What Does It Mean To Be Coherent? Mathematics And Science Teachers Consider Coherency In Curriculum Decision Making

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WHAT DOES IT MEAN TO BE COHERENT?
MATHEMