1 described how he had a mixture of students in his class and how some were A or B students but “…aren’t interested in doing the Chemistry and Physics….”

Moreover, Teacher 7 explained how some students would “sit, zone out, and stare” and “play with the phone…" as she described the challenges of unengaged students when attempting to foster data literacy in her Chemistry class. Furthermore, Teacher 4 stated, “I’m kind of having a hard time doing that though” as she replied to item 9. As Teacher 1 indicated, it was evident that some of his students were not engaged during the classroom observation as some students did not get up to participate in the lab and he had few responses to the many questions he asked the students.

Extending on this topic, Teacher 1 explained how some of his students sit and rather sleep than participate, and Teacher 6 explained how students prefer to sleep rather than watch videos. Likewise, Teacher 7 had to remind her students not to sleep, but one still did during her classroom observation. Additionally, Teachers 5 and 8 had at least four students each sleep in their class throughout the duration of the classroom observations even after being rejected several times.

Although physical science teachers expressed sleeping more in their interviews, it was detected more among life science teachers in the classroom observations. Specifically, the two teachers that used mainly direct, lecture style instruction had more students sleeping and unengaged in their class.

Force. Force was indicated when teachers described how they made students complete certain tasks to foster data literacy. For instance, Teacher 7 stated, “I made them use their textbook.” In Teacher 7’s interview, she explained how she believed reading was necessary to foster data literacy as it provided background information that was difficult to capture in a presentation and thus helped provide deeper, conceptual understanding. During her interview, she described how reading was fundamental in science to develop a deep understanding and explained how she had to take the textbook home herself to read it to improve her own understanding of data depicted in the periodic table. However, she explained how it was challenging to have students do this and as a result, their conceptual understanding was often negatively impacted. Teacher 7 also explained how she believed reading textbooks improved overall literacy skills, which she believed positively correlated with students’ data literacy. The emphasis of incorporating reading as a way to foster data literacy was similar to Teacher 3’s explanation as she described how she used a variety of scientific articles connected to students' interest to advance students' data literacy.

Extending on the topic of forcing students to complete task to foster data literacy, Teacher 1 explained how he tries to motivate but how it was challenging. Nonetheless, he stated, "We have to get them to participate." These findings were also revealed in classroom observations. For example Teachers 5 and 8 tried several times to force their students to sit up, pay attention, and take the data literacy notes during their lecture, but many still refused.

Forgotten. Forgotten was indicated when teachers described how they felt like data literacy gets lost in high school. For example, Teacher 2 stated, "I feel like it kind of gets lost in the mix because it's not a specific standard that they're forced to focus on."

Need for improvement. Need for improvement was indicated when teachers described areas that they believed needed refined to improve students' data literacy. For example, Teacher 1 stated, "I feel like we need improved labs."

Ineffective. Ineffectiveness was indicated when teachers described ways the curriculum could be improved to foster data literacy. For example, Teacher 6 stated, "I think if you get too stoic and stay on older issues, you will not…the curriculum won't be effective."

Premade materials. Premade materials were indicated when teachers described how they used existing sources of data. For example, Teacher 1 explained that he used data from course instruction and explained, "It's been pre-done." Similarly, Teacher 2 explained how she used premade data from progress learning and described the sources of data she used as "The questions that are already in there." Likewise, classroom observations demonstrated Teacher 2's use of premade materials. For example, she explained during the observation how her activator was obtained from another state's EOC.

Similar to interviews and observations, analysis of documents revealed how much resources were obtained from premade materials. For example, Teachers 5 and 8 provided the same guiding notes used to teach a population dynamic lesson. However, on each paper, there was a copyright notation from Emma the Teachie (2022). Thus, this solidified teachers' comments centered on only using premade resources as both teachers stated this when I asked for something they have created. Likewise, Teachers 2 and 5 provided the same station activity, which was Scholastic Teacher Resources and the author's name was Michael Priesley. Likewise, Teacher 6 provided an activity, which was created by The Trendy Science Teacher. She indicated that she did not have any original documents that she had made.

Need for change. Need for change was indicated when teachers described how the curriculum needed to be revised to foster data literacy. Teacher 7 emphasized this by explaining the need to improve reading to foster data literacy in science. She explained how students did not like to read. Teacher 7 replied to item 9, "…I think a lot of our young people will run into problems if we don't change some things…if we don't insist that they read and, and be resourceful."

Purposeful. Purposeful was indicated when teachers described how they believed data literacy instruction should be more intentional. For example, Teacher 2 explained how she believed the science curriculum could be improved by being "…intentional about setting time." Moreover, Teacher 6 emphasized being intentional in her response to item 17 as she replied, "I think with most problems they can be overcome if you just listen." Like interviews, purpose was revealed in document analyses. For example, Teacher 4's activity stated the objective of the osmosis lab, which included, "to stimulate osmosis and observe how cells are affected when submerged in different types of solutions."

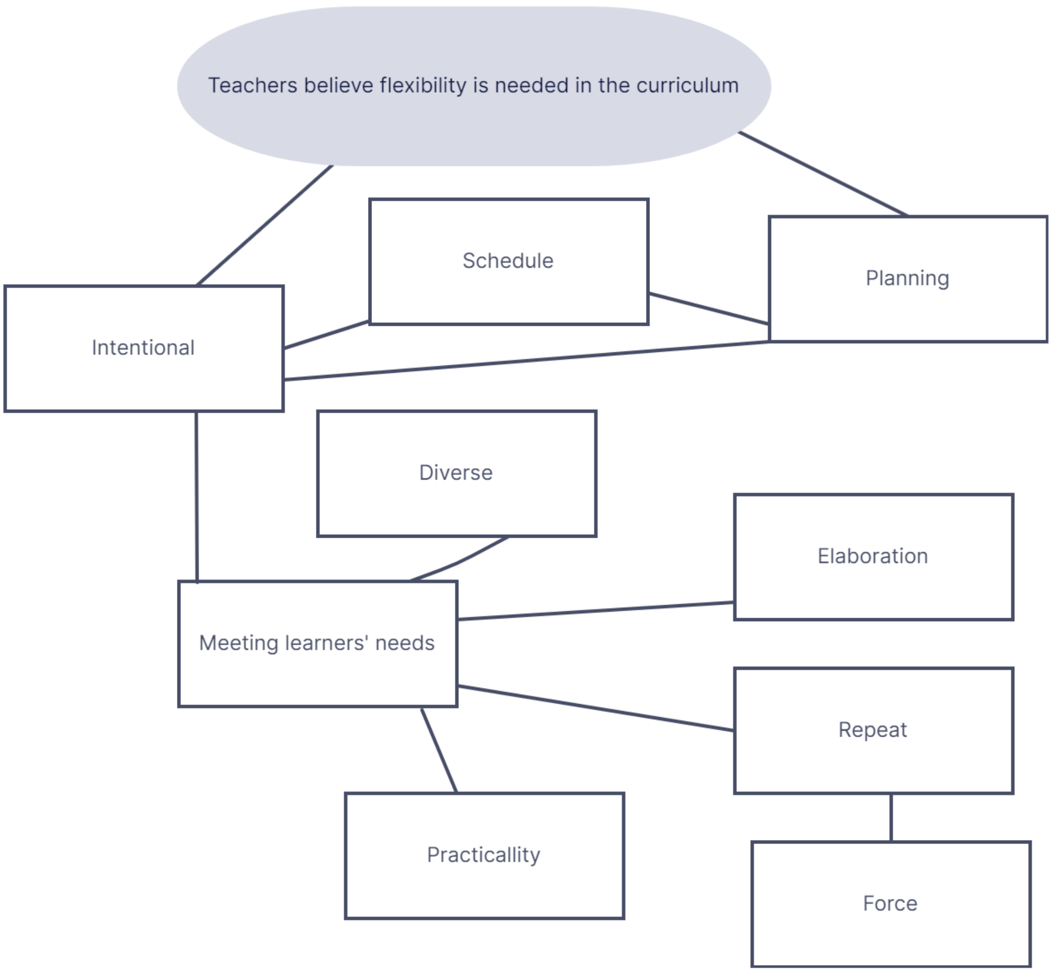
The overarching theme suggests that teachers believe the science curriculum should be devised in a way to better foster data literacy. This was revealed among life science and physical science teachers. However, lack of engagement was highly prevalent among 50% of the life science teachers, which used primarily lecture style, whole group instruction in their observations. These findings imply that teachers should adjust their instructional approaches to include hands-on learning using a student-centered approach where the student is the primary thinkers and the teacher serves as the facilitator of learning. Moreover, rather than using primarily premade materials and data, use of authentic materials and data may lend its way to increasing student engagement in science data literacy.

Teachers believe Flexibility is needed in the Curriculum

RQ 3. The following categories were used to reveal teachers believe flexibility is needed in the curriculum: Intentional, schedule, planning, diverse, meeting learners' needs, elaboration, repetition, force, and practicality. Intentional was directly connected to teachers believe flexibility is needed in the curriculum theme, repetition, planning, and intentional. This is because teachers described a need to reteach data literacy concepts, which needed to be planned in pacing guides and needed to be intentionally implemented to improve how students work through concepts related to data literacy. Likewise, schedule was found to be directly connected to teachers believe flexibility is needed in the curriculum theme, planning, intention, and meeting learners' needs as teachers described how the curriculum should allow timing for plans of re-teaching data literacy through intentional instruction to meet students' needs. Extending on the topic of meeting learners' needs, teachers emphasized opportunities for elaboration in data literacy, repetition, and practicality to intentionally address learners' diverse needs. Lastly, force was connected to repetition as teachers, such as Teacher 7, explained how she had to force her students to repeat data literacy tasks to reinforce learning. Figure 28 illustrates the relationship of the categories used to discover the theme teachers believe flexibility is needed in the curriculum for RQ 3.

Figure 28

Connection of categories used to reveal teachers believe flexibility is needed in the curriculum for RQ 3.



Schedule. Schedule was indicated when teachers described timing or pacing as a factor when students need additional time to work through data literacy problems in science.

Teacher 1 explained how he implemented a lab and how it was "…a time to get them up out of their seats because we spend too much time in our seats…." Using different lenses to address time, Teacher 2 stressed the importance of timing when describing how "…setting time…" in the science curriculum intentionally including data could improve data literacy. Nonetheless, Teacher 7 stated "And you got to take into account, each teacher is going to have to spend more time on simple topics because today students do not study, so you're fighting against that." Thus, recognizing that timing in the pacing guide is challenging in science.

Planning. Planning was indicated when teachers explained data literacy learning being scheduled in the curriculum. This category was found to be connected to schedule and repeat as teachers emphasized setting time aside for reiterating concepts. For instance, Teacher 7 stated, "…you have to take these things into consideration…" as she described how she had to plan to repeat concepts.

Intentional. Intentional was indicated when teachers described how data literacy needs to be addressed more intentionally. Teacher 2 described how she believed that teachers needed to be "…more intentional about including…" data literacy needs in PLCs. Likewise, Teacher 2 also stated, "…maybe if you were intentional about setting time…and if the curriculum focused or targeted on specific things about data" as she described how the curriculum could be designed to support data literacy.

Meeting learners' needs. Meeting learners' needs was revealed when teachers explained the data literacy in the science curriculum. For example, Teacher 7 explained that she believed the science curriculum "…needs to be devised to meet students where they are" as she responded to item 14.

Diverse. Diverse was indicated when teachers described a variety of ways to address students' data literacy needs. For example, Teacher 1 explained how students needed to have more active learning when working with data literacy; whereas, Teacher 7 stressed repetition and reading to advance how students work through concepts related to data literacy. Similarly, Teacher 3 stressed collaboration while reading to advance data literacy like Teacher 2. Thus, teachers described diverse ways in how students work through concepts related to data literacy to meet learners' needs, especially since most learners do not have much data literacy background.

Practicality. Practicality was indicated when teachers explained how the curriculum design should be changed to meet learners' needs. For instance, Teacher 7 said, "I think it needs to be more realistic with today's students." She elaborated how expectations, such as reading, have changed over the decades in education.

Elaboration. Elaboration was indicated when teachers described how students' work in data literacy was expanded. For example, Teacher 6 explained how she used class discussions while watching real-life cases to "…expand on a longer discussion…."

Repeat. Repeat was indicated when teachers described constraints in the pacing and instructional timing but recognized a need to repeat and reiterate. Thus, connecting the categories schedule and repeat. For example, Teacher 7 stated, "You're having to reiterate, repeat, reteach, you know? Over and over…."

Force. Force was indicated when teachers described how they had to force students to do particular tasks to work through data literacy. For example, Teacher 7 described how she had students read their textbook and "…made them search it out…" as she explained how students worked through data literacy related to electron configuration concepts.

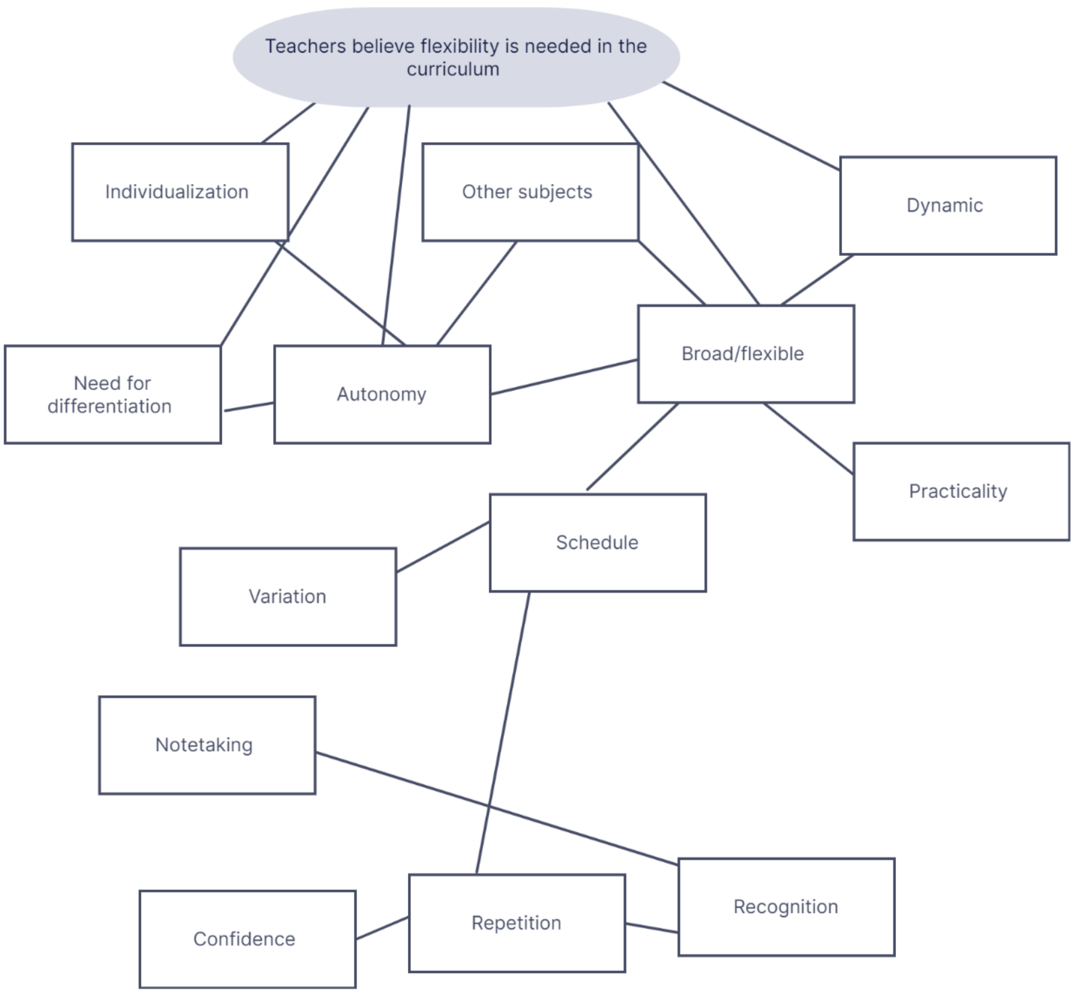
These findings imply that a flexible curriculum that allows time to address data literacy needs in-depth and differentiate learning to meet all learners' needs with emphasis on repetition, elaboration, and practicality would improve how students work through concepts related to data literacy. Consequently, this suggests that the district may be able to improve students' learning by revising pacing guides and to allow flexibility for teachers to intentionally implement data literacy in their science classes to improve how students work through concepts related to data literacy.

RQ 4. Like RQ 3, the findings for RQ 4 suggest that teachers believed the science curriculum should be revised in a way to offer greater flexibility to scaffold and foster data literacy. The categories individualization, other subjects, autonomy, need for differentiation, broad/flexible, practicality, dynamic, schedule, variation, note taking, recognition, repetition, and confidence were used to reveal the theme teachers believe flexibility is needed in the curriculum for RQ 4. Autonomy was found to be connected to individualization, other subjects, broad/flexible, and need for differentiation as teachers emphasized students choices as a way to foster data literacy with an integration of other subjects.

Moreover, broad/flexible was found to be connected to practicality and dynamic as teachers emphasized using practical strategies and evolving with current issues as a way to foster data literacy. Also connected to broad/flexible was schedule, which was connected to variation and repetition, which was revealed as teachers emphasized the need for flexibility in the curriculum to allocate time for a variety of strategies to foster data literacy and repetition to increase students' confidence. Thus, repetition was found to be connected to confidence and recognition, and recognition was found to be connected to note taking as teachers described how they incorporated note taking as a way to help students first recognize information. Lastly, dynamic, need for differentiation, broad/flexible, and individualization were all found to be directly connected to the teachers believe flexibility is needed in the curriculum theme. Figure 29 demonstrates the relationship of the categories used to reveal this theme.

Figure 29

The connection of categories used to reveal teachers believe flexibility is needed in the curriculum theme for RQ 4.



Individualization. Individualization was indicated when teachers described how they provided individual instruction to foster data literacy. For example, Teacher 1 stated, "…it does give me a little time to go around and look individually…" in reference to implementing simple labs in his class. Moreover, individualization was detected among the classroom observations.

For example, Teacher 1 provided direct assistance for students that needed additional help. This was similar to Teacher 3's use of individuation instructional approaches as she circled the room and asked probing questions to guide students in Physics. Likewise, Teacher 6 had a student that did not want to present orally, so the student created the PowerPoint and stood at the front of the room, but the teacher provided the oral presentation. Overall, individualization was evident among physical teachers but limited among life science teachers. This is because physical science teachers included more student centered approaches that allowed for exploratory, flexibly learning while 75% of the life science teachers used whole group instruction and activity throughout the duration of their classroom observations.

Other subjects. Other subjects were indicated when teachers described how improving data literacy in science would improve students' performance in other classes. For example, Teacher 3 emphasized incorporated scientific articles in her classes to improve students' data literacy in science and stated, "…that's going to help them not only in the science classroom, but also in the English classroom with reading their literary assessment in understanding and analyzing how that works scientifically, and it will also let them progress and become better writers themselves." Similarly, Teacher 7 stated, "I appreciate the mathematics and all…" as she explained the importance of understanding the process.

Autonomy. Autonomy was indicated when teachers described how they incorporated choices as a strategy to foster data literacy. For example, Teacher 3 stated, "They can choose" in reference to selecting articles for a data literacy activity in her class. Similarly, Teacher 6 explained how she incorporated autonomy as a means to foster and scaffold data literacy. She explained, "There aren't really any rules. Um, I'll show a movie and one of my students will say (Teacher 6's name), and we will pause the movie and go back and say did you get what was going on?"

Extending on the topic of autonomy, Teacher 4's activity allowed students to choose their model cell and type of solution to conduct an osmosis lab. Students had the option to select a gummy bear, celery, potato, carrot, or egg. Nonetheless, all carried out the same type of osmosis lab to obtain the similar data for interpretation of cellular tonicity.

Need for differentiation. A need for differentiation was indicated when teachers described the variety of students' data literacy abilities. It was evident there was a need for differentiation as teachers explained how some struggled with data literacy while others needed to not be given "every single thing" as indicated by Teacher 7. Moreover, Teacher 1 stated, "…we really have a mix in Physical Science um, there are some ex-Ed students that do struggle. It's just hard. And you know, some solid 'B' students and maybe even some 'A' students…."

Broad/flexible. Broad/flexible was indicated when teachers described a wide range of strategies used to foster data literacy. For example, Teacher 6 replied to item 9 by stating "And then use that to apply to a future case or to whatever else is going on," which suggests she viewed data literacy applicable to a variety of learning concepts in her class. Comparably, Teacher 2 viewed data literacy in Biology as being broad and suggested a clearer focus could improve the science curriculum. For example, she stated, "Because in high school, it is very broad. It's kind of everything about data, so maybe if it was maybe a little more specific it would help." Teacher 7 stated, "I don't feel comfortable uh, adhering to the sets of rules…." She further explained a need for flexibility in the science pacing curriculum by stating, "I would love to do that, but I don't see the point if my students don't know the information. If they're struggling, and I move on to something else, what…what, what am I going to do?"

Practicality. Practicality was indicated when teachers explained how the curriculum design should be changed to meet learners' needs. For example, teacher 7 explained how she thought the curriculum should "…be more realistic with today's students."

Dynamic. Dynamic was indicated when teachers described how the curriculum should be evolving to foster data literacy. For example, Teacher 6 stated, "I think the best design is to be constantly changing, to be evolving with issues as new issues arise." This was also evident in her classroom observation as she focused on recent, relevant cases in her Forensics course.

Schedule. Schedule was indicated when teachers described timing or pacing as a factor to foster data literacy. For example, Teacher 7 stated, "…you got to take into account, each teacher is going to have to spend more time on simple topics because today's student does not study, so you're fighting against that." Teacher 1 explained time was a constraint in attempting to make changes to the curriculum, He stated, "I feel mainly there's not a whole lot of time with everything else we have to do to improve on that so I have taken what we have done in the past…." Like the interviews, the category schedule was revealed in classroom observations. For example, Teacher 2 explained the instructions of the station activity and said, "When the timer goes off, move to another station even if you aren't done. I apologize but if we have more time towards the end, then you can go back."

Variation. Variation was indicated as teachers shared the diverse length of time they allocated to data literacy in science. For example, Teacher 2 stated, "How much time? Not enough." However, teacher 3 replied, "I don't really look at it as a time. It's more of an incorporation to what we're doing because science is a lot of data on its own…" She further explained, "It's more of an incorporation every single day." Similarly, Teacher 4 stated, "I feel like I use it every day." Comparably, Teacher 5 replied, "…we'll probably be allocating at least a good portion of the day if not all 90 minutes today….” Nonetheless, when asked to provide a percentage similar to other teachers, she stated, “…it's probably a good 20-30%....” This was in a close range of Teacher 1’s response, which stated, “I would say 20% is generous.” Moreover, Teacher 8 replied, “So, I would say probably every um…eee, at least every lecture or a few times a week.” Nonetheless, similar to Teacher 1, Teacher 8 also stated, “I would say probably 20%....” Lastly, Teacher 7 stated, “That I'm struggling with. I'm struggling with it.”

Note taking. Note taking was indicated when teachers emphasized students taking notes as a way to scaffold and foster data literacy. Teachers 1, 2, 5, 7, and 8 described note taking while Teacher 7 put greater emphasis on it as a strategy to foster learning. For example, she explained how she will ask simple questions and if students cannot answer the questions, that will tell her “…you're not taking good notes.”

Recognition. Recognition was indicated when teachers described how they introduced materials to help students recognize it. For example, Teacher 5 stated, Just making sure that they know what it looks like so that when they can encounter it, they may not know how to read it, but they can at least go “Okay, I know what this is” in her responses to item 4 as she explained strategies used to foster data literacy.

Repetition. Repetition was indicated when teachers described how repeated exposure fostered data literacy. Teacher 2 stressed repeated exposure by saying, “…the more…they saw it, the better they were at umm, reading.” Additionally, when asked how she advances students' data literacy, Teacher 2 replied, “Practice, practice, practice.” She further explained, “The more they practice and have conversations about it, I feel like the more confident they become….”

Similarly, Teacher 5 emphasized repetition as she explained, “…they are going to get repetition and hopefully learn how to read it.” Similarly, Teacher 7 explained how she incorporated repetition in her warm up questions as she stated, “They get the same questions recycled in their warm up.” Teacher 7 also explained how she used worksheets as a way to accompany students’ notes for students to practice what they are learning. For example, she stated, “…we have worksheets that accompany those, so once we finish or sometimes in the middle of a presentation uh, we stop, and we’ll give them a worksheet just to see if what we’re saying is sinking in.” Comparably, Teacher 6 emphasized repetition as she explained, “…the more you study something, the more comfortable you become with it. You become fluent in that language….” Likewise, Teacher 8 stated she, “Just kind of reiterates…” explanations extracted from resources in progress learning to foster data literacy in Biology. Additionally, Teacher 3’s response focused on repetition as she stated, “…the more that they are shown different articles, different lab reports, different magazines, etc. that deals with science…it's going to make them grow in their literary text….”

Extending on repetition, teachers revealed this theme in their classroom instructional approaches. For example, Teacher 1 projected a question and stated, “We did this at the beginning yesterday so let’s do it again real quickly.” Likewise, it was evident that he incorporated practice activities as a way to implement repetition and reiterate concepts to prepare students for assessments. For example, he reminded students that they would have a quiz on the concepts they were reviewing using the quizzes and density lab. Similarly, during the observation, he explained to the students multiple times how to calculate densities as students completed the lab. Moreover, activators was a code used to identify repetition as activators observed included review from previous material taught. Teachers 1, 2, 5, 7, and 8 included activators in their observations.

Confidence. Confidence was indicated when teachers described how they used strategies to foster students' data literacy by increasing their confidence. For example, Teacher 2 was asked how she advanced students' data literacy to which she replied, "The more they practice and have conversations about it, I feel like the more confident they become…."

These findings suggest that the curriculum and pacing guide should be reviewed and revised to ensure time is allocated for teachers to implement differentiation, individualization, and choices in their science classes. Moreover, the category dynamic was revealed when Teacher 6 suggested that the curriculum should be evolving with current issues. This is likely an area that needs to be further addressed as most teachers indicated they used premade materials and data, which may suggest such materials may be outdated and influence students' lack of interest. Additionally, the findings suggest that repetition through repeat instruction, re-teaching, and practice were common ways teachers fostered data literacy. Thus, this implies that teachers should take this into consideration when developing unit plans to ensure time is allocated in this area.

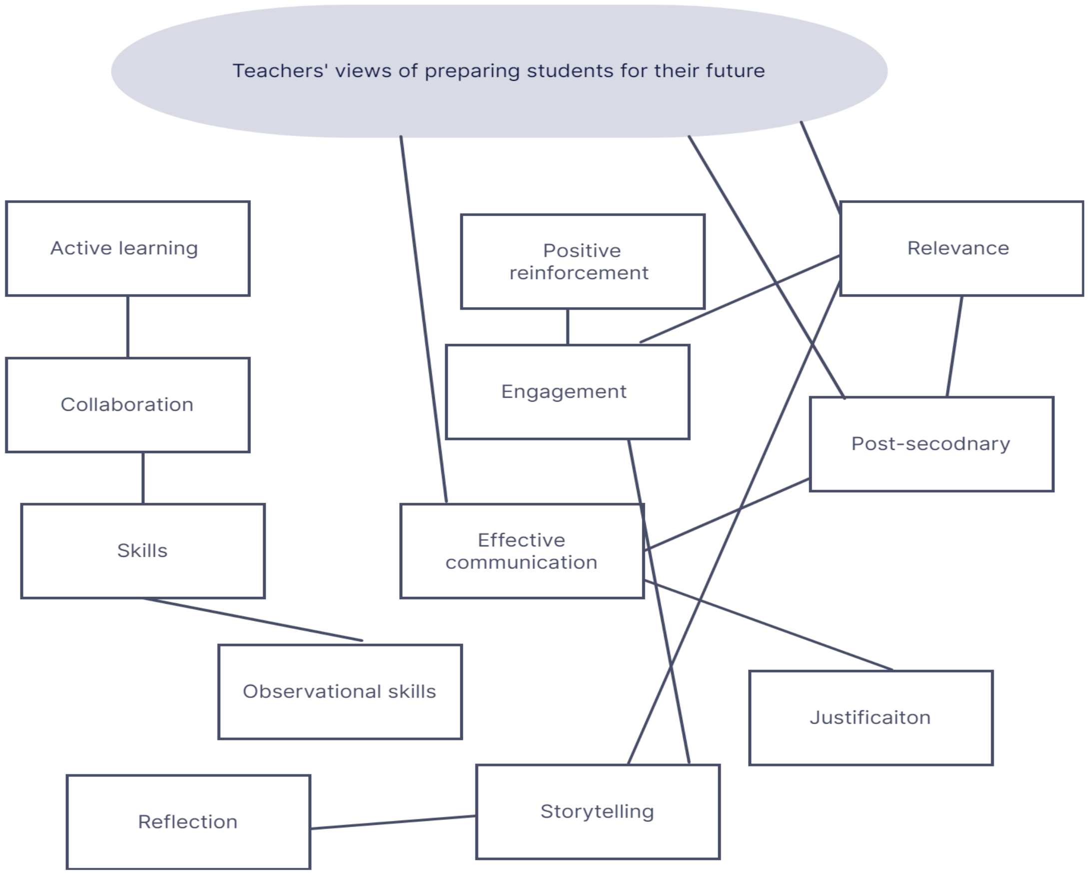
Teachers Believe Preparing Students for their Future was Vital

RQ 4. Teachers believe preparing students for their future was vital theme was revealed by the following categories: Active learning, relevance, engagement, positive reinforcement, collaboration, skills, observational skills, reflection, storytelling, post-secondary, effective communication, and justification.

Effective communication was found to be connected to the theme of preparing students for their future, post-secondary, and justification because teachers emphasized students knowing how to communicate as a skill needed in the real-world. Relevance was found to be connected to the theme of preparing students for their future, post-secondary, and engagement as teachers emphasized using real-life strategies to engage students and prepare them for after high school. Positive reinforcement was found to be connected to engagement as Teacher 8 used candy as an incentive for her students to engage in class discussions. Additionally, active learning was found to be connected to collaboration as students worked in groups to actively complete activities. Skills were found to be connected to collaboration because Teacher 1 emphasized collaboration was a skill students needed to prepare them for future careers. Likewise, observational skills were found to be connected to skills as teachers described how observational skills were needed to foster data literacy but also beneficial outside of education. Moreover, reflection was found to be connected to storytelling as teachers were reflective in their practices and experiences as they answered interview questions, and storytelling was a way Teacher 6 described how she reflected and shared her real-life experiences to students. Figure 30 demonstrates the relationship of categories used to reveal this theme for RQ 4.

Figure 30

Connection of categories used to reveal teachers believe preparing students for their future was vital for RQ 4.



Active learning. Active learning was indicated when teachers described or implemented learning by doing as a strategy to scaffold and foster data literacy. For example, Teacher 3 explained how students "…can perform their own labs and get their own data, and we will analyze it by creating graphs." Similarly, Teacher 1 stated, "We use labs to generate a source of data." This was also evident in his observations as he implemented a density lab where students had to actively engage in learning and calculate the density of different objects in the classroom. Moreover, Teacher 3 implemented a lab in her class, which required students to use the metric system by measuring objects in the room and converting numbers. Comparably, Teacher 2 implemented active learning in her class observation by having students rotate around the room to seven different stations to assess data literacy aligned to population dynamics in Biology.

Additionally, active learning was revealed among teacher observations. For example, Teachers 1 and 3 had their students engaged in a lab where they obtained and interpreted data sources, and teacher 2 had her students complete a collaborative station activity. Nonetheless, little active learning was observed among Teachers 5 and 8.

Like interviews and observations, document analyses indicated active learning. For example, Teacher 1 provided a data literacy activity, which was a heating curve lab. In this activity, students had to use lab materials to view the phases of matter of water and compare and contrast data sources. After students obtained their data sources, they created graphs. Similarly, Teacher 3 provided a data literacy activity, which required students to obtain data using scientific notation and unit conversions.

Overall, physical science teachers emphasized and implemented more active learning than life science teachers. For example, Teachers 1 and 3 discussed and implemented labs in their observations. Likewise, Teacher 6 had her students present cases to the class. Only Teacher 2 of the life science teachers clearly implemented active learning during the observation. However Teacher 4 did discuss how she implement an osmosis lab the day prior to her classroom observation. Nonetheless, Teachers 5 and 8 had less active learning in their observations as a majority of their instruction was lecture style. Physical science teachers had a stronger focus on labs. Teachers 1 and 3 described the same rocket lab they have implemented in physics.

Relevance. Relevance was indicated when teachers described how they implemented strategies related to students' lives to foster data literacies. For example, Teacher 7 explained how she had her students "…present orally two paragraphs on a current science event" every Friday in Chemistry. Likewise, Teacher 1 stated, "I try to make it for them to understand how it plays a part in their lives."

Like the interviews, teachers incorporated real-life connections in their instructional approaches during classroom observations. For example, Teacher 2 asked, "If I was drag racing, which one would that place in?" Similarly, Teacher 5 provided an example of blowing a dandelion's seeds as an example of random dispersion.

Similar to interviews and observations, real-life connections were revealed in document analyses. For example, Teacher 3's data literacy activity required students to obtain data from common classroom objects, such as pencils, desks, notebooks, and the classroom walls. Likewise, Teacher 3's assessment included real-life connections by having students obtain, convert, and interpret data sources related to a rocket lab to assess students' learning of velocity, distance, and acceleration in Physics. Additionally, Teacher 4's activity included questions that applied concepts to real-life, such as the use of sprays. Similarly, another question in her document asked, "What would happen to your cells if you got an IV drip that was not very concentrated?" Thus, these questions related concepts learned in the lab to students' lives and bodies. Between life science and physical science teachers, physical science teachers emphasized and incorporated more examples and activities of real-life situations.

Engagement. Engagement was indicated when teachers described how they used relevant materials to spark interest among students and observations of students engaged with working with concepts related to data literacy. For example, Teacher 3 described how she incorporated relevant research articles as a strategy to "…interest the kids…." Similarly, Teacher 4 described how she presented her students with problems, such as water intoxication as a way to "hook" them and "…get them thinking about what we're going to be discussing later on."

Moreover, engagement was also detected among the teachers' classroom observations.

For example, although Teacher 1 did not have students willing to answer his questions, he had many participate in the density lab and make an attempt to complete it. Moreover, Teacher 2 had 100% engagement in the station activity she implemented in her Biology class. Similarly, students responded to the questions she asked. For example, one student replied, “You’re going up a hill” to a question the teacher asked related to a graph.

Although a moderate to high engagement was detected for Teachers 2 and 4, Teachers 5 and 8 had limited engagement in their class compared to the other life science teachers and physical science teachers. Thus, overall engagement appeared to be higher among physical science teachers compared to life science teachers. Several factors likely contributed to these findings. First, physical science teachers had more hands-on learning activities. Additionally, physical science teachers incorporated more real-life connections in their class compared to life science teachers overall. For example, Teacher 1 had his students calculate densities of common classroom items, Teacher 3 referenced winning a race to stress the importance of precise micro-units, and Teacher 6’s entire lesson focused on a person wrongfully convicted of a crime. Thus, these relevant connections likely contributed to increased student engagement. It is difficult to state whether or not teachers’ years of experience had an influence on student engagement because Teachers 2, 5, 6, 7, and 8 all had limited experience in teaching high school science.

Positive reinforcement. Positive reinforcement through extrinsic motivation was indicated as teachers provided rewards for participation. For example, Teacher 8 told students that as they answered questions, she was going to hand out candy for those who participated and answered. However, four students still had their heads down and thus appeared to not be motivated by the rewards offered.

Collaboration. Collaboration was indicated when teachers described how they used group work to foster data literacy. For example, Teacher 2 explained that "…peer interaction and discussions…" were common strategies she used to scaffold data literacy. Similar to Teachers 2 and 3 who described how they used collaborative groups as a strategy to foster data literacy, Teacher 4 described how she also implemented this and developed groups based on students' grades. For example, she stated, "I take pretty much the students that have the same grade, and I put those students into one group and then as… as they get I guess better grades, they'll be grouped together too so they're working in different groups." Additionally, Teacher 2 described how collaboration increases students' confidence. For example, she said, "You know, two brains are better than one, and it builds confidence, and it helps them to troubleshoot off of each other." Similarly, Teacher 3 stated, "…starting with easier articles at first or easier graphs to interpret at first to try to build up their confidence…."

Additionally, teachers' confidence was a topic of interest during classroom observations. Some teachers, such as teachers 3 and 4, displayed a lack of confidence in interviews but confidence in classroom observations. Nonetheless, Teachers 5 and 8 displayed a lack of confidence in their observations like their interviews.

Moreover, collaboration was a central focus among several of the classroom observations. For example, Teacher 2 explained to her students that she wanted them to "Interact, get up, and talk about the data." Moreover, Teacher 3 had her students work in groups to complete a metric lab. Students worked together and helped each other out when needed. In contrast, Teacher 4 had little collaboration in her class as students worked independently on all assignments. It was very quiet in her room. This was similar to Teacher 5's and 8's observation.

Like interviews and observations, collaboration was detected in document analyses. For example, Teachers 1 and 3 provided data literacy lab activities, which required students to work together to obtain and interpret data sources. Moreover, Teacher 3 provided a rocket lab as a data literacy assessment. This assessment required students to work together to perform the rocket lab and answer questions associated with data obtained and calculated.

Collaboration was emphasized and implemented more among physical science teachers than life science teachers as revealed in the interviews and observations. For example, Teachers 1 and 3 had their students complete a lab collaboratively. Similarly, Teacher 6 had her students engage in discussions as a way to analyze Forensic cases. Teacher 7 did not explicitly instruct students to work together. However, during the observations, students moved their chairs and engaged in discussions as they worked through electron configuration. Little collaboration took place in Teacher 5's, 4's and 8's classroom. However, Teacher 2 did implement a collaborative station activity during her classroom observation. Teachers 3, 6, and 7 emphasized discussions as a way to incorporate collaboration in their classes.

Skills. Skills were indicated when teachers described differentiation in skills as a strategy to target data literacy. For example, Teacher 3 explained how she grouped students ". . . based on skill" as a way for students to collaborate and help each other.

Observation. Observation was indicated when teachers emphasized targeting observation skills as a way to foster data literacy. For example, Teacher 6 explained, "…I told them that's what I wanted them all to be, observant…" She reiterated the need to be observant outside of science and explained how it was useful in any investigative approach. For instance, Teacher 6 stated, "…but there's a lot of careers that would focus on this, and I want them to be able to be observant and understand how that applies in life." Comparably, Teacher 4 stated her students needed "Better observation skills" to overcome challenges with data literacy.

Taking the topic of observations in a different direction, Teacher 1 appeared to use observations as a way to locate students struggling with the density lab so that he can provide additional assistance to facilitate data literacy learning. For example, he identified students that did not know how to properly use a scale to get the mass of an object to calculate its density. Consequently, he stated, “When you weigh the water, make sure you zero out the scale”

As emphasized in Teachers 4’s and 6’s interview, the document they supplied emphasized interpretations of observations. For example, Teacher 4’s activity required students to record their observations and make conclusions based on observational data from an osmosis lab. Comparably, Teacher 6’s activity required students to be observant while watching an episode of the Avery case to answer questions associated with the video.

Reflection. Reflection was indicated when teachers described how they used reflexive questioning to improve students’ data literacy. Teacher 4 emphasized reflective practices and how she had her students consider questions such as, “What do you know? What do you want to know? What have you learned?”

Taking the topic of reflection in a different direction, Teacher 2 stated, “I guess I should do that” as she explained how she did not necessarily use the local context to foster data literacy. Similarly, when asked about item 8, Teacher 1 replied, “Scaffolding…yeah, I need to work on that.” Likewise, Teacher 7 explained how she was “…still learning how to unpack some of the standards”

Similarly, reflection was also identified among the classroom observations. For example, Teacher 7 explained to students how she had misconceptions and had to study the periodic table herself. Comparably, reflections were indicated in document analyses as prompts in the documents required students to think about their own thinking. For example, one question in the

Teacher 3's document activity asked, "1. The SI unit for mass is the kilogram. Why do you think the kilogram is a better unit for mass than the gram?"

Storytelling. Storytelling was indicated when teachers discussed how they told stories of their experiences as a strategy to make data literacy relevant to students. Teacher 6 revealed this category. For example, Teacher 6 stated, "I'll tell a lot of stories from my experience." She explained how this engaged the students as "…they really like that part." Additionally, she explained how the sources of data she used in her class were usually "…from the stories that we use and the cases that we use."

Post-secondary. Post-secondary preparation was indicated when teachers described strategies they implemented that also helped prepare students to be successful after high school. For example, Teacher 6 explained how she implemented oral presentations to get students "…comfortable presenting because you never know and later on in life you never know. They may want to go for a doctoral degree and from my understanding, you have to defend a thesis, so you have to be comfortable speaking with people. And secondly, uh, many of my seniors may be headed into the job force or some other type of uh, something else where they need to hone their skills in terms of conversation and presentation." Moreover, Teacher 7 explained how she was trying to teach her students to be resourceful by utilizing information in their textbook in Chemistry. She stated, "You get on a job, they hand you an employee manual, and you break a cardinal rule in the company. No one accepts you don't know where to find it." Additionally, Teacher 1 suggested that collaboration was an important part of helping students prepare for their future. Specifically, he stated, "So helping them with going out in the real-world unless you are going to be a lab rat and work by yourself." Similarly, Teacher 5 stated how she would likely give students a lab report assignment "Because if they go on to college, they will need to know how to write a lab report." Physical science teachers focused more on post-secondary education as this theme was revealed among all physical science teachers.

Effective communication. Effective communication was indicated when teachers stressed using strategies of communicating data orally. Teachers 6 and 7 stressed this. Teacher 6 explained how she had her students present to the class because she believed they needed to "know how to speak to adults." Similarly, Teacher 7 stressed communicating data and stated, "…know your material so well so that you can stand up here and have a conversation about your material, so I'm just trying to teach that life skill along with science because the worst thing in the world is to encounter people who have problems expressing themselves." She further explained that if students do not know how to effectively communicate, then they "…struggle in the workforce."

Justification. Justification was indicated when teachers had their students cite evidence to justify their claims as a strategy to foster data literacy. For example, Teacher 6 had her students make claims on Avery's innocence or guilt and use evidence to support their claim. For example, one student suggested there were inconsistencies in the statements used as evidence in the Avery case and argued that the data did not align to prove his guilt. He suggested that there were no clear connected dots in the evidence, which was needed to convict Avery of murder.

Moreover, justification was revealed in document analyses. For example, Teacher 4's document asked students to answer an osmosis question and explain why or why not following their response. Similarly, two other questions in her activity required students to justify their responses by using data and observations. For example, one asked, "What type of solution would you identify your solution 1 as? Justify your answer using your data and observations from table 1."

These findings suggest that physical science teachers' conceptions of data literacy centered on using real-life connections with a focus on post-secondary preparation. Thus, these findings also imply that physical science teachers were more up-to-date with relevant topics and issues in the world related to science, which also likely contributed to the higher level of engagement detected among physical science teachers compared to life science teachers.

Considering the previous findings, this overarching theme suggests that teachers should devise a curriculum that promotes autonomy and flexibility for students to explore their own interest and advance skills needed as future adults. Thus, conversations and demonstrations of how what students are learning in class relates to their future would likely be beneficial in fostering data literacy in science.

Summary for each RQ

RQ 1 Summary

Overall, the findings for RQ 1 assert that teachers' lack confidence in their conception of data literacy in science. Many lacked confidence as they responded to questions that addressed their conceptions of data literacy in the interview. This suggests that some teachers may not have a complete idea of data literacy. Nonetheless, some teachers, such as Teacher 7, recognized ambiguity in data literacy in science as she suggested there needed to be resources available with central information to help teachers know what to teach, which led to the development of the theme teachers believe discrete understanding of data literacy is needed

Although diverse in many of their responses, teachers shared common views in what they knew about data literacy in science. For example, teachers' data literacy conceptions centered on understanding their students' past experiences and prior learning with data literacy so that they can meet the learners' needs, and teachers emphasized making connections as a way to teach students data literacy in science. Teachers described a variety of ways to connect data literacy to students, such as interdisciplinary methods, which all teachers disclosed.

Despite similarities detected throughout the interview, each teacher had a unique idea of data literacy, which varied based on perceptions. This aided in answering RQ1 as it implies teachers' conceptions of data literacy are based on individual perceptions, which are shaped from past experiences. Differences in past experiences helps explain RQ1 and further explains how each teacher's conceptions were diverse in certain ways.

While past experiences shaping diverse conceptions, teachers' conceptions of data literacy in science included connecting data sources with science concepts through relevant and engaging strategies. Lastly, teachers' conceptions of data literacy was based on observations and detections of data literacy needs, which varied based on perceptions.

RQ 2 Summary

Overall, the findings for RQ 2 suggest that teachers' views of students' data literacy in their classes depend on students' past experiences. All teachers cited past experiences affecting students' data literacy. Teachers indicated that limited students' experiences in data literacy negatively impacted students meeting their expectations of data literacy in their science classes. Moreover, teachers indicated that such deficiencies in data literacy by the time they reach their high school science classes negatively impact students meeting their expectations of skills, depth of knowledge, and depth of learning of data literacy in their science classes. Consequently, teachers explained how they had to allocate additional time to reteach concepts or teach concepts that students should have been previously taught in order for students to meet their expectations. Even then, teachers, such as Teacher 7, explained how this was difficult to accomplish while also trying to stay on pace with the science curriculum as individualization and additional help through facilitated data literacy learning was essential based on students' previous experiences in order for students to meet teachers' expectations of data literacy in their science classes. These findings suggest that teachers' expectations of students' data literacy was based on their past experiences, and earlier exposure with learning retention was needed for students to meet teachers' expectations of data literacy in their science classes. Nonetheless, teachers' expectations varied as teachers cited different observations and senses used as they explained their expectations, which likely contributed to diverse perceptions leading to differences in conveyed expectations. Likewise, these findings also suggest that teachers' past experience of data literacy likely impacted their perceptions and interpretation of data literacy expectations for students in their science classes.

Additionally, teachers lack confidence with data literacy theme revealed that nearly all teachers lacked confidence in describing their expectations of students' data literacy, which assert that students' data literacy is likely directly affected as teachers struggled in describing times that students were engaged or what engagement in data literacy in their class looked like.

Teachers had different views and expectations of representing data in their science classes. For example, some teachers had positive perspectives towards modeling, implementing labs, and real-life applications for students to meet their expectations of data literacy. However, others, such as Teachers 1 and 3 emphasized integrated subjects in their expectations of students' data literacy. Teacher 3 suggested that knowing essential vocabulary was necessary before students could engage in other data sources and thus emphasized readings in her expectations of representing data literacy in her science classes. Although teachers had different views of representing data literacy, all recognized that data literacy representation was necessary for students to reach their expectations in their science classes. These implications suggest that a focus on data literacy representation that is more cohesive among teachers may help improve teachers’ confidence with data literacy and help students meet teachers’ expectations of data literacy in their science classes.

Extending on a need for a cohesive understanding of data literacy, the theme teachers believe discrete understanding of data literacy is needed revealed that teachers recognized a lack of transparency in data literacy expectations in the curriculum and suggested that refined, clearer expectations would aid in students meeting their expectations of data literacy in their science classes as this will offer a strategic, common avenue for teachers to foster data literacy in their science classes.

Lastly, teachers believe there are inadequacies in students’ data literacy theme suggested that teachers emphasized data literacy deficiencies negatively impacting students’ learning and ability to meet expectations in high school science classes. Since there are inadequacies in students’ data literacy, teachers indicated that they had to lower their expectations. Consequently, these findings assert that targeted interventions of students' data literacy would facilitate students reaching teachers’ data literacy. Nonetheless, considering teachers lack confidence with data literacy as found for RQ 1, 2, and 3, the findings suggest that training first targeted towards teachers centered on data literacy in science would likely be beneficial first so that they can then use their learning to help advance data literacy in their science classes and adequately guide students in meeting data literacy expectations.

RQ 3 Summary

The findings demonstrate that like RQ 1 and 2, teachers viewed students' previous experiences with data literacy as a factor that affected how they worked through concepts related to data literacy. They explained how students' past experiences with data literacy affected their knowledge, understanding, depth of learning, reasoning, and skills as they worked through concepts related to data literacy. Thus, teachers explained how students' past experiences affected how challenging the materials could be, progression in the curriculum, and the level of assistance needed. Consequently, these findings imply that early exposure with emphasis on retention would help in advancing how students work through concepts related to data literacy.

Nonetheless, like RQ 1 and 2, differences in teachers' perception was also detected, which likely contributed to diverse interpretations of how students work through concepts related to data literacy. Teachers described different senses they used as they explained how students worked through data literacy, and the explanations varied across teachers, which aligned to the literature suggesting that there is not a single agreed upon understanding of data literacy making it open for interpretation.

Moreover, like RQ 1 and 2, teachers demonstrated lack of confidence as they responded to items aligned to RQ 3 suggesting that they lacked confidence in data literacy, which likely affected how students worked through concepts related to data literacy in their science classes. Consequently, this implied that teachers would benefit from targeted data literacy training, as some teachers indicated they were uncertain of what data literacy was and others stated they had not really thought of data literacy before. Therefore, professional learning centered on data literacy for teachers would likely improve how students work through concepts related to data literacy in science.

Similar to teachers' perceptions, teachers' views of representing data literacy varied. Nonetheless, many stressed data modeling, visuals, collaboration, active learning, and relevance as necessary ways to represent data as students worked through concepts related to data literacy. Although there was a broad spectrum of how teachers believe data literacy representation could be implemented, teachers cited resources as a limitation. Consequently, the findings suggest that clearer communication and district training could aid in teachers having a more uniform view of data representation in their classes and a better understanding of how they can teach concepts related to data literacy, which will affect how students work through concepts related to data literacy in their science class.

Like RQ 2, RQ 3 revealed that teachers had strong views of inadequacies in data literacy affecting how students worked through concepts related to data literacy. Teachers suggested that such inadequacies were because of students' lack of motivation, superficial learning, ineffective instruction, and important concepts being overlooked and/or forgotten. Consequently, teachers viewed students' data literacy as deficient by the time they came to their class, which suggested that early intervention targeting students' data literacy needs and motivation would likely improve inadequacies in learning.

Lastly, teachers believe there is a need for flexibility in the curriculum was revealed as they described how students needed additional support as they worked through concepts related to data literacy. Teachers stressed a need for additional planning in the curriculum to provide intentional data literacy instruction to meet the needs of diverse learners through repetition, practicality, and elaboration. Consequently, these findings suggest that the district may want to target curriculum pacing to improve how students work through concepts related to data literacy in science.

RQ 4 Summary

Similar to RQs 1, 2, and 3, RQ 4 findings demonstrate that the way teachers foster data literacy was dependent on students' past experiences, which information is obtained through feedback of students' understanding. Teachers used this information to implement gradual progression in data literacy learning. However, the challenge of this progression was typically low, especially in the beginning of their course as teachers indicated that students often come to them with little data literacy knowledge and understanding. Thus, these findings suggest that early intervention in lower grades could advance students' data literacy and allow teachers to implement more rigorous data literacy instruction in high school science to promote critical thinking.

Moreover, perception was found to influence communication of data literacy as revealed in the other RQ findings, and this was found to be closely connected to past experiences. Differences in perceptions likely contribute to variations of analyzing and communicating data sources as revealed among physical science and life science teachers. This mirrors past literature, which indicates that there is not a single agreed upon definition of data literacy, which likely influences teachers' conceptions and ways they foster data literacy in their science classes.

Extending on similarities identified among the RQs, lack of confidence was also revealed for RQ 4, which influenced the way teachers fostered data literacy in their science classes. Although lack of confidence was identified in data sources for all teachers, it was more prevalent among life science teachers. These findings imply that professional development on data literacy will likely improve teachers' confidence, which is connected to self-efficacy and improved students' learning.

Similar to RQ 3, RQ 4 identified that teachers believed there were inadequacies in the current science curriculum. A need to find ways to engage students through purposeful instruction was identified. Several students in Teachers 5 and 8 class slept through nearly the entire lecture during the classroom observation. Additionally, it was evident that teachers used mostly premade materials and data, some of which were outdated as also indicated by Teacher 1 in his interview. Thus, these findings assert that revising the curriculum, especially the life science curriculum, to include more hands-on learning using a student-centered instructional approach will likely improve student engagement. Moreover, as the literature suggests, authentic materials and data would likely improve relevance and engagement in science data literacy learning.

Teachers believe there are inadequacies in the curriculum demonstrated a need to revise the science curriculum, which was also revealed as teachers revealed timing as a factor that influenced how data literacy was fostered. Some teachers, such as Teachers 2 and 7, indicated that students struggle with data literacy even after practice and thus needed additional time allocated to them through differentiated learning. Thus, these findings revealed that the science curriculum needed to be reviewed and revised to ensure adequate time is included for practice and differentiated learning to meet all students' data literacy needs.

Overall, physical science teachers emphasized collaboration, active learning, and student centered approaches more than life science teachers. Only one of the life science teachers included collaboration and student centered approaches in their observation; whereas, collaboration and student centered approaches was revealed among all physical science teachers Likewise, all physical science teachers emphasized preparing students for their future as a way to foster data literacy in their classes. These findings imply that strategies used to foster data literacy are also beneficial for postsecondary education and careers and thus should be considered when designing and implementing data literacy instruction in science. Moreover, considering the findings, which demonstrated that physical science teachers included more hands-on learning, had higher student engagement, and more confidence, life science teachers would likely benefit by collaborating with physical science teachers so that they can share the strategies they use to foster data literacy with a postsecondary preparation emphasis.

The final chapter discussed the findings in connection with literature cited in Chapter II. Analysis of the findings are discussed for each RQ in order, which is followed by a reflection from the researcher, discussion of limitations, recommendations, implications, and a proposed dissemination plan.

Chapter V: Conclusions

The present research employed a qualitative case study design to discover life science and physical science teachers' conceptions, expectations, and strategies used to foster data literacy. Data were obtained through semi-structured interviews, classroom observations, and document analyses. Open coding, axial coding, and thematic analysis were used to analyze the data. This final chapter will discuss the findings presented in Chapter IV in connection with the literature in Chapter II. Additionally, limitations, recommendations, implications, and a dissemination plan.

Summary of the Study

The present research was situated on addressing the problem of underdeveloped data literacy among students in science in the school district where the researcher works by first identifying teachers' conceptions of data literacy and strategies used to foster data literacy in science classes. Limited research was available to address teachers' conceptions of students' data literacy and differences, if any, between life science and physical science high school teachers. Thus, the purpose of the present research was to use a qualitative research design to discover the conceptions life science and physical science high school teachers have toward students' data literacy and strategies used as well as differences, if any, between the two groups of teachers in a district located in west-central Georgia.

Semi-structured interviews, classroom observations, and document analysie were used to answer four research questions centered on data literacy in high school science classes. Eight teachers were included in the research and selected using non-random sampling. Barriball and While (1994) suggest that semi-structured interviews aid the researcher in gaining in-depth data through open-ended predetermined prompts with use of follow-up questions when needed.

Moreover, observations allowed the researcher to obtain data in the natural setting, which was each teacher's classroom for the present study (Merriam & Tisdell, 2016). Document analyses supplied supplementary objective data to other qualitative approaches, such as interviews and observations (Bowen, 2009; Fereday & Muir-Cochrane, 2006). In the present study, document analyses followed interviews and classroom observations, and interviews were used as the primary source of data collection. Data were analyzed using open coding, axial coding and thematic analysis to identify overarching themes. The subsequent sections will discuss key findings aligned to literature cited in Chapter II, a discussion of limitations, recommendations, implications, and a proposed dissemination plan.

The key findings align with much of the literature that addresses data literacy in science. For example, all teachers demonstrated a lack of confidence in their conceptions and instructional practices of data literacy. Moreover, students' past experiences influenced teachers' expectations and practices used to foster data literacy. Furthermore, teachers' past experiences appeared to affect their perception and interpretation of data literacy conceptions, expectations, and strategies used to foster learning. This is aligned to the transformative learning theory, which suggests individuals make sense through their own experiences and interpretation of sense making varies based on one's belief, expectations, experiences, and purpose (Bush et al., 2020; King et al., 2019; Perry, 2021).

Comparably, teachers shared different ideas of representing data literacy, but emphasized visuals, such as graphs, tables, charts, and images to portray data literacy. Additionally, teachers viewed data literacy in a broad sense and suggested that it should be integrated with other subjects, and physical science teachers emphasized a focus on postsecondary education using data literacy. However, teachers believe discrete understanding of data literacy is needed and inadequacies in data literacy in science was revealed. These key findings will be further discussed in connection with the literature in the subsequent section.

Analysis of Findings

RQ 1

The findings revealed that teachers lacked confidence in data literacy in science, and many teachers indicated limited conceptions of data literacy in response to items in the interview aligned to RQ 1. This was similar to literature, which found that students and teachers were deficient in data literacy (Cezar & Maçada, 2021; Kennedy-Clark et al., 2020; McCoy & Shih, 2016). Similar to previous research (Papamitsiou et al., 2021; Shernoff et al., 2017; Vanhoof et al., 2013; Yang, 2022), all teachers expressed some level of lack of confidence, which indicated training should be developed to make improvements in this area. This suggestion aligns with Miller et al. (2021), which found that professional development improved teachers' confidence and has the potential to positively influence self-efficacy, which has a direct effect on instructional practices (Ceylan, 2020). Moreover, these trainings should center on data driven decision making to improve teachers' conceptualization of data literacy (Green et al., 2015; Ndukwe & Daniel, 2020; Piro & Hutchinson, 2014; Raak et al., 2021; Schramm-Possinger & Harris, 2021).

Elaborating on this topic, teachers demonstrated uncertainty in data literacy, and some could not provide responses to items in the interview as they indicated they had not experienced the questions being asked related to engaging students in data literacy and helping students overcome problems connected to data literacy. These findings align to the transformative learning theory, which suggest conceptions are influenced by experience (Mezirow, 2009). Thus, limited experiences result in limited conceptions of data literacy. Consequently, these findings suggest that teachers in the district would benefit from individualized data literacy trainings as revealed in the literature (Filderman et al., 2021; Ndukwe & Daniel, 2020; Raffaghelli & Stewart, 2020; Shernoff et al., 2017; Yang, 2022).

Like the prior research (Shernoff et al., 2017), the present study found that teachers expressed a need for additional data literacy support. For example, Teacher 4 stated she would like to know more about data literacy since it would help improve her students' learning. This was similar to Danley's (2020) research that found teachers had additional questions related to learning data literacy and Green et al.'s (2015) findings, which indicated teachers were eager to learn more about collecting and analyzing data and how to use data to inform instruction after being introduced to it in workshops. Consequently, this further solidifies the need to implement professional learning centered on data informed teaching practices (McCoy & Shih, 2016; Ndukwe & Daniel, 2020; Raak et al., 2021; Shernoff et al., 2017).

Furthermore, targeting confidence could improve self-efficacy, which has a direct effect on performance (Ceylan, 2020; Young-Ju et al., 2000). Yang (2022) found that positive data attitudes affected teachers' ability to analyze, process, share, and present sources of data. The implications of targeting students' self-efficacy and confidence lend its way to increasing student engagement as revealed by Simon et al. (2022) and was a common topic identified in the present research.

Ideas of Data Literacy. Like the literature (Bowler et al., 2019; Kennedy-Clark et al., 2020; Shernoff et al., 2017), which provided multiple definitions of science data literacy, the way teachers defined data literacy varied. These differences are likely due to teacher behavior, teacher background, and personal views, which have been found to impact data use among teachers (Schramm-Possinger & Harris, 2021; Stephenson & Patti, 2007). Thus, this aligns to the transformative, which maintains that people must make their own interpretation through change in schemes and critically reflect to lead to perspective transformation (Dirkx, 1998).

However, all participants described data literacy to include being able to read and interpret data related to science concepts, which mirrored Gibson and Mourad (2018), Macaroglu (2004), and Yang (2022) central findings. Overall, teachers' definition of data literacy in the present study centered on the ability to obtain, extract, organize, analyze, interpret, and use data to make informed decisions, predictions, and apply data understanding to other contexts.

Teacher 1 viewed data literacy more in a quantitative perspective, which aligned to Kjelvik and Schultheis (2019) definition of data literacy and Raffaghelli and Stewart (2020) research findings. Unlike some of the literature, which emphasized conceptions over skills (Green et al., 2015; Wolff et al., 2019), some teachers stressed skills in their explanations of data literacy in science. However, some studies, such as McCoy and Shih (2016) stressed the importance of analyzation skills to advance data literacy. Comparably, Kennedy-Clark et al. (2020) findings suggested data related skills and competencies were needed to prepare pre-service teachers.

Past Experiences Affecting Data Literacy. All four RQs revealed that teachers believed students' past experiences with data literacy in science affected their expectations, how students work through concepts related to data literacy in science, and strategies used to foster data literacy, which aligns to Sezen-Barrie et al. (2015) discoveries that found teacher faced obstacles related to students' preconceived understandings.

Teachers Believe Data Literacy Learning Involve Observation and Detection of Effective Instruction. Teachers believe data literacy learning involve observation and detection of effective instruction was identified as a subtheme teachers believe students' prior learning experiences determine their data literacy for RQ 1 as the findings revealed that teachers' conceptions of data literacy centered on observation and detection of effectiveness, which was similar to prior research (Macaroglu, 2004). These findings also aligned to Llewellyn (2013) which emphasized being able to discern between deceptive claims and substantial claims supported by sources of evidence. This was also revealed in all data collection methods for Teacher 6.

RQ 2

Comparable to Sugiarti et al. (2021), the present research demonstrated that teachers' conceptions of students' data literacy related to science concepts were deficient. Teachers expressed how students' data literacy was below their expectations and how it was often forgotten at the high school level. Likewise, they described how they had to lower their expectations due to deficiencies in students' data literacy as identified in the literature (Jordan et al., 2019; Lestari & Rosana, 2020; Sugiarti et al., 2021; Vanhoof et al., 2013).

Teachers Believe Past Experiences Determined Students' Data Literacy. Teachers' data literacy expectations were dependent on their belief of students' abilities, which was viewed to be shaped from past experiences. These views are similar to Lotter et al. (2007) research, which suggests that teachers' beliefs about students' abilities impact instructional decisions.

Document analyses and interviews revealed predictions, which were categorized as direction. Teacher 8 suggested that being able to make data predictions illustrated a deeper level of learning and mastery of standard was an expectation but was commonly difficult to achieve due to her students' limited past experiences with data literacy. However, her view aligned to Kjelvin and Schultheis' (2019) recommendations of having students identify patterns and make predictions using raw, complex data to improve students' data literacy in science.

Teacher Perception Affecting Translation of Data Literacy. Vocabulary through use of knowing and understanding scientific definitions was emphasized among and described as an expectation among Teachers 3, 5, and 7. This was also illustrated in Teacher 7's activator. However, Sezen-Barrie et al.'s (2015) findings indicated that a focus on definitions compared to collaboration was less effective. Nonetheless, Teachers 2 and 3 suggested that collaborative work improved students' data literacy confidence, which aligned to Carlson and Bracke's (2015) findings of increased confidence when students worked together and engaged in discussions.

RQ 3

Teachers explained how students have a more challenging time evaluating, interpreting, and assessing data compared to collecting data, which matched the literature (Lestari & Rosana, 2020; Suryadi et al., 2021). Teachers 1, 2, and 7 expressed how they had students at different levels in their classes, which results in variation in how students work through concepts related to data literacy. Additionally, teachers described a need to support those that required additional assistance. Consequently, this led to the development of differentiation and individualization as categories, which aligned to prior research that found individual approaches to advance students' data literacy (Belland & Kim, 2021).

Interdisciplinary. Teachers suggested that students' understanding in other subjects, such as mathematics and English, impacted how students worked through concepts related to data literacy. This was similar to other research that focused on data literacy through a lens of other subjects, which suggest that interdisciplinary methods can support how students work through data literacy concepts (Cavalluzzo et al., 2013; Celik, 2014; Giamellaro et al., 2020).

Data Literacy Representation. Although all teachers emphasized using visuals to advance students' data literacy, many teachers explained how students struggled in this area, such as Teacher 4's description of conveying scientific data displayed in graphics. This was similar to Roberts and Brugar (2017) findings, which demonstrated that students' graphic literacy rate was not on target with reading and comprehension. However, Usova and Laws (2021) found that students' ability to evaluate data, analyze data, and draw conclusions from data improved when visualization was implemented.

Teachers Believed There were Inadequacies in Students' data Literacy and a Need for Change. Lack of engagement and motivation was revealed among teacher interviews and observations. Thus, this contributed to inadequacies in data literacy learning and how students worked through concepts related to data literacy. Some teachers, such as Teachers 5 and 8, supplied their students with limited real-life connections of what they were learning in the class. The lack of student connection to the concepts likely contributed to the lack of engagement and how students worked through data literacy, as research suggests that teachers should present a motivating context when first engaging students in similar authentic data literacy activities (Bodzin & Shive, 2003). Nonetheless, Teacher 4 described how she incorporated relevant instruction at the beginning of her lessons by giving students a 'hook' as she explained how she had her students examine real-life water intoxication cases. Moreover, Teacher 6's conception of data literacy focused on using data sources from observations as evidence to support claims, which aligns to Sezen-Barrie et al. (2015) that found teachers should use data sources as evidence to teach content through application and Macaroglu (2004) findings that emphasized data collection through observations. Thus, students need to understand what and why they are learning concepts through real-life connections to advance higher order thinking (Hume & Coll, 2010; Sugiarti et al., 2021).

RQ 4

Like Cavalluzzo et al. (2013) research, teachers emphasized early intervention as a way to foster data literacy in the present study, which also aligns to studies centered on improving teachers' data literacy through early intervention preservice programs (Henderson & Corry, 2021; Raffaghelli & Stewart, 2020).

Teachers' lack of confidence and deficiencies in data literacy likely contributed to the limited data literacy proficiency among students as research suggests that teachers should be competent in authentic, relevant data literacy learning (Cannon, 2022; Sugiarti et al., 2021; van den Bosch et al., 2017). Thus, if teachers are deficient in this area, they are not able to provide effective instructional support to foster data literacy learning among their students. Moreover, the findings suggest future research could target these areas to improve the inadequacies revealed in the present research related to teachers' conceptions of students' data literacy. Additionally, the discoveries suggest that teachers' data literacy should be first targeted to improve data literacy in science.

Flexibility, Authentic Learning, and Application to other Subjects. The present research found teachers to focus on incorporating interdisciplinary/other subjects to advance students' data literacy, which was aligned to Dichev and Dicheva (2017), Hooft et al. (2012), and Vahey et al. (2012) research, which integrated other subjects to advance students' science data literacy. However, Shernoff et al. (2017) indicated that teachers experienced challenges when integrating data literacy in the context of their curriculum. This struggle was also depicted in the present research as Teacher 2 indicated she needed to do better, Teacher 1 described how he needed relevant, updated data aligned to the context of his class, and Teacher 4 indicated she would like to know more about data literacy in science to support her students' learning. This was similar to McCoy and Shih (2016) findings, which indicated preservice teachers needed additional support after conducting educational research that emphasized interdisciplinary approaches.

Teacher 7 reflected on her instructional practices in her interview and observation, and explained how her reflection improved her approach of teaching students how to interpret data in the periodic table. This was similar to other research, which incorporated professional development centered on reflecting on teaching data to improve teachers' data literacy confidence (Danley, 2020; Kennedy-Clark et al., 2020).

Furthermore, interviews, observations, and document analyses revealed that teachers incorporated a variety of modalites of learnings, which is suggested to prompt deeper understanding (Whitman & Kellher, 2016). Sezen-Barrie et al. (2015) found that different modalities advanced students' understanding deeper understanding in science.

Extending on students' understanding, the present research revealed that teachers used a variety of assessments to elicit students' feedback and obtain information of students' knowledge and understanding of science data literacy. The diversity in assessments aligns to Conn et al. (2020) and Filderman et al. (2021), which suggest variety in assessments are needed to identify students' knowledge and conceptualization of concepts.

However, document analyses revealed that some teachers, such as Teachers 2's, 4's, and 7's assessments were composed mostly of multiple choice items and thus limited the data that could be obtained of students' thought processes and misconceptions like constructed response items can reveal (Celik, 2014). Consequently, one recommendation of improving students' data literacy would be for teachers to incorporate open-ended questions in their assessments like Teachers 1 and 3 to monitor students' conceptual understanding of data literacy in science.

Nonetheless, the use of multiple choice items mirror how the Biology EOC is administered, and Teacher 8 indicated that including materials and strategies that were similar to how students will be evaluated in Biology was "…advantageous in the long run." Teachers 3, 4, 7, and 8 elicited students' feedback to gauge students' understanding and efficiency of resources and strategies used to foster data literacy, which is comparable to Raak et al. (2021) and Usova and Laws (2021) research that found teachers viewed feedback data as a way to determine students' understanding and best data literary strategies.

Teacher Perception Affect Translation of Data Literacy. Like Kjelvin and Schultheis (2019), which emphasized data curation, teachers emphasized using visuals as a way to organize data to improve communication and advance students' data literacy. This was modeled in many of the teachers' documents and observations, where tables were used as a way to organize and visually represent data for interpretation purposes. Moreover, Teachers 3 and 7 emphasized organization in their interviews and observations by describing and using graphic organizers, tables, and stock cards. This aligned to Spillane's (2012) research, which suggested organization in data should be considered because it allows identification of patterns and relationships.

Teachers Believe Data Literacy can be Represented Many Ways. All teachers incorporated visuals as a way to elicit students' communication of data with use of tables, graphs, and charts. This aligned to Miller et al. (2021) emphasis on using tools to visualize data to prompt students to communicate and make inferences of data. This was similar to Roberts and Brugar (2017) research, which found graphical representations to have positive implications in students' learning and Loftus and Madden (2020), which argued that visuals improved data literacy.

The primary use of models identified in the present research focused on visuals and class demonstration. Nonetheless, teachers indicated that showing and demonstrating data literacy was a way they fostered learning. Thus, teachers could take the concept of modeling a step further using a model-based approach, which has been found to be an effective instructional design in science (Jordan et al., 2019).

Taking representation of data in a different direction, Teachers 2 and 8 explained how they believed a common location of data already available related to scientific concepts would be beneficial, and Teacher 7 expressed a need for an online module for teachers to obtain data literacy resources to support students' learning. Consequently, her suggestion connected to Sander (2020) research, which focused on investigating online resources used to improve critical big data literacy. The findings suggested that programs should be implemented to extend the use of a variety of data sources to promote critical thinking.

All participants included simple visuals as models to illustrate data sources. However, Teacher 1 explained how he used demonstrations prior to having students work independently on activities and suggested that this improved students' learning. This was similar to Rahmawati et al. (2020) research, which implemented an integration of a discovery learning model to empathize analyzing and interpreting data. The research also used technology and found that students' data literacy increased when technology was embedded in the STEM approaches.

Although teachers used basic technology in the present study, few indicated technology should be used as a strategy to foster data literacy. Nonetheless, Teacher 6 explained how she used videos and Teacher 2 described how she used progress learning to foster data literacy. Despite the fact that basic technology was implemented among teachers, advanced technology as suggested by Zucker et al. (2014) with a focus on smartgraphs was not identified in the present research. In fact, Teacher 7 had negative perspectives of using too much technology and suggested that traditional instruction with textbooks was necessary for students' understanding, which contradicts much literature that suggests technology is advantageous to improve students' data literacy and understanding (Cui & Zhang, 2022; Magana, 2017). Nonetheless, the implications of Rahmawati et al. (2020) research aligned to Teacher 1's emphasis on updated technology to prepare students for a data-driven world. However, a focus on technology was basic compared to research, which integrated data literacy using advance software to improve students' learning (Dunlap & Piro, 2016; Loftus & Madden, 2020; Zucker et al., 2014).

Data Literacy Inadequacies and a Need for Discrete Understanding. Like Khan and Mason (2021) findings, the present study found that the science curriculum needs to be revised to support data literacy with emphasis on critical thinking, problem solving, and essential skills needed to be data literate. A need for discrete data literacy understanding was revealed in the findings and aligned to previous literature (Bowler et al., 2019; Kennedy-Clark et al., 2020; Shernoff et al., 2017). Teacher 4 suggested the curriculum should be revised to include clearer standards, and Teacher 8 stressed a better understanding of learning objectives associated with what should be taught. Consequently, both teachers' focus on a better understanding of standards aligned to Spillane (2012), which emphasized framing the practice of data literacy with clear objectives.

All teachers indicated that the majority of their materials and data sources were premade, which contradicts much of the literature that suggested authentic materials and data sources should be used to foster data literacy in science (Jordan et al., 2019; Kjelvin & Schultheis, 2019; Sezen-Barrie et al., 2015). For example, Teacher 1 explained in his interview how he used pre-made materials and mostly pre-made data but suggested that much was outdated. Nonetheless, teachers expressed a need for access to more data. Consequently, the implications suggest that the curriculum should be revised to promote the use of authentic data as it gives meaning and provides a context of real-world learning (Loftus & Madden, 2020). Therefore, integration of authentic data could also lend a way to increase students' future preparation and engagement in learning.

Moreover, Teacher 3's conception of data literacy incorporated student choices in reading scientific articles to extract data sources, which is similar to data collected in Medova et al. (2022) and findings that indicated student autonomy as a key feature in activities that advance students' statistical reasoning and science learning. Likewise, Teacher 4 allowed her students to choose how to create their lab, which aligned to Chin et al. (2016) and Medova et al. (2022) emphasis on student choices in their learning. Additionally, Teachers 3 and 7 explained how they had their students choose a science topic to explore based on individual interest, which likely increased student engagement as indicated in Harris et al. (2012) and Whitman and Kellher (2016) findings.

Additionally, time spent was a code that arose multiple times in the data sources and was coded for the category schedule. Teachers revealed this code as they described how timing needed to be considered when developing the science curriculum to foster data literacy and how they had to go back and reteach data literacy concepts that students failed to master. Thus, teachers suggested that additional time was needed to improve students' data literacy in science, which supports Belland and Kim (2021) findings that indicated time spent was a positive indicator of students' performance.

Preparing Students for Their Future. The present research findings demonstrated that active learning was more common among physical science teachers than life science teachers as student-centered approaches were only identified among one life science teacher. Moreover, lack of engagement was more prevalent among life science teachers, which suggests that student-centered approaches improve students' engagement and learning. This aligns to previous research, which emphasized inquiry, student-centered learning (Bodzin & Shive, 2003; Erwin, 2015; Hume & Coll, 2010; Wolff et al., 2019). Nonetheless, it is important to note that the inquiry model was not fully observed among any teachers. This is because the inquiry model encourages students to engage in exploratory learning by making relevant connections, engaging in high level thinking, and developing questions sought to be answered. Although Teachers 1 and 3 had their students engage in a lab in their observation, the lab required students to follow specific instructions and thus offered limited exploration. Similarly, both labs focused more on lower level DOK questions rather than higher level thinking. Thus, improvement in this area could be made to benefit instructional approaches among all science teachers. However, Teachers 1 and 3 had their students obtain their own data, which has been found to advance students' thinking of the quality of data sources (Wolff et al., 2019). Thus, student engagement was likely higher in Teachers 1's, 3's, and 6's observations compared to Teachers 5 and 8 because students were responsible for obtaining their own data, which instills purpose by promoting students to engage in analyzing and interpreting the data (Medova et al., 2022).

Extending on the previous topic of technology, game-based learning was not revealed in the present research as found in the literature (Belland & Kim, 2021; Seymoens et al., 2020; Werning, 2020) and NAEP's suggestions of improving science scores. Nonetheless, active learning and relevance, and components of game-based learning, was commonly revealed among teachers and aligned with much of the literature findings (Seymoens et al., 2020; Usova & Laws, 2021). Teacher 6 described how she used storytelling as a way to incorporate real-life connections and student engagement in her class. This aligns to research that found high quality classroom stimulation when these factors were integrated in students' data literacy learning (Usova & Laws, 2021). Likewise, Carlson and Bracke (2015) found that concepts that were connected to students' lives were most engaging to them. Moreover, Teacher 6's use of storytelling as a data literacy strategy aligns with Giamellaro et al. (2020), which found a positive effect on using narratives to explain data connected to science topics.

Collaboration through discussions was revealed as a category to all RQs as teachers 1, 2, 3, 6, and 7 emphasized this in their interview and classroom observations as a way to improve data literacy, which mirrored Bowler et al. (2019) and Sezen-Barrie et al. (2015) findings of participants believing that conversation about data can improve data literacy. Likewise, Teachers 1, 6, and 7 viewed collaboration as a form of communication to prepare students for post-secondary careers, which is aligned to Celik (2014) and Lestari and Rosana (2020) research.

Student centered approaches were more prevalent among physical science teachers compared to life science teachers, and teachers that incorporated student-centered approaches had higher engagement levels in their classroom observations, which aligns to an inquiry discovery learning model (Moon, 2020). The present study's findings aligned to Ellwein et al. (2014) research, which indicated that students were engaged in learning modules that implemented student-centered approaches using self-directed activities.

Physical science teachers incorporated more active learning in their class and also had higher engagement levels, which was depicted in their classroom observations. This aligned to Usova and Laws (2021) research, which incorporated hands-on learning and found that students expressed interest in learning practical data literacy skills that enhanced their learning and preparedness for careers. Thus, this was also similar to physical science teachers' emphasis on preparing students for their future and Teacher 7's suggestion of realistic data literacy learning. Moreover, physical science teachers emphasized relevant learning to engage students and prepare them for their future aligns to Khan and Mason (2021) implications.

This also aligns to the topic of citizen science, which incorporates real-life issues often at the community level (Celik, 2014; Jordan et al., 2015; Vahey et al., 2012). Relevant teaching through community-based instruction was an area of Teach 6's focus as she explained how she believed that the science curriculum should be consistently evolving with community issues to foster data literacy, which is similar to Whitman and Kellher (2016) focus on schools staying up-to-date on instructional practices and Lotter et al. (2007) emphasis on using the local context to incorporate relevant instruction. Additionally, Teacher 6's views were similar to Ellwein et al. (2014), Farrell et al. (2021), Harris et al. (2012), and Werning (2020) findings, which discovered that authentic data could be used to solve real-life problems to improve students' local communities. Elaborating on relevance, Teacher 1 expressed a need for lab equipment to be aligned to what real-scientists use in preparation for students interested in STEM careers. This aligns to Dresner and Moldenke (2002) research, which stressed teacher-scientist incorporation. However, post-secondary learning and/or careers was not a topic of discussion among life science. This was an interesting finding in the present research as much of the life science and physical science NGSS standards center on inquiry-based science setting that emphasizes preparing scientists and citizens (Gould et al., 2014).

A Need for Additional Training. Extending on the topic of using relevant data to improve students' data literacy, the results of the present research suggest that teachers' data literacy should first be targeted so that their confidence and instructional approaches can be improved to support teachers. This aligns with much of the literature review (Cannon, 2022;

Ceylan, 2020). Teacher 2 suggested that data literacy instruction should be more intentional and emphasized allocating more time early in students' education to data literacy to improve students' learning, which was similar to Carlson and Bracke (2015) and Ceccucci et al. (2015) that indicated courses designed to target data literacy improved students' learning. Thus, like the literature (Filderman et al., 2021; Ndukwe & Daniel, 2020; Schramm-Possinger & Harris, 2021; Shernoff et al., 2017), a need for training was revealed in the present study. Therefore, teachers will likely benefit from also using relevant data to improve their conceptions of data literacy (Celik, 2014; Macaroglu, 2004; Sander, 2020).

Much of the teachers included in the present study had limited experience in the high school science setting. This likely contributed to the lack of confidence among the teachers and the inability to answer all questions in the interview and supply all requested documents. Moreover, Teachers 5, 6, 7, and 8 were new to the high school, which likely impacted the knowledge of incorporating data literacy in their science classes. This is because knowledge of the context of the classroom and school is directly linked to pedagogical content knowledge (Liepertz & Borowski, 2018; Whitman & Kellher, 2016).

Extending on the topic of pedagogical content knowledge, teachers' limited experiences likely contributed to data being under conceptualized among teachers, which was also discovered in Spillane (2012) findings. Thus, like Henderson and Corry (2021) and McCoy and Shih (2016), teachers in the district would benefit from training centered on data navigation, analysis, and interpretation after learning more about the district and community context.

Collaboration among teachers was found to be effective in teacher data literacy training in previous research (Danley, 2020; Filderman et al., 2021; Possinger & Harris, 2021; Whitman & Kellher, 2016). This was similar to Teacher 1's expression of how he appreciated PLCs as an opportunity to collaborate and improve his instruction, which aligns to Dunlap and Piro (2016) and Piro and Hutchinson (2014) findings that indicated data chats were an effective strategy to promote collaboration among preservice and in-service teachers. Like Teacher 1, Teacher 2 suggested PLCs were useful in teachers sharing instructional data literacy ideas to improve teaching, which is comparable to Filderman et al. (2021) research, which found a collaborative training format to have a significant impact on teacher knowledge and teacher outcome. These findings align to Vygotsky's social learning theory.

Similar to other research (Cezar & Maçada, 2021; Wolff et al., 2016), the implications of the present study suggest that teachers need more training and practices engaging in data to foster students' learning in a data driven age. Moreover, like the literature that emphasized incorporating authentic materials and data (Jordan et al., 2019; Kjelvin & Schultheis, 2019; Sezen-Barrie et al., 2015), Kennedy-Clark et al. (2020) findings assert that authentic professional learning is most effective in improving data literacy. Therefore, the district should identify individual teachers' data literacy needs and provide authentic professional learning tailored for each teacher's needs (Danley, 2020; Dresner & Moldenke, 2002; Stephenson & Patti, 2007).

Overall, physical science teachers incorporated many of the strategies used to advance students' data literacy learning by requiring students to obtain their own data to instill purpose using student centered approaches (Medova et al., 2022). Likewise, physical science teachers' conception of students' data literacy was similar to the Sugiarti et al. (2021) and Suryadi et al. (2021), which found that students struggled in reaching advanced competencies that required analyzing and interpreting sources of data connected to science concepts and this was influenced based on students' prior learning experiences. Table 23 illustrates differences revealed between life science and physical science teachers in the present research to answer RQ 4.

Table 23

Differences in findings between life science and physical science teachers

Life Science	Physical Science
Lecture style instruction (75%)	Student-centered instruction (100%)
Less student engagement and some had students asleep in class (50%)	More student engagement
Less confidence with data literacy	More confidence with data literacy
Focused more on instruction rather than a connection	All teachers incorporated relevance in their instruction
Emphasized preparing students for their standardized test	Emphasized preparing students for their future
Lecture style learning where data were presented in PowerPoints or on worksheets (75%)	Active learning that involved data collection
Less collaboration (25%)	More collaboration (100%)

There are many aspects that can account for the differences found among life science and physical science teachers in the present study. First, life sciences and physical science courses have different standards, and much of the physical science standards include clear, quantitative data literacy learning objectives aligned to science topics. For example, Physics and Chemistry courses' standards center on mathematical computations. For example, standard SC3a in Chemistry require students to "Use mathematics and computational thinking to balance chemical reactions…." Similarly, standard SP2c in Physics require students to "Use mathematical representations to calculate magnitudes and vector components for typical forces including gravitational force, normal force, friction forces, tension forces, and spring forces" and standard SP3b in Physics require students to "Use mathematics and computational thinking to analyze, evaluate, and apply the principle of conservation of energy and the Work-Kinetic Energy Theorem, calculate the kinetic energy of an object, and calculate the amount of work performed by a force on an object." Therefore, these standards center on some of the advanced data literacy competencies presented in the present research conceptual framework.

However, the emphasis on mathematical computation and thinking in life science classes vary as some, such as Anatomy and Physiology and Environmental Science focus more on knowledge of body systems and Earth systems rather than skills in mathematical computations (Georgia Department of Education, 2023). Consequently, these variations in standards may contribute to the differences in conceptions, expectations, and strategies used to foster data literacy among science teachers. Although all teachers demonstrated some level of lack of confidence in data literacy, life science teachers appeared to have less confidence in science data literacy compared to physical science teachers, which is likely due to experience and exposure of data literacy and is influenced based on course standards and thus impacts the way teachers engage their students in science data literacy.

Nonetheless, much of the literature suggest that collaboration, active learning, and student centered approaches improved students' science data literacy (Bowler et al., 2019; Moon, 2020; Seymoens et al., 2020; Sezen-Barrie et al., 2015; Usova & Laws, 2021). However, only one of the life science teachers incorporated these strategies, which likely impacted the lack of engagement noted among life science teachers as 50% of the life science teachers had students sleeping throughout their classroom observations. Likewise, prior research suggests that relevance is necessary when engaging students in science data literacy learning (Celik, 2014; Jordan et al., 2015; Vahey et al., 2012), which may also contribute to the findings of the present study as physical science teachers emphasized relevant instruction to prepare students for their future. Thus, a lack of relevance among life science teachers likely contributed to less student interest and engagement (Carlson & Bracke, 2015; Ellwein et al., 2014; Farrell et al., 2021; van 't Hooft et al., 2012).

Reflection. In addition to the implications of targeting teachers' data literacy, the findings offer an avenue for the researcher to revise her data literacy approaches. For example, she learned of the impact of collaboration and incorporates this more in her class as a way to foster data literacy learning in the classroom. Likewise, Teacher 6, who taught Forensics like the researcher, provided insight on ways to incorporate technology to engage students in real-life cases. Similarly, the research has promoted the researcher to be more intentional in her data literacy instruction and ensure that a variety of modality of learnings are included to meet the needs of all students. Much of the findings were similar to what were expected and aligned to prior research. However, there were some surprising discoveries. For example, advanced technology was not used or emphasized among any of the teachers. The researcher expected teachers to incorporate technology through game-based learning and simulations, but this was not the case. Likewise, the researcher expected to find some differences among life science and physical science teachers. However, the use of research-based instructional approaches to engaged students being identified much more among physical science teachers compared to life science teachers was surprising. Lastly, the researcher expected teachers' data literacy to be lower than needed; however, she did not expect some teachers to be unfamiliar with the term itself. These findings influence the researcher's instructional approaches and the way she offers collaborative ideas among teachers to improve students' data literacy.

Limitations

Although the research was carefully implemented, several limitations must be recognized. For example, the sample size accounted for only a small representation of science teachers in the district. Moreover, the response rate for teachers in other schools was low as the researcher reached out multiple times to teachers but failed to get responses. Additionally, teachers from two of the traditional high schools were included rather than all three that are in the distinct. This is because the researcher could not obtain a cooperative letter from one of the school's principals, which was a material needed for IRB approval. Similarly, most of the participants included in the study were from the researcher's school placement as only one participant from the second high school provided a consent form.

Extending on the limited heterogeneous sample, only one male was included in the present study. However, there is only one male present in the researcher's school. Therefore, this lack of diversity represents one of the research sites. Furthermore, teachers included in the study had limited years of experience, which constricted their ability to answer all questions. Nonetheless, some had scientific backgrounds and alternative careers, which offered instructional approaches aligned to real-life to prepare students for their future (Dresner & Moldenke, 2002; Gibson & Mourad, 2018; Mamedova et al., 2021; Wolff et al., 2016). Although the research was carried out based on the IRB approval timeline, retrieval of data throughout the school year would have likely yielded a richer data supply, especially for teachers with limited teaching experiences.

Recommendations

The findings of the research offer much information for future recommendations. First, the present study should be replicated with teachers who offer more years of experience teaching high school science. This will help contribute to a richer data supply and provide a clearer picture of experienced teachers' data literacy practices.

Moreover, many of the teachers indicated that they had not really thought about data literacy, displayed interest in learning more about it, or indicated that the questions in the interview had them thinking more about data literacy. Thus, future research should model this design including the same participants to determine if the research influenced reflective practices as suggested in the transformative learning theory (Mezirow, 2009; Strange & Gibson, 2017). This would also help increase the reliability of the present study.

Additionally, although lack of confidence was detected among all teachers, it was more prevalent among life science teachers, which aligns to the present research conceptual framework in that there is a matrix of data literacy competencies, which likely affects confidence levels. Physical science teachers had increased student engagement, student-centered approaches, and emphasized post-secondary preparation. Since much of the literature focuses on targeting preservice teacher education (Cannon, 2022; Conn et al., 2020; Dunlap & Piro, 2016; Kennedy-Clark et al., 2020; Schramm-Possinger & Harris, 2021), exploring the differences in preservice training between life science and physical science preparation programs may provide a deeper understanding of the findings obtained and supply better information on how life science teachers can incorporate strategies to increase students' data literacy through relevant instruction.

Lastly, the present research used only a qualitative approach to triangulate data sources. Therefore, much of the findings were open to interpretations. Consequently, future research should consider using a mixed method approach to obtain qualitative and quantitative data sources. Moreover, since the present study focused only on teachers' conceptions, the district would likely benefit by focusing on students' conceptions and performance through use of a mixed method approach to determine the effectiveness of strategies being implemented in the classroom. One research design model that could help illuminate the effectiveness of data literacy instruction and strategies among teachers is use of a pretest/posttest design (Hooft et al., 2012) for students to compare performance at the beginning of the course and end of the course for each student and also compare performance of groups of students among science teachers. The findings could be used to share ideas and resources in collaborative meetings and training.

Implications of the Study

The implications of the study suggest that all science teachers would benefit from training centered on data literacy. This area should first be targeted as advancing teachers' conceptions of data literacy should have a direct effect on students' data literacy. Since teachers had different conceptions and experiences with data literacy, the training should focus on a matrix of data literacy learning to meet each teacher's needs. Consequently, the district should first develop a questionnaire that addresses teachers' needs on data literacy and areas of improvements that they feel need to be targeted the most. Curriculum specialists and literacy specialists should be assigned to evaluate this data to determine the training that needs to be implemented to facilitate teachers' data literacy. This training should be ongoing and flexible to accommodate teachers' busy schedules (Mandinach & Gummer, 2016; Whitman & Kellher, 2016). The ongoing training should be implemented throughout the school year using a variety of instructional platforms such as in-person, hybrid, and synchronous instructional designs. Regardless of the platform, collaboration among teachers should be a focus used to facilitate learning as this was found to be beneficial in the present research and in previous studies (Bowler et al., 2019; Sezen-Barrie et al., 2015).

Additionally, since the results of the study revealed that physical science teachers had more student engagement, clearer conceptions, and research-based instructional approaches compared to life science teachers, the district should revise the structure of PLCs to allow collaboration among departments rather than only subjects as currently implemented. Should broadening the PLCs in this perspective demonstrate to be effective to improving teachers' data literacy, then the district should consider designing rotational PLCs that offer a mixture of teachers from different content areas, which will help incorporate interdisciplinary approaches as revealed in the present research and previous literature (Bodzin & Shive, 2003; Dichev & Dicheva, 2017; McCoy & Shih, 2016; Medova et al., 2022; Usova & Laws, 2021; van 't Hooft et al., 2012; Vahey et al., 2012).

In addition to training and collaboration among science teachers, incorporating teacher-scientist interaction would be helpful in increasing teachers' data literacy so that they can support their students and encourage students to think like scientists. Likewise, establishing these relationships would help students see the relevance in the data literacy science concepts they are learning. Consequently, the district should allocate funding and time for teachers to meet with local scientists to facilitate this close interaction to improve data literacy instructional approaches (Cezar & Maçada, 2021; Giamellaro et al., 2020). These interactions will help lend way to guest speakers and field trips to allow students to see science in practice and prepare them for their future as discovered in the present research and prior studies (Celik, 2014; Erwin, 2017; Gould, et al., 2014; Lestari & Rosana, 2020).

Considering that all teachers displayed some need for training centered on data literacy and much of the literature focused on targeting preservice teachers (Cannon et al., 2020; Celik, 2014; Danley, 2020; Dunlap & Piro, 2016; Macaroglu, 2004; McCoy & Shih, 2016; Mensah, 2011; Sezen-Barrie et al., 2015), the district should develop partnerships with surrounding universities and colleges to discuss a need to target data literacy in teacher education programs.

Additionally, expanding data literacy using a collaborative approach among stakeholders will positively impact informed decision making (Conn et al., 2020; Filderman et al., 2021).

The district already has a close partnership with one local college where preservice teachers are often recruited. Thus, the district should focus on this college first. To do this, curriculum specialists and literacy specialists should meet with leaders in the school to present the need to include data literacy and these meetings should be ongoing to ensure preservice teachers receive adequate training prior to employment (Mandinach & Gummer, 2016).

Furthermore, the district currently has many specialist roles, such as mathematical interventional specialist, curriculum specialist, mentor program specialist, and literacy specialist, but they do not have a specific position for a data literacy specialist. Consequently, if funding permits, the district should develop a position for a data literacy specialist who can rotate to schools in the district and attend PLCs to support teachers' data literacy needs.

Each RQ revealed that teachers believed students' past experience impacted their conceptions, expectations, and instructional approaches in the classroom. Moreover, many of the teachers indicated that such past experiences impacted how students worked through data literacy concepts in their science classes. Consequently, the findings indicated that teachers' should first identify students' past experiences with data literacy and implement differentiated instruction to promote equity in their classes.

Lastly, once teachers' data literacy needs are addressed, the district should develop data literacy programs that are implemented in primary school and continue to middle and high schools as suggested by teachers in the current research and prior studies (Bush et al., 2020; Roberts & Brugar, 2017; Vahey et al., 2012; van 't Hooft et al., 2012). These programs should implement gradual progression to address the matrix of data literacy facets (Gibson & Mourad, 2018),

Dissemination of the Findings

The present research findings will be presented to leaders in the school district. The researcher will reach out to central office district leaders to identify a date to meet and present the findings and discuss future steps related to the implications of the present study. If schedules permit, the researcher will meet with leaders in spring 2024 prior to summer break. This will ensure enough time is allocated for the district to implement revisions and develop training to address data literacy. During the meeting with leaders, the researcher will use a PowerPoint presentation to present major findings of the present research to illustrate a need of targeting teachers' data literacy. If the district decides to incorporate the recommendations, the training will begin to be implemented in fall 2024 after science teachers are evaluated on their current data literacy knowledge and needs. Ongoing teacher questionnaire data will be obtained during the implementation of these plans to determine the effectiveness of the differentiated data literacy training and revisions will be made as needed. If data demonstrates the continuous training to be effective, the district should extend these trainings for all teachers by spring 2025.

In addition to school leaders, the researcher plans to present the findings to leaders and college professors in the educational program in the local college that shares a current partnership with the district. The researcher will share these findings in spring 2024 during post planning for professors. The researcher will discuss how the educational program can be revised to support preservice teachers' data literacy needs using a PowerPoint presentation. Should the school leaders and professors decide to revise the science educational program to incorporate data literacy, resources will be provided to facilitate the implementation of the recommendations.

Use of a pretest/posttest model for preservice science teachers will be used to evaluate students' growth in data literacy at completion of the program. Likewise, qualitative questionnaire data will be obtained from preservice teachers. Moreover, twenty random teachers will be selected to obtain qualitative data each year for three years to evaluate how they feel the incorporation of data literacy instruction in their teacher preparedness program enabled them to be proficient in data literacy in science to support their students.

Conclusion

This research helped illuminate teachers' current conceptions and instructional practices being implemented in the class. Nonetheless, major findings indicated that all teachers would benefit from additional training. Thus, the district should consider this as a step to improving students' learning in addition to collaboration in the district, surrounding educational programs, and scientists. Moreover, the research provided additional ideas for the researcher to incorporate in her class to foster data literacy learning. It has allowed the researcher to include intentional data literacy instruction and understand that lessons must address the deficiencies in data literacy and meet students' individual needs. Likewise, the research has sparked additional interest in finding ways to foster data literacy to improve science instruction and consider changes that need to be made in the current curriculum to prepare students for postsecondary education and careers.

References

Adnan, Mulbar, U., Sugiarti, & Bahri, A. (2021). Biology science literacy of junior high school students in south Sulawesi, Indonesia. *Journal of Physics: Conference Series, 1752*(1). doi:https://doi.org/10.1088/1742-6596/1752/1/012084

Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism vs interpretivism. *Global Academic Journal of Humanities and Social Sciences*, *2*(3), 39-43. 10.36348/gajhss.2020.v02i03.001

Angers, J. & Machtmes, K. L. (2005). An ethnographic-case study of beliefs, context factors, and practices of teachers integrating technology. *The Qualitative Report, 10*(4), 771-794. https://doi.org/10.46743/2160-3715/2005.1832

Balakrishnan, V., & Claiborne, L. B. (2012). Vygotsky from ZPD to ZCD in moral education: Reshaping Western theory and practices in local context. *Journal of Moral Education*, *41*(2), 225–243. https://doi.org/10.1080/03057240.2012.678056

Barriball, K. L., & While, A. (1994). Collecting data using a semi-structured interview: Discussion paper. *Journal of Advanced Nursing-Institutional Subscription*, *19*(2), 328-335.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report, 13*(4), 544-559. http://www.nova.edu/ssss/QR/QR13-4/baxter.pdf

Belland, B. R., & Kim, N. J. (2021). Predicting high school students' argumentation skill using information literacy and trace data. *Journal of Educational Research*, *114*(3), 211–221.

Bezen, S., Bayrak, C., & Aykutlu, I. (2016). Physics teachers' views on teaching the concept of energy. *Eurasian Journal of Educational Research, 64,* 109–124.

Black, P., Harrison, C., Lee, C., Marshall, B., & William, D. (2003). *Assessment for learning: Putting it into practice.* McGraw-Hill Education (UK).

Bodzin, A. M., & Shive, L. (2003). The best of both worlds: Using authentic data and the world wide web to promote inquiry. Paper presented at the 2003 National Science Teachers Association Annual Meeting, March 27- 30, Philadelphia, PA.

Bowen, G. A. (2009). Document analyses as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27-40.

Bowler, L., Acker, A., & Chi, Y. (2019). Perspectives on youth data literacy at the public library: Teen services staff speak out. *Journal of Research on Libraries and Young Adults, 10*(2), 1-21.

Bruton, A., Conway, J., H., & Holgate, S. T. (2000). Reliability: What is it and how is it measured? *Physiotherapy, 86*(2), 94-99.

Bush, S. B., Cook, K. L., Edelen, D., & Cox, R. (2020). Elementary students' STEAM perceptions: Extending frames of reference through transformative learning experiences. *Elementary School Journal, 120*(4), 692–714. https://doi.org/10.1086/708642

Byee, R. W. & Fuchs, B. (2006). Preparing the 21st century workforce: A new reform in science and technology education. *Journal of Research in Science Teaching, 43*(4), 349-352.

Cannon, S. O. (2022). Investigating and interrogating: Rethinking statistics curriculum for preservice teachers. *Curriculum & Teaching Dialogue*, *24*(1/2), 233–250.

Carlson, J., & Bracke, M. S. (2015). Planting the seeds for data literacy: Lessons learned from a student-centered education program. *International Journal of Digital Curation, 10*(1), 95-110. Doi 10.2218/ijdc.v10il.348.

Cavalluzzo, L., Geraghty, T. M., Steele, J. L., Alexander, J. K., Society for Research on

Educational Effectiveness (SREE), & CNA Corporation. (2013). Using data to inform decisions: How teachers use data to inform practice and improve student performance in mathematics. In *Society for Research on Educational Effectiveness*. Society for Research on Educational Effectiveness.

Ceccucci, W., Tamarkin, D., & Jones, K. (2015). The effectiveness of data science as a means to achieve proficiency in scientific literacy. *Information Systems Education Journal*, *13*(4), 64–70.

Celik, S. (2014). Chemical literacy levels of science and mathematics teacher candidates. *Australian Journal of Teacher Education*, *39*(1). http://dx.doi.org/10.14221/ajte.2014v39n1.5

Ceylan, E. (2020). Science teachers' self-efficacy in instruction and self-efficacy in student engagement across Estonia, Japan, and Turkey. [Estonya, Japonya ve Türkiye'deki Fen Öğretmenlerinin Öğretimdeki ve Öğrenci Motivasyonundaki Öz-yeterlikleri] *Journal of Education and Future,* (18), 29-41. doi:https://doi.org/10.30786/jef.751536

Cezar, B. G. D. S. & Maçada, A. C. G. (2021). Data literacy and the cognitive challenges of a data-rich business environment: An analysis of perceived data overload, technostress and their relationship to individual performance. *Aslib Journal of Information Management, 73*(5), 618-638. doi:https://doi.org/10.1108/AJIM-01-2021-0015

Chin, D. B., Blair, K. P., & Schwartz, D. L. (2016). Got game? A choice-based learning assessment of data literacy and visualization skills. *Technology, Knowledge and Learning, 21*(2), 195-210. doi:https://doi.org/10.1007/s10758-016-9279-7

Choy, L. T. (2014). The strengths and weaknesses of research methodology: Comparison and complimentary between qualitative and quantitative approaches. *IOSR Journal of*

Humanities and Social Science, *19*(4), 99-104.

Cofie, N., Braund, H., & Dalgarno, N. (2018). Eight ways to get a grip on intercoder reliability using qualitative-based measures. *Canadian Medical Education Journal, 13*(2), 73-76. https://doi.org/10.36834/cmej.72504

Conn, C., Bohan, K., Bies-Hernandez, N.Powell, P. Luzarder, J., Scholz, C., & Frederking, D. (2020). Teaching and assessing data literacy: Resource guide for supporting pre-service and in-service teachers. Northern Arizona University.

Cui, Y. & Zhang, H. (2022). Integrating teacher data literacy with TPACK: A self-report study based on a novel framework for teachers' professional development. *Frontiers in Psychology,* 13, 1-17. https://doi.org/10.3389/fpsyg.2022.966575

Cypress, B. (2017) Rigor or reliability and validity in qualitative research: Perspectives, strategies, reconceptualization, and recommendations. *Dimensions of Critical Care Nursing, 36*(4), p 253-263.DOI: 10.1097/DCC.0000000000000253

Dani, D. (2009). Scientific literacy and purposes for teaching science: A case study for Lebanese private school teachers. *International Journal of Environmental Science and Science Education, 4*(3), 289-299.

Danley, A. J. (2020). Providing teacher candidates experience in data teams: Analyzing literacy data. *SRATE Journal*, *29*(1).

Davenport, T., & Patil, D.J. (2012) Data scientist: The sexiest job of the 21st century. Harvard Business Review, September 2022.

DiCecco, V. M. and M. M. Gleason (2002). Using graphic organizers to attain relational knowledge from expository text. *Journal of Learning Disabilities 34*(4).

Dichev, C., & Dicheva, D. (2017). Towards data science literacy. *Procedia Computer Science*, *108*, 2151-2160. 10.1016/j.procs.2017.05.240

D'Ignazio, C. (2017). Creative data literacy: Bridging the gap between the data-haves and data-have nots. *Information Design Journal, 23*(1), 6-18. DOI: 10.1075/idj.23.1.03dig

Dirkx, J. (1998). Transformative learning theory in the practice of adult education: An overview. *PAACE Journal of Lifelong Learning, 7*, 1-14.

Dunlap, K., & Piro, J. S. (2016). Diving into data: Developing the capacity for data literacy in teacher education. *Cogent Education, 3*(1). doi:https://doi.org/10.1080/2331186X.2015.1132526

Dresner, M., & Moldenke, A. (2002). Authentic field ecology experiences for teachers. *The American Biology Teacher*, 659-663.

Ellwein, A. L., Hartley, L. M., Donovan, S., & Billick, I. (2014). Using rich context and data exploration to improve engagement with climate data and data literacy: Bringing a field station into the college classroom. *Journal of Geoscience Education*, *62*(4), 578–586. doi: 10.5408/13-034

Ergler, C. (2017). Beyond passive participation: From research on to research by children. *Methodological Approaches; Evans, R., Skelton, T., Holt, L., Eds*, 97-115.

Erwin, R. W., Jr. (2015). Data literacy: Real-world learning through problem-solving with data Sets. *American Secondary Education*, *43*(2), 18–26.

Eshun, E. F., & Graft-Johnson, K. G. D. (2012). Learner perceptions of assessment of creative products in communication design. *Art, Design & Communication in Higher Education*, *10*(1), 89–102. https://doi.org/10.1386/adch.10.1.89_1

Evans, R. W. (1989). Teacher conceptions of history. *Theory & Research in Social Education*, *17*(3), 210-240.

Farghaly, A. (2018). Comparing and contrasting quantitative and qualitative research approaches in education: The peculiar situation of medical education. *Education in Medicine Journal*, *10*(1).

Farrell, A., Buckman, K., Hall, S. R., Muñoz, I., Bieluch, K., Zoellick, B., & Disney, J. (2021). Adaptations to a secondary school-based citizen science project to engage students in monitoring well water for arsenic during the COVID-19 pandemic. *Journal of STEM Outreach*, *4*(2).

Fereday, J. & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods, 5*(1), 1-11. http://www.ualberta.ca/~iiqm/backissues/5_1/pdf/fereday.pdf.

Filderman, M. J., Toste, J. R., Didion, L., & Peng, P. (2021). Data literacy training for K-12 teachers: A meta-analysis of the effects on teacher outcomes. *Remedial and Special Education, 0*(0), 1-16. doi 10.1177/07419325211054208

Foote, K. D. (2021). A brief history of data literacy. *Data Topics.* Retrieved from https://www.dataversity.net/a-brief-history-of-data-literacy/#

Forero, R., Nahidi, S., De Costa, J., Mohsin, M., Fitzgerald., G., Gibson, N., McCarthy, S., & Aboagye-Sarfo, P. (2018). Application of four-dimension criteria to assess rigour of qualitative research in emergency medicine. *BMC Health Serv Res, 18*(1), 120. doi: 10.1186/s12913-018-2915-2. PMID: 29454350; PMCID: PMC5816375.

Forster, M., Bestelmeyer, S., Baez-Rodriguez, N., Berkowitz, A., Caplan, B., Esposito, R., Grace, E., & McGee, S. (2018). Data jams. *Science Teacher*, *86*(2), 48–53.

Frank, J. (2017). Realizing a democratic community of teachers: John Dewey and the idea of science education. *Education Science, 7,* 1-10.

Georgia Department of Education. (2022, November). *College and career ready performance index(CCRPI)*. Atlanta, GA: Author. Retrieved from http://ccrpi.gadoe.org/Reports/Views/Shared/_Layout.html

Georgia Department of Education. (2023, January). *Science Georgia standards of excellence*. Atlanta, GA: Author. Retrieved from https://www.georgiastandards.org/Georgia-Standards/pages/science.aspx

Giamellaro, M., O'Connell, K., & Knapp, M. (2020). Teachers as participant-narrators in authentic data stories. *International Journal of Science Education*, *42*(3), 406-425. https://www.tandfonline.com/action/showCitFormats?doi=10.1080/09500693.2020.1714093

Gibson, J. P. & Mourad, T. (2018). The growing importance of data literacy in life science education. *American Journal of Botany, 105*(12), 1-4. doi:10.1002/ajb2.1195

Gould, R., Sunbury, S., & Dussault, M. (2014). In praise of messy data. *Science Teacher, 81*(8), 31–36.

Governor's Office of Student Achievement. (2023). *K-12 Public school's report cards.* https://gaawards.gosa.ga.gov/analytics/saw.dll?dashboard

Green, J. L., Schmitt-Wilson, S., & Versland, T. M. (2016). Teachers and data literacy: A blueprint for professional development to foster data driven decision making. *Journal of Continuing Education and Professional Development*, *3*(1). 14-32. doi:10.7726/jcepd.2016.1002

Greene, M. J. (2014). On the inside looking in: Methodological insights and challenges in conducting qualitative insider research. *The Qualitative Report*, *19*(29), 1-13.

http://www.nova.edu/ssss/QR/QR19/greene15.pdf

Greer, R., & Curty, R. G. (2022). Investigating teaching practices in quantitative and computational Social Sciences: A case study. *IASSIST Quarterly*, *46*(3), 1–15. https://doi.org/10.29173/iq1039

Guba E. G., & Lincoln, Y. (1981). *Effective evaluation.* Jossey-Bass.

Guion, L. A. (2002). Triangulation: Establishing the validity of qualitative studies. *University of FloridaExtension Institute of Food and Agriculture Sciences,* 1-3.

Hammett, A., & Dorsey, C. (2020). Messy data, real science: Exploring harmful algal blooms with real-world data. *Science Teacher*, *87*(8), 40–48. digital.nsta.org/publication/?m=13885&i=657109&p=0

Hannan, A. (2007). Interviews in education research. *Retrieved February 28*, 2023.

Harris, C., Berkowitz, A. R., & Alvarado, A. (2012). Data explorations in ecology: Salt pollution as a case study for teaching data literacy. *The American Biology Teacher, 74*(7), 479-484. Retrieved from https://www.proquest.com/scholarly-journals/data-explorations-ecology-salt-pollution-as-case/docview/1282292163/se-2

Henderson, J., & Corry, M. (2021). Data literacy training and use for educational professionals. *Journal of Research in Innovative Teaching & Learning, 14*(2), 232-244. doi:https://doi.org/10.1108/JRIT-11-2019-0074

Hoepfl, M. C. (1997). Choosing qualitative research: A primer for technology education researchers. *Journal of Technology Education, 9*(1). 47-63.http://scholar.lib.vt.edu/ejournals/JTE/v9n1/hoepfl.html.

Holbrook, J., & Rannikmae M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education, 4*(3), 275-288.

Hsieh, H-F. & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277-1288. DOI:10.1177//1049732305276687

Hume, A., & Coll, R. (2010). Authentic student inquiry: The mismatch between the intended curriculum and the student-experienced curriculum, *Research in Science & Technological Education, 28*:1, 43-62, doi: 10.1080/02635140903513565

Hunter-Thomson, K. (2019). Data literacy 101: What do we really mean by "data"? *Science Scope, 43*(2), 84-88. Retrieved from https://www.proquest.com/scholarly-journals/data-literacy-101-what-do-we-really-mean/docview/2277983743/se-2

Jabareen, Y. (2009). Building a conceptual framework: Philosophy, definitions, and procedure. *International Journal of Qualitative Research.* Retrieved from http://ejournals.library.ualberta.ca/index.php/IJQM/article/view/6118/5892

Jordan, R., Crall, A., Gray, S., Phillips, T., & Mellor, D. (2015). Citizen science as a distinct field of inquiry, *BioScience*, 65(2), 208–211, https://doi.org/10.1093/biosci/biu217

Jordan, R., Sorensen, A. E., Shwom, R., Robinson, J. M., Isenhour, C., Gray, S., Nucci, M., & Ebert-May, D. (2019). Using authentic science in climate change education. *Applied Environmental Education & Communication*, *18*(4), 350-38. https://doi.org/10.1080/1533015X.2018.1431162

Kaldenberg, E. R., Watt, S. J., and Therrien, W. J. (2015). Reading instruction in science for students with learning disabilities: A meta-analysis. *Learning Disabilities Quarterly, 38*(3), 160-173.

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, *72*(12), 2954-2965.http://dx.doi.org/10.1111/jan.13031

Kennedy-Clark, S., Galstaun, V., Reimann, P., Martyn, T., Williamson, K., & Weight, J. (2020). Voices on data literacy and initial teacher education: Pre-service teachers' reflections and recommendations. *Australian Journal of Teacher Education, 45*(7), 60-76. Retrieved from https://ro.ecu.edu.au/ajte/vol45/iss7/4

Khan, K., & Mason, J. (2021, November). The M in STEM and issues of data literacy. In 29th International Conference on Computers in education (pp. 632-637). Asia-Pacific Society for Computers in Education.

King, B., Dinsmore, C., Thornton, A., Beyer, W., Akiva, K., & Dalton, C. J. (2019). Multidisciplinary team-based model for faculty supports in online learning. *Collected Essays on Learning and Teaching, 12,* 127–138. http://dx.doi.org/10.22329/celt.v12i0.5382

Kippers, W. B., Poortman, C. L., Schildkamp, K., & Visscher, A. J. (2018). Data literacy: What do educators learn and struggle with during a data use intervention?. *Studies in Educational Evaluation, 56,* 21-31. https://doi.org/10.1016/j.stueduc.2017.11.001

Kjelvik, M., & Schultheis, E. H. (2019). Getting messy with authentic data: Exploring the potential of using data from scientific research to support student data literacy. *CBE Life Science Education, 18*(2), 1-8. DOI:10.1187/cbe.18-02-0023

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational context. *International Journal of Higher Education, 6*(5), 26-41.doi:10.5430/ijhe.v6n5p26

Koelsch, L. E. (2013). Reconceptualizing the member check interview. *International Journal of Qualitative Methods, 12*(1), 168–179. https://doi.org/10.1177/160940691301200105

Krauss S. E., Hamzah A., Omar Z., Suandi T., Ismail I. A. & Zahari M. Z. (2009). Preliminary investigation and interview guide development for studying how Malaysian farmers form their mental models of farming. *The Qualitative Report, 14*(2), 245-260. https://doi.org/10.46743/2160-3715/2009.1382

Krauss, S. E. (2005). Research paradigms and meaning making: A primer. *The qualitative report*, *10*(4), 758-770.

Krueger, R. and Casey, A. (2009). Focus groups: A practical guide for applied research. (5th Ed.). *Sage.*

LeCompte, M. D. (2000). Analyzing qualitative data. *Theory into Practice, 39*(3), 146-154.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1,* 138-147.

Lee, V. R., & Wilkerson, M. (2018). Data use by middle and secondary students in the digital age: A status report and future prospects. Commissioned Paper for the National Academies of Sciences, Engineering, and Medicine, Board on Science Education, Committee on Science Investigations and Engineering Design for Grades 6-12. Washington, D.C. http://sites.nationalacademies.org/DBASSE/BOSE/DBASSE_071087To enable screen reader support, press Ctrl+Alt+Z To learn about keyboard shortcuts, press Ctrl+slash

Lestari, W. Y., & Rosana, D. (2020). Analysis of junior high school students' data literacy in ciamis with local potential kampung adat kuta. *Journal of Physics: Conference Series, 1440*(1) doi:https://doi.org/10.1088/1742-6596/1440/1/012097

Liepertz, S., & Borowski, A. (2018). Testing the consensus model: Relationships among physics teachers' professional knowledge, interconnectedness of content structure and student achievement. *International Journal of Science Education, 41*(7), 71– 92. https://doi.org/10.1080/09500693.2018.1478165

Llewellyn, D. (2013). Making and defending scientific arguments. *Science Teacher*, *80*(5), 34–38.

Loftus, M., & Madden, M. G. (2020). A pedagogy of data and artificial intelligence for student subjectification. *Teaching in Higher Education*, *25*(4), 456–475.

Lotter, C., Hardwood, W. S., & Bonner J. J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching, 44*(9), 1318-1347. doi: 0.1002/tea.20191

Macaroglu, A. E. (2004). Teaching scientific literacy through a science technology and society course: Prospective elementary science teachers' case. *Turkish Online Journal of Educational Technology - TOJET*, *3*(4), 58–61.

Magana, S. (2017) *Disruptive classroom technologies*. SAGE Publishing Company.

Mamedova, S., Stephens, M., Liao, Y., Sennett, J., Sirma, P., National Center for Education Statistics (NCES) (ED/IES), & American Institutes for Research (AIR). (2021). 2012-2016 Program for international student assessment young adult follow-up study (PISA YAFS): How reading and mathematics performance at age 15 relate to literacy and numeracy skills and education, workforce, and life outcomes at Age 19. Research and Development Report. NCES 2021-029. In *National Center for Education Statistics*. National Center for Education Statistics.

Mandinach, E. B., & Gummer, E. S. (2016). What does it mean for teachers to be data literate: Laying out the skills, knowledge, and dispositions. *Teaching and Teacher Education, 60,* 366-376. https://doi.org/10.1016/j.tate.2016.07.011

McCoy, C., & Shih, P. C. (2016). Teachers as producers of data analytics: A case study of a teacher-focused educational data science program. *Journal of Learning Analytics*, *3*(3), 193–214.

Medová, J., Sedmáková, Z., Uhrecký, B., & Valovičová, Ľ. (2022). Designing activities to develop statistical literacy in primary pupils while conducting physics laboratory work in informal settings. *Education Sciences, 12*(4), 246. doi:https://doi.org/10.3390/educsci12040246

Meesuaisinta, M., Pathumcharoenwattana, W., & Boonprakob, P. (2014). The main elements of a transformative learning process to enhance authentic self-esteem of male violent juvenile delinquents: A systematic review study,Procedia - Social and Behavioral Sciences, 152, 925-930. https://doi.org/10.1016/j.sbspro.2014.09.344.

Mensah, F. M. (2011). The destin: Preservice teachers' drawings of the ideal elementary science teachers. *School Science and Mathematics, 111*(8), 379-388. https://doi.org/10.1111/j.1949-8594.2011.00103.x

Merriam, S. B. & Tisdell, E. J. (2016). Qualitative research: A guide to design and implementation. (4th Ed.). John Wiley & Sons, Inc.

Mezirow, J. (2009). *An overview on transformative learning*. In K. Illeris (Ed.), Contemporary theories of learning. Routledge.

Miller, K., Yoon, S., Shim, J., & Cottone. (2021). Integrating data literacy into secondary school science: An exploratory study of a pilot professional development. International Society of the Learning Science, 781-784.

Moon, K. (2020). *A case study of the perceptions of education stakeholders of STEAM integration in a K-8 setting.* Concordia University, St. Paul. Digital Commons https://digitalcommons.csp.edu/cup_commons_grad_edd/449

Myers, D. (2016). School reform: America's winchester mystery house. *International Journal of Education Policy & Leadership, 11*(4).

National Assessment of Education Progress (NAEP). (2022). *Science.* Washington, D. C.: Author. Retrieved from https://nces.ed.gov/nationsreportcard/science/

National Assessment of Education Progress (NAEP). (2023). *State performance compared to the nation..* Washington, D. C.: Author. https://www.nationsreportcard.gov/profiles/stateprofile?chort=2&sub=SCI&sj=AL&sfj=NP&st=MN&year=2015R3

Ndukwe, I. G., & Daniel, B. K. (2020). Teaching analytics, value and tools for teacher data literacy: A systematic and tripartite approach. *International Journal of Educational Technology in Higher Education, 17*(22). https://doi.org/10.1186/s41239-020-00201-6

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. www.nextgenscience. org/next-generation-sciencestandards.

Nowicki, S. (2016). *Choice or chance understanding your locus of control and why it matters.* Prometheus Books.

Ofori-Attah, K. (2021). Early childhood education and instructional ecology: A Vygotskian approach in teaching early childhood social studies. *Athens Journal of Education*, *8*(2), 139–160. https://doi.org/10.30958/aje.8-2-2

Ornstein, A. C. & Hunkins, H. P. (2017). *Curriculum: Foundations, principles, and issues, 7th edition.* Pearson.

Papamitsiou, Z., Filippakis, M. E., Poulou, M., Sampson, D., Ifenthaler, D., and Giannakos, M.

(2021). Towards an educational data literacy framework: Enhancing the profiles of instructional designers and e-tutors of online blended courses with new competences. *Smart Learning Environments, 8(*18), 1-26. https://doi.org/10.1186/s40561-021-00163-w

Patino, C. M. & Ferreira, J. C. (2018). Internal and external validity: Can you apply research study results to your patients? *J Bras Pneumol 44*(3), 183. doi: 10.1590/S1806-37562018000000164. PMID: 30043882; PMCID: PMC6188693.

Perry, S. A. B. (2021). Participatory feeling: Re-visioning transformative learning theory through heron's whole person perspective. *Adult Education Quarterly, 71*(4), 338–355. https://doi.org/10.1177/07417136211016779

Pieper, I., & Thomson, C. J. (2016). Beneficence as a principle in human research. *Monash Bioethics Review*, *34*, 117-135.

Piro, J. S., & Hutchinson, C. J. (2014). Using a data chat to teach instructional interventions: Student perceptions of data literacy in an assessment course. *The New Educator, 10*(2), 95111. http://www.tandfonline.com/action/showCitFormats?doi=10.1080/1547688X.2014.898479

Potter, W. J., & Levine-Donnerstein, D. (1999) Rethinking validity and reliability in content analysis, *Journal of Applied Communication Research, 27*(3), 258-284, DOI: 10.1080/00909889909365539

Pulla, V., & Carter, E. (2018). Employing interpretivism in social work research. *International Journal of Social Work and Human Services Practice*, *6*(1), 9-14.

Raak, K. Eisenschmidt, E., & Tammets, K. (2021). Exploring the perceptions of Estonian teachers' data use in school development. *Education Science, 11.*

Raffaghelli, J. E., & Stewart, B. (2020). Centering complexity in "educators" data literacy to support future practices in faculty development: a systematic review of the literature. *Teaching in Higher Education*, *25*(4), 435–455. https://doi.org/10.1080/13562517.2019.1696301

Rahmawati, L., Wilujeng, I., & Satriana, A. (2020). Application of STEM learning approach through simple technology to increase data literacy. *Journal of Physics: Conference Series, 1440*(1) doi:https://doi.org/10.1088/1742-6596/1440/1/012047

Rashid, Y., Rashid, A., Warraich, M. A., Sabir, S.S., & Waseem, A. (2019). Case study method: A step-by-step guide for business researchers. *International Journal of Qualitative Methods, 18,* 1-13. https://doi.org/10.1177%2F1609406919862424

Reed, D. K., Jemison, E., J. Sidler-Folsom, and A. Weber. (2018). Electronic graphic organizers for learning science vocabulary and concepts: The effect of online synchronous discussion. *The Journal of Experimental Education 35*(4).

Reid, A. M., Brown, J. M., Smith, J. M., Cope, A. C., & Jamieson, S. (2018). Ethical dilemmas and reflexivity in qualitative research. *Perspectives on Medical Education*, *7*, 69-75. https://doi.org/10.1007/s40037-018-0412-2

Roberts, K. L., & Brugar, K. A. (2017). The view from here: Emergence of graphical literacy. *Reading Psychology*, *38*(8), 733–777.

Rogayan, D.V., Jr., and Macanas, G.A. (2020). AGHAMIC Action Approach (A3): Its effects on the pupils' conceptual understanding on matter. *Journal for the Education of Gifted Young Scientists, 8*(1), 223-240. http://dx.doi.org/10.17478/jegys.635161

Sampson, D., & Fytros, D. (2008). Competence models in technology-enhanced competence-based learning. In H. H. Adelsberger, Kinshuk, J. M. Pawlowski, & D. G. Sampson (Eds.), International handbook on information technologies for education and training (2nd ed., pp. 155–177). Springer.

Sander, I. (2020). What is critical big data literacy and how can it be implemented? *Internet Policy Review, 9*(2), 1-22.

Schmoker, E. A. (2011). Focus: Elevating the essentials to radically improve student learning. Association for Supervision and Curriculum Development.

Schramm-Possinger, M., & Harris, L. (2021). Investigating teachers' practices and beliefs of data literacy to enhance pre-service teacher education. *SRATE Journal, 30*(1).

Segal, D. L., Coolidge, F. L., O'Riley, A., & Heinz, B. A. (2006). Structured and semistructured interviews. In *clinician's handbook of adult behavioral assessment*, 121-144. Academic Press.

Sezen-Barrie, A., Moore, J., & Roig, C. E. (2015). Discovering plate boundaries in data-integrated environments: Preservice teachers' conceptualization and implementation of scientific practices. *International Journal of Science Education*, *37*(12), 2013-2037.DOI: 10.1080/09500693.2015.1061226

Sequeira, A. H. (2014). Conceptualization in research. *Psychology of Innovation Journal CMBO*.

Seymoens, T., Van Audenhove, L., Van den Broeck, W., & Mariën, I. (2020). Data literacy on the road: Setting up a large-scale data literacy initiative in the databuzz project. *Journal of Media Literacy Education*, *12*(3), 102–119.

Shernoff, D., J, Sinha S., Bressler, D. M., & Schultz, D. (2017). Teacher perceptions of their curricular and pedagogical shifts: Outcomes of a project-based model of teacher professional development in the next generation science standards. *Front. Psychol,* *8,* 989. doi: 10.3389/fpsyg.2017.0098

Simon, M., Prather, E., Rosenthal, I., Cassidy, M., Hammerman, J., & Trouille, L. (2022). A new curriculum development model for improving undergraduate students' data literacy and self-efficacy in online astronomy classrooms. *Astronomy Education Journal*,*2*(1). doi: 10.32374/AEJ.2022.2.1.043ra

Smith, V. L., & Clark, H. H. (1993). On the course of answering questions. *Journal of memory and language*, *32*(1), 25-38.

Spillane, J. P. (2012). Data in practice: Conceptualizing the data-based decision-making phenomena. *American Journal of Education*, *118*(2), 113-141. http://www.jstor.org/stable/10.1086/663283?origin=JSTOR-pdf

Stahl, N. A., & King, R. A. (2020). Expanding approaches to research: Understanding and using trustworthiness in qualitative research. *Journal of Developmental Education 44*(1), 26–28.

Stephenson, E., & Patti, S. C. (2007). Incorporating data literacy into undergraduate information literacy programs in the social sciences: A pilot project. *Reference Services Review, 35*(4), 525-540. doi:https://doi.org/10.1108/00907320710838354

Stoepker, P., & Dauenhauer, B. (2020). Secondary student and teacher perceptions of classroom physical activity. *Physical Educator, 77*(5), 813–828. https://doi.org/10.18666/TPE-2020-V77-I5-10108

Strange, H., & Gibson, H. J. (2017). An investigation of experiential and transformative learning in study abroad programs. *Frontiers: The Interdisciplinary Journal of Study Abroad, 29*(1), 85–100. https://doi.org/10.36366/frontiers.v29i1.387

Sund, P. (2016). Discerning selective traditions in science education: A qualitative study of teachers' responses to what is important in science teaching. *Cultural Studies of Science Education, 11*(2), 387-409. doi:https://doi.org/10.1007/s11422-015-9666-8

Sugiarti, Mulbar, U., Adnan, & Bahri, A. (2021). Students' scientific literacy skill: The starting point of chemistry learning in the junior high school. *Asia - Pacific Forum on Science Learning and Teaching, 20*(2), 1-20. Retrieved from https://www.proquest.com/scholarly-journals/students-scientific-literacy-skill-starting-point/docview/2620028893/se-2

Suri, H. (2011). Purposeful sampling in qualitative research synthesis. *Qualitative Research Journal*, *11*(2), 63-75. https://doi.org/10.3316/QRJ1102063

Suryadi, Mahardika, I. K., Supeno, & Sudarti. (2021). Data literacy of high school students on physics learning. *Journal of Physics: Conference Series, 1839*(1) doi:https://doi.org/10.1088/1742-6596/1839/1/012025

Sutton, J. & Austin, Z. (2015). Qualitative research: Data collection, analysis, and management. *Canadian Journal of Hospital Pharmacy (CJHP), 68*(3), 266-231.

Taylor, R. T., & Gunter, G. G. (2009). Literacy leaders: Changing student achievement. *New England Reading Association Journal, 45*(1), 20-26, 96-97. Retrieved from https://www.proquest.com/scholarly-journals/literacy-leaders-changing-student-achievement/docview/89071328/se-2

Taylor-Powell, E. & Renner, Marcus. (2003). Analyzing qualitative data*. Program Development & Evaluation,* 1-10.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, *27*(2), 237-246. DOI: 10.1177/1098214005283748

Tikka, P., & Oinas-Kukkonen, H. (2019). Tailoring persuasive technology: A systematic review of literature of self-schema theory and transformative learning theory in persuasive technology context. *Cyberpsychology, 13*(3), 67–88. https://doi.org/10.5817/CP2019-3-6

Tygel, A., & Kirsch, R. (2015). Contributions of Paulo Freire for a critical data literacy. In *Proceedings of Web Science 2015 Workshop on Data Literacy* (pp. 318-34).

United States Department of Education. (2021). *Every Student Succeeds Act.* Washington, D.C.: Author. Retrieved from https://www.ed.gov/essa?src=ft

Vahey, P., Rafanan, K., Patton, C., Swan, K., van't Hooft, M., Kratcoski, A., & Stanford, T. (2012). A cross-disciplinary approach to teaching data literacy and proportionality. *Educational Studies in Mathematics*, *81*(2), 179–205. DOI 10.1007/s10649-012-9392-z

Van den Bosch, R. M., Espin, C. A., Chung, S., Saab, N. (2017). Data-based decision making: Teachers' comprehension of curriculum-based measurement progress-monitoring graphs. *Learning Disabilities Research & Practice, 32*(1), 46-60. DOI: 10.1111/ldrp.12122

Vanhoof, J., Verhaeghe, G., Petegem, P. V., & Valcke, M. (2013). Improving data literacy in schools: Lessons from the school feedback project. *In Data-based Decision Making in Education* (pp. 113-134). Springer, Dordrecht.DOI 10.1007/978-94-007-4816-3_7

van 't Hooft, M., Vahey, P., Swan, K., Kratcoski, A., Cook, D., Rafanan, K., Stanford, T, & Yarnall, L. (2012). A cross-curricular approach to the development of data literacy in middle grades: The thinking with data project. *Middle Grades Research Journal, 7*(3), 19-33. Retrieved from https://www.proquest.com/scholarly-journals/cross-curricular-approach-development-data/docview/1459220433/se-2

Walters, C. H. (2001). Assumptions of qualitative research methods. *Perspectives in Learning*, *2*(1), 14.

Washington Office of Superintendent of Public Instruction. (2021). No child left behind act of

2001. Olympia, WA: Author. Retrieved from https://www.k12.wa.us/policy-funding/grants-grant-management/every-student-succeeds-act-essa-implementation/elementary-and-secondary-education-act-esea/no-child-left-behind-act-2001#:~:text=The%20No%20Child%20Left%20Behind,and%20once%20in%20high%20school.

Werning, S. (2020). Making data playable: A game co-creation method to promote creative data literacy. *Journal of Media Literacy Education*, *12*(3), 88–101.

Wiens, V., Kyngäs, H., & Pölkki, T. (2019). Insight from focus group interviews: Adolescent girls' well-being in relation to experiences of winter, nature and seasonal changes in Northern Finland. *Scandinavian Journal of Caring Sciences*, *33*(4), 969–977. https://doi.org/10.1111/scs.12695

Whitman, G. & Kelleher, I. (2016). *Neuroteach brain science and the future of education.* Rowman & Littlefield.

Whitt, N. H. (2013). An overview and guide to qualitative data analysis for integral researchers. *Integral Research Center*, *1*(75), 76-97.

Wolff, A., Gooch, D., Montaner, J. J. C., Rashid, U., & Kortuem, G. (2016). Creating an understanding of data literacy for a data-driven society. *The Journal of Community Informatics, 12(3),* 9–26. https://doi.org/10.15353/joci.v12i3.3275

Wolff, A., Wermelinger, M., & Petre, M. (2019). Exploring design principles for data literacy activities to support children's inquiries from complex data. *International Journal of Human-Computer Studies, 129,* 41-54.http://dx.doi.org/doi:10.1016/j.ijhcs.2019.03.006

Yang, C. (2022). Index system construction and model analysis of university teachers' data literacy ability. *Journal of Higher Education Theory and Practice, 22*(2), 66-82.

Yasar, M. D. (2020). Chemistry teachers' assessment literacy in Turkey. *Journal of Baltic Science Education, 19*(1), 76–90.

Young-Ju, J., Bong, M., & Choi, H. (2000). Self-efficacy for self-regulated learning, academic self-efficacy, and internet self-efficacy in web-based instruction. *Educational Technology, Research and Development, 48*(2), 5. Retrieved from https://www.proquest.com/scholarly-journals/self-efficacy-regulated-learning-academic/docview/218033921/se-2

Zucker, A. & Kay, R., & Staudt, C. (2014). Helping students make sense of graphs: An experimental trial of smartgraphs software. *Journal Science Education Technology, 2*3, 441-457. DOI 10.1007/s10956-013-9475-3

Appendices

Appendix A

IRB Approval Email

Exempt Approval Protocol 23-044

IRB <irb@columbusstate.edu>

Thu 6/15/2023 5:17 PM

To:Bridget Smith [STUDENT] <smith_bridget2@students.columbusstate.edu>;Deniz Peker <peker_deniz@columbusstate.edu>
Cc:IRB <irb@columbusstate.edu>;Institutional Review Board <instituional_review@columbusstate.edu>

Institutional Review Board
Columbus State University

Date: 6/15/23
Protocol Number: 23-044
Protocol Title: Teachers' Conceptions of Students' Data Literacy in Life Science and Physical Science Classes
Principal Investigator: Bridget Smith
Co-Principal Investigator: Deniz Peker

Dear Bridget Smith:

The Columbus State University Institutional Review Board or representative(s) has reviewed your research proposal identified above. It has been determined that the project is classified as exempt under 45 CFR 46.101(b) of the federal regulations and has been approved. You may begin your research project immediately.

Please note any changes to the protocol must be submitted, using a Project Modification form, to the IRB before implementing the change(s). Any adverse events, unexpected problems, and/or incidents that involve risks to participants and/or others must be reported to the Institutional Review Board at irb@columbusstate.edu or (706) 507-8634.

If you have further questions, please feel free to contact the IRB.

Sincerely,

Amber Dees, IRB Coordinator

Dr. Amber Dees
State Authorization and Academic Compliance Coordinator
Office of the Provost and Executive Vice President

Institutional Review Board Coordinator
Chair of the Faculty Research and Dr. Gregory P. Domin Graduate Research Conference

Book time to meet with me

Appendix B

District Consent Form

Application for Research Study in Troup County Schools

TCSS
Troup County School System
100 N. Davis, LaGrange, Georgia 30241
706.812.7900

APPLICATION FOR RESEARCH STUDY IN TROUP COUNTY SCHOOLS
(Revised 11/2019)

Please print or type.

Name: Smith (Last) Bridget (First) Nicole (Middle) Phone: 706-616-5972

Address: 281 Almond Rd (Address) Lagrange, (City) GA (State) 30241 (Zip)

Employer: Troup County School System Present Position: Science Teacher

Business Phone: 706-616-5972 Email: smithbn12@troup.org
smith_bridget2@columbusstate.edu

College or Institute Sponsoring Project: Columbus State University

Name of Individual Sponsoring Study: ______

Address of Sponsor: 4225 University Ave, Columbus, GA 31907

Phone Number: 706-507-8800

Beginning Date/Ending Date of Study: August 1st, 2023 - September 12th 2023
Data collection: Approximately 6 weeks but will be based on teachers' availability, so the study may extend past September 12th. Data analysis and writing will take approximately 6 months.

No surveying of students in Troup County Schools will be permitted without express consent of the Superintendent.

Signature of Supervising Individual: ______

1

SYNOPSIS OF RESEARCH (purpose, procedure, and anticipated results):

The purpose of the research is to discover teachers' conceptions of student data literacy and strategies used to foster data literacy in life science and physical science classes. I will use semi-structured interviews, classroom observations and document analysis to obtain data. I anticipate different conceptions of data literacy among teachers. Moreover, I expect to find different ~~sta~~ strategies used to foster data literacy. I hope that my findings can be used to improve the science curriculum and offer support for teachers in instructional strategies.

(Attach additional pages, if needed)

POPULATION INVOLVED:

Teachers: Yes ✓ No ___ Grade(s) ___ Number 6-8

Others: Yes ___ No ___ Specify ___ Number ___

Identify Characteristics of Research Subjects:

Science high school teachers (Grades 9-12) I plan to categorize teachers as life science or physical science teachers.

Specify Amount of Time Needed: ___

Schools: Trap High School (If I am not able to obtain 6-8 participants from the chosen school, then I plan to include other teachers from Callaway High School)

Number: 6-8

If you have a preference, list school(s) by name:
Trap High School
Callaway High School } if needed

Will you need access to students' permanent records? Yes ___ No ✓

2

APPLICANT AGREEMENT/CONDITIONS
FOR CONDUCTING RESEARCH IN TROUP COUNTY SCHOOLS

I understand that no participant(s) or school(s) will be identifiable through this research project. I recognize that the research is not completed until a copy of the results is sent to the address listed below:

Please attach a copy of all correspondence (cover letter, questionnaire(s), etc.) that you intend to send to Troup County staff. Please send this completed application with requested materials to:

[redacted] & Accountability
[redacted]

No students will be surveyed as part of this study. I realize that I will be notified in writing concerning the status of this research.

Bridget Smith ______ 4/13/2023
Signature of Applicant ______ Date

FOR SYSTEM'S USE ONLY:	
Date application received: 4/18/2023	
Date applicant notified: 4/21/2023	
Approved ✓	Not Approved ______
Authorized Signature [signature]	Date 4/21/2023

3

Appendix C

Columbus State University IRB Informed Consent Form

COLUMBUS STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD

Informed Consent Form

You are being asked to participate in a research project conducted by Bridget Smith, a student in the Curriculum and Leadership doctoral program in the department of Teacher Education, Leadership and Counseling at Columbus State University. Dr. Deniz Peker, a faculty member at Columbus State University will be supervising the study.

I. Purpose:
The purpose of this project is to discover teachers' conceptions of student data literacy and strategies used to foster data literacy in high school life science and physical science classes.

II. Procedures:
Once informed consent is obtained, data collection will begin, which will include an interview, an observation, and document analysis. One interview and one observation will be completed for each participants. Participants will be reached out via email to schedule an interview and observation. Interviews will last approximately 45 minutes, and classroom observations will last 45 minutes. Document analysis will follow interviews and observations. Each participant will be asked to provide a data literacy activity and evaluation they have used in their classes. All data collection will be based on the convenience of the participant. The total anticipated time requirement for participants from initial involvement with the study through completion is 4 to 6 weeks. The data will not be used for future studies except for conference presentations and journal articles that will be generated from the dissertation study.

III. Possible Risks or Discomforts:
This research involves minimal risks. Nonetheless, to ensure the researcher alleviates feelings of discomfort, the researcher will engage in a two-way conversation when conducting interviews and offer clarification when needed. When conducting classroom observations, the researcher will sit to the side of the room to ensure not to disrupt the class.

IV. Potential Benefits:
Since the high school Georgia science standards heavily emphasize data literacy, discovering conceptions of data literacy and strategies used to foster data literacy in high school science classes can help inform instruction on ways to support student learning. The results of the study can be used to revise science curriculum and develop training to improve instructional approaches to increase student achievement.

V. Costs and Compensation:
Should you decide to participate in the study, you will receive a $25 Visa gift card at the completion of your participation.

Revised 10/01/2017

VI. Confidentiality:
Your participation in the study will be confidential. Your name will be replaced with a pseudonym to preserve your identity. All data obtained will be kept on a password protected computer and stored in a locked filing cabinet. Identifying data will only be accessed by the researcher, Bridget Smith, and her dissertation chair, Dr. Deniz Peker. Once the study is completed and defended, all data will be destroyed. Digital data will be destroyed by permanently deleting all files, and data on paper will be shredded. All data will be destroyed no later than one year from the date data collection began.

VII. Withdrawal:
Your participation in this research study is voluntary. You may withdraw from the study at any time, and your withdrawal will not involve penalty or loss of benefits.

For additional information about this research project, you may contact the Principal Investigator, Bridget Smith at 706-616-5972 or smith_bridget2@students.columbusstate.ed. If you have questions about your rights as a research participant, you may contact Columbus State University Institutional Review Board at irb@columbusstate.edu.

I have read this informed consent form. If I had any questions, they have been answered. By signing this form, I agree to participate in this research project.

______________________________ ______________

Signature of Participant Date

Revised 10/01/2017

Appendix D.

Email sent to science teachers to solicit participants.

Good morning,

My name is Bridget Smith, and I am a doctoral candidate at Columbus State University in the Curriculum and Instruction track. I have created a research design that explores teachers' conceptions and strategies used to foster data literacy under the direction of Dr. Deniz Peker, my dissertation chair. The focus of my research is to identify current teacher conceptions of student data literacy and practices used to improve students' data literacy in science classes. I would greatly appreciate your willingness to participate in this research. The study will include teacher interviews, classroom observations, and document analyses. All participants' confidentiality will be protected. Therefore, no identifying information will be used. If you would like to receive additional information on my research, please feel free to contact me at smith_bridget2@students.columbussttae.edu or 706-616-5972.

Please respond to this email with a copy of your completed consent form to participate in this study. I look forward to hearing from you soon. Thank you for your time and consideration.

Sincerely,

Bridget Smith

Appendix E

Participant Consent Form and Background Questionnaire

Thank you for your willingness to participate in my study, which centers on teachers' conceptions of student data literacy in life science and physical science classes and strategies used to foster data literacy. As part of my research, I would like to complete interviews, classroom observations, and artifact analysis. Your participation is voluntary. Thank you for agreeing to participate in this research. Please complete the consent form and short background questionnaire below.

1. What is your highest level of education?
2. How many years of experience do you have teaching?
3. What is your current position?
4. What subject do you primarily teach?
5. What is your race?
6. What is your gender?

Informed Consent Form

You are being asked to participate in a research project conducted by Bridget Smith, a student in the Curriculum and Leadership doctoral program in the department of Teacher Education, Leadership and Counseling at Columbus State University. Dr. Deniz Peker, a faculty member at Columbus State University will be supervising the study.

I. Purpose:
The purpose of this project is to discover teachers' conceptions of student data literacy and strategies used to foster data literacy in high school life science and physical science classes.

II. Procedures:
Once informed consent is obtained, data collection will begin, which will include an interview, an observation, and document analysis. One interview and one observation will be completed for each participants. Participants will be reached out via email to schedule an interview and observation. Interviews will last approximately 45 minutes, and classroom observations will last 45 minutes. Document analysis will follow interviews and observations. Each participant will be asked to provide a data literacy activity and evaluation they have used in their classes. All data collection will be based on the convenience of the participant. The total anticipated time requirement for participants from initial involvement with the study through completion is 4 to 6 weeks. The data will not be used for future studies except for conference presentations and journal articles that will be generated from the dissertation study.

III. Possible Risks or Discomforts:
This research involves minimal risks. Nonetheless, to ensure the researcher alleviates feelings of discomfort, the researcher will engage in a two-way conversation when conducting interviews and offer clarification when needed. When conducting classroom observations, the researcher will sit to the side of the room to ensure not to disrupt the class.

IV. Potential Benefits:
Since the high school Georgia science standards heavily emphasize data literacy, discovering conceptions of data literacy and strategies used to foster data literacy in high school science classes can help inform instruction on ways to support student learning. The results of the study can be used to revise science curriculum and develop training to improve instructional approaches to increase student achievement.

V. Costs and Compensation:
Should you decide to participate in the study, you will receive a $25 Visa gift card at the completion of your participation.

Revised 10/01/2017

Appendix F

Email to Review Transcript for Member Checking

Thank you for your willingness to participate in this research study. As part of the study, you will have the opportunity to review and approve of the transcript created from the interview conducted. Please find the transcript attached to this email and review it at your convenience. If you find any changes necessary, please return to me within 10 days of receiving this email. If you have any questions, please feel free to contact me.

Thank you so much for your willingness to participate and support in this research!

Sincerely,

Bridget Smith
smith_bridget2@students.columbucstate.edu
706-616-5972

Appendix G

Email to Schedule Interview and Observation Appointment

Thank you so much for your willingness to participate in my research study. As previously mentioned, your confidentiality will be maintained and no identifying information will be used. My research focuses on teachers' conceptions of students' data literacy and strategies used to foster data literacy in science classes. As a participant in this study, you have the right to accept or decline participation. `As part of the study design, you will voluntarily participate in a face-to face interview. Please click the link to select a time that works best for you. When scheduling an observation, please be sure to select a day that a data literacy lesson will take place in your science class.

If you have any questions or concerns, please feel free to contact me anytime at smith_bridget2@students.columbusstate.edu or 706-616-5972. Thank you for your time and support!

Sincerely,

Bridget Smith

Appendix H
Semi-structured interview questions

Descriptive/Grand Tour Question

1. Can you tell me what you know about data literacy in physical science/life science? (RQ 1)

Structural Questions:

2. What specific science data literacy knowledge and skills do you expect your students to possess? (RQ 2)
3. How do students perform or work through different concepts related to data literacy? (RQ 3)
4. What strategies and resources do you use to foster data literacy? (RQ 4)
5. How do you use data literacy strategies to improve students' data literacy in science? (RQ 4)
6. How do you assess students on data literacy in physical science/life science? (RQ 3)
7. How do you use the local context to teach data literacy? (RQ 4)
8. What specific instructional strategies do you use to scaffold and foster data literacy in physical science/ life science? (RQ 4)
9. What sources of data do you use to teach data literacy physical science/ life science classes? (RQ 4)
10. What supports, training, or resources do you feel would be necessary for teachers to be effective in teaching students data literacy? (RQ 3)
11. How do you advance student data literacy from being able to explore and obtain data to being able to interpret and use data to make decisions? (RQ 3 and RQ 4)
12. How are PLCs used to target student data literacy needs? (RQ 3)

13. How much time do you allocate for students to learn data literacy in your class? (RQ 4)
14. How can the science curriculum be designed to support data literacy in science? (RQ 3 and RQ 4)

Contrast Questions:

15. What is your definition of data literacy? (RQ 1)
16. Tell me about a time when your students were highly engaged in working with data. What was it like, what data did they use, and what data literacy skills did you observe them using? What made you think they were highly engaged with data? (RQ 2 and RQ 3)
17. Tell me about a time when you or your students struggled working with data. What was the problem like, was the problem overcome? If so, how; if not, what was needed or missing to overcome the problem? (RQ 2, 3, and 4)
18. Do you feel that any additional information should be added to provide a clear picture of your conception of data literacy in science? (RQ 1)

Appendix I

Observation Guide

1. The teacher appears to be confident in data literacy instruction (Kjelvin &Schultheis, 2019; Miller et al., 2021).
2. The teacher uses verbal strategies to support data literacy in science (Dunlap & Piro, 2016).
3. The teacher uses written strategies to support data literacy in science (Seymoens et al., 2020; Usova & Laws, 2021)
4. The teacher uses visuals to connect data and content learning (Chin et al., 2016; Farrell et al., 2021; Harris et al., 2012).
5. The teacher uses a variety of instructional strategies to scaffold and foster data literacy. (Kjelvin & Schultheis, 2019; Wolff et al., 2019)
6. The teacher uses active learning strategies (Seymoens et al., 2020; Usova & Laws, 2021).
7. The teacher embeds data literacy learning opportunities in the curriculum (Dichev & Dicheva, 2017; van 't Hooft et al., 2012).
8. Cross-curricular pedagogical strategies are used to support data literacy (Kennedy-Clark et al., 2020; Vahey et al., 2012; van 't Hooft et al., 2012)
9. The teacher utilizes technology to foster data literacy learning (Belland & Kim, 2021; Kjelvin & Schultheis, 2019; Usova & Laws, 2021; Wolff et al., 2019; Zhang, 2022).
10. The teacher acknowledges a matrix of data literacy understanding and differentiates learning for students (Danley, 2020; Gibson & Mourad, 2018; Medova et al., 2022).
11. The teacher uses real-life data and situations to advance students' learning (Cavalluzzo et al., 2013; Piro & Hutchinson, 2014; van den Bosch et al., 2017).

12. The teacher utilizes collaborative learning to advance data literacy (Bodzin & Shive, 2003; Carlson & Bracke, 2015; Ellwein et al., 2014; Raak et al., 2021; Usova & Laws, 2021).
13. The teacher utilizes explicit instruction to advance data literacy (Dunlap & Piro, 2016)

Appendix J

Example of Observation Narrative

Teacher 3 Observation Narrative

On August 9, 2023 I observed Participant 3 during fourth block, which was an accelerated physics class. The course was composed of juniors, and thus students were in the eleventh grade. Students identified as gifted or advanced in capabilities with an above average academic record (all A's and B's) are enrolled in accelerated physics. Nonetheless, physics is considered an elective science. Therefore, students placed in this course can elect to take a different science course if seats permit.

The lesson focused on mathematical conversions using the metric system. Conversations took place with the participant prior and after the observations to develop a better understanding of the lesson being observed and how it related to data literacy in physics. Although conversions using the metric system are not connected to a direct Georgia of Science Excellence for high school physics, the Participant implemented this lesson in the first week of school to ensure students understand the metric system used in science and how it relates to measurements they are likely more familiar with. Participant 3 believed this was an important prior knowledge needed before carrying out investigations that required students to use the metric system to obtain, evaluate, and communicate sources of data related to speed, velocity, distance, acceleration, and time (SP1). Thus, this lesson led into standard SB1 later that week.

I entered the class at the beginning of the fourth block. The class was entirely full. Consequently, I brought a stool from outside in and sat on the left-hand side of the room in a corner to ensure I was a passive participant during the duration of the observation. I initially noticed the grouping of students in the room. There were two groups of five students, five groups of four students, and one group of two students sitting at a smaller bench table close to the front of the classroom where the teacher's desk was located (Collaborative-12). The class began at 1:45 PM. As soon as the bell rang, the teacher shut the door and began instruction, which was delivered at the front of the classroom initially, and then she walked class around the classroom to check students' work.

Participant 3 began with recapping on what they did the day before in class and reminded students what students should have completed that was posted in canvas, which was an online learning portal that some teachers utilized (Technology-9). Students were instructed to pull out their classwork/homework that should be completed as she walked around the room and recorded attendance (Variety-5). Before circulating the room, Participant 3 also wrote the instructions on the Smartboard over the assignment displayed.

The instructions specifically stated "Continue working on practice problems from yesterday" (Written-3, Active-6, Technology-9).

Thus, it was evident the teacher incorporated technology when appropriate in her lesson as Chromebooks, calculators, and a Smartboard were utilized by students and the teacher during the duration of the observation. Therefore, this was an example of how the teacher utilized technology to foster data literacy (Technology-9). The problems displayed in canvas required students to convert different measurements using the metric system (Scaffold-5, Technology-9, Matrix-10). Some problems required one-step conversions, while others were multi-step problems. For example, one problem required students to convert grams into kilograms, and another problem required students to know one meter equals 100 cm to complete the conversion (Matrix-10).

Students pulled out their work from their bags. Some students appeared to have completed it, while others were asking for help from their peers and from the teacher. As the teacher circulated around the room, she provided assistance for students who needed additional help or clarification on the problems posted in canvas (Variety-5).

As the teacher circulated the room, she checked students' work. When students asked for assistance, the teacher referenced previous concepts students' had learned in class. Thus, it was evident the teacher was connecting students' prior knowledge with new concepts in the class (Confidence-1).

The teacher provided assistance for students who were struggling with the metric system. For example, the teacher explained that "One foot is twelve inches" to a student (Verbal-2, Variety-5). Thus, this was an example of the teacher providing a verbal strategy to support the student's data literacy.

Moreover, the teacher encouraged students to collaborate and discuss the problems in their small groups (Collaborative-12). Thus, this was another example of how the teacher uses a variety of instructional strategies to foster data literacy (Variety-5). The level of engagement was high. Most students completed the work and discussed the problems within their groups (Collaborative-12). However, a few were off task with other conversations.

All students responded to the teacher and focused on their work when redirected by the teacher. For example, the teacher stated to a group of students that were talking about sports "Alright guys, y'all need to make sure you are on task with your activity."

A male student asked for assistance, so the teacher walked over to his table and further broke down the steps to solve the problem the student was stuck on. The student was stuck on a multi-step conversion problem. He seemed to understand how to convert one measurement to another. However, he did not understand how to convert measurements using multiple steps. The teacher walked over and explained the conversion using a step-by-step process. Thus, this was another example of a verbal strategy the teacher used to support data literacy (Verbal-2). Furthermore, this was also an example of how the participant used a variety of instructional strategies to scaffold and foster data literacy (Variety-5).

Additionally, since there were different levels of problems presented to students in the assigned work and some students needed additional support on multi-step conversion problems, this was also an example of how Participant 3 acknowledged a matrix of data literacy understanding and differentiated learning for students (Matrix-10).

As students were still working on the problems posted in canvas, the teacher circulated around the room five times (Active-6, Technology-9). As she noticed students who were wrong or needed additional help, she assisted by providing guiding questions. Thus, this was another example of how the teacher used instructional strategies to foster data literacy (Variety-5). The teacher utilized collaborative learning and peer work in the class (Collaborative-12). However, when certain students needed additional support, the teacher provided direct, one-on-one instruction by going to their table and breaking down components of the metric system and asking guiding questions (Explicit-13). Thus, this was another example of how the teacher utilized a variety of instructional strategies to foster data literacy (Variety-5) and how the teacher differentiated learning for students (Matrix-10). Another example of how the teacher fostered data literacy and differentiated learning was when she told a student "This needs to be grams, and this needs to be milligrams, so leave the numbers and just change the units. Okay, so now this is going to cancel out" (Verbal-2, Variety-5).

Thus, in this situation, it was apparent that the student was struggling with writing the correct units, so the teacher provided assistance to ensure units were canceled in order for conversion to be accurate. I noticed that at least four students asked for assistance on the multi-step conversion problem as Participant 3 circulated the room and provided assistance to students who were struggling. Thus, this reminded me of Participant 3 describing how students often struggle with multi-step problems in their interview response (Variety-5).

The teacher then proceeded to the front of the room and changed screens on the Smartboard where the answers for some of the problems were displayed (Technology-9). The teacher stated "Hey guys, the answers to the first 3 are on the board. I will show you how to work through them, and I will show you how I would read the problem so that you can understand when we get to other problems" (Verbal-2, Written-3, Matrix-10, Technology-9).

At 1:57pm, the teacher transitioned from circulating the room and observing the students work to providing direct instruction at the front of the room where the Smartboard and teacher's desk was located (Technology-9). Participant 3 broke down how to solve the first three problems with premade answers on a sheet that was displayed (Written-3, Variety-5, Technology-9, Matrix-10 Explicit-13).

The teacher read each problem and instructed students to identify the unknown and given (Verbal-2, Written-3, Variety-5, Matrix-10). Specifically, the teacher instructed the students to circle the unknown and underline the given. The teacher modeled this on the board with an electronic purple pen (Visual-4, Technology-9). The teacher then explained the steps of solving each problem and explained how units cancel out (Verbal-2, Explicit-13). Thus, the teacher provided explicit instruction after circulating the room and after student collaboration at the beginning of class. Therefore, this explicit whole group instruction is an example of how

Participant 3 used verbal strategies to support data literacy in science, how the teacher used written strategies to support data literacy in science (Written-3), the use of visuals to connect data and content learning (Visuals- 4), and how the teacher used a variety of instructional strategies to scaffold and foster data literacy (Variety-5).

After discussing the answers to the first three problems through the whole group discussion and explicit instruction and modeling, the teacher stated she was going to continue with the lesson but that the answer to how to solve all the problems would be posted in canvas (Variety-5, Technology-9). The teacher encouraged the students to work through the problems and then check their answers because they might see similar problems later.

At 2:01 PM, the teacher circulated the room again to check students' work. During this time, the teacher provided small group and one-on-one instruction for students who were struggling with some problems (Explicit-13) and provided guided questioned to facilitate learning, which are other examples of how the teacher scaffolded and fostered data literacy (Variety-5) and how the teacher differentiated learning (Matrix-10).

The teacher saw a student struggling with using milliseconds. Consequently, the teacher went over to the student and provided assistance (Variety-5). Then, the teacher spoke to the whole class and asked "If you have ever been in a race, swimming or anything like that, can you win a race by a mil-second?" Many students shouted "Yes". The teacher then further explains the importance of a mil-second even though it is small (Real-life-11). This is an example of how the teacher incorporated real-life data and situations to advance students' data literally.

At 2:06 PM, the teacher told the whole class to look at question 8 because a lot of students were stuck on this question. The teacher explained how this was a multi-step problem and how the units must first be converted to grams and then kilograms (Verbal-2, Variety-5).

The teacher illustrated this on the board and stated as she wrote it on the board: "So when you do that, it ends up at 6.4 kg" (Verbal-2, Written-3, Visual-4, Variety-5). Then, the teacher provided examples of how to write scientific notations by presenting examples on the board that were typed on a Google doc (Written-3).

Participant 3 told the students to discuss the problems and that they would post the answer sheet to the problems online after their discussion (Technology-9, Collaboration-12).

Therefore, the emphasis on group discussions was another example of how the teacher incorporated collaboration and active learning in their lesson to advance students' data literacy (Active-learning-6).

The teacher then continued to circulate around the room, while lecturing from notes on the board (Explicit-13). A clicker was used to change notes so that Participant 3 could still circulate around the room (Written-3, Technology-9). Therefore, this is an example of how the teacher used written strategies to support data literacy (Written-3). Moreover, this is also an example of how the teacher used verbal strategies to support data literacy (Verbal-2) and used a variety of instructional strategies to scaffold data literacy (Variety-5).

Throughout the entire observation, the teacher embedded data literacy opportunities in the curriculum. This was evident as all activities and lectures that were observed during the observation centered on data literacy (Embed-7). Moreover, throughout the observation, students worked in small groups where they were sitting to complete the problems in canvas. Afterwards, students worked in small groups to complete the lab, which required students to use the metric system to measure different objects in the classroom. Consequently, this is an example of how the teacher utilized collaborative learning to advance students' data literacy (Collaboration-12).

The teacher was structured in the delivery of the lesson observed. Therefore, it consistently appeared that the teacher was confident in data literacy instruction throughout the lesson as she provided guided questions to those who needed additional support, and this was also a way that the teacher scaffolded learning (Confidence-1, Variety-5).

At 2:11PM, the teacher passed out a neon yellow/green sheet that had three hole punched in it to students and told the students that this paper was their new best friend. The teacher emphasized the importance of not losing it. Moreover, the teacher told the students if they lose their sheet, that it would only be replaced one time. The teacher then explained that the sheet was for formulas and conversion needed for quizzes and tests (Visual-4, Variety-5, Matrix-10).

The teacher then displayed a chart with different conversions and informed the students to copy the chart on a small section on their sheet of paper that was passed out. This appeared to be a way that the teacher scaffolded data literacy learning as many students were struggling with multi-step problems. The teacher gave students small rules for those who wanted to draw straight lines on their sheet (referred to as stock) chart. The chart was displayed on the promethean board and illustrated prefixes and number of base units (Visual-4, Variety-5, Matrix-10). On the left side column kilo, hekto, deca, base unit, deci centi, and milli were displayed. Therefore, on the right side column 1,000, 100, 10, 1, 0.01, and 0.001 were displayed. Students had approximately three minutes to copy the chart on their stock paper. The teacher instructed the students to put their stock paper in their folder after they were completed with copying the chart displayed on the Smartboard. The teacher also reminded students not to lose the paper again.

As some students were finishing copying the chart on the board, the teacher passed out a lab sheet, which had a front and back side to it (Written-3). At 2:17, the teacher went back to the front of the room and printed off an extra sheet for a student (Technology-9). At 2:20 PM, the teacher went to the front of the room and provided whole-class instruction, which included directions on completing the lab assignment (Verbal-2). The teacher explained that each student had to complete their own lab sheet. This lab centered on practice with conversations (Embed-7). The teacher instructed students not to break the rulers or meter stick.

In this lab, students had to measure various objects in the classroom (Active-6). The teacher explained the importance of the metric system and compared meters with inches.

The teacher then instructs students to measure pencils, notebooks, tables, and walls in the classroom (Active-6). The teacher recommended starting at the top of the top when measuring the wall to ensure accuracy (Variety-5). The teacher then referred to a question on the back of the sheet, which required students to re-measure to ensure accuracy in their data (Verbal-2, Written-3). She informed the students that their bathroom break would be at 2:45 pm, and walked and stood at their desk at 2:26 while students completed the experiment.

The teacher actively observed and provided assistance when necessary to students who had questions (Variety-5). However, the teacher answered a question with a question, which was a way she fostered critical thinking in the classroom and ensured that the students were the primary thinkers in the lesson (Verbal-2, Variety-5 Matrix-10). Students worked in their groups where they were sitting to complete the lab, but all had their own sheet to write down their own data (Collaboration Item 12).

Additional Classroom Notes

I also observed the structure of the room and drew a sketch of it as a source of data for my observation. The classroom was set up like a traditional high school lab as lab tables were located in the center of the classroom. The teacher had trophies displayed and family pictures close to their desk. I also noticed that 11 tiles in the ceilings were painted with scientific concepts. However, the scientific concepts seemed to capture more life science classes, specifically anatomy, as different bodily organs and systems were painted on these tiles. During the observation, it felt extremely warm. Thus, I documented this as a feeling in my reflective Journal. However, I believe I was coming down with something and this was not entirely an accurate perception of the room temperature.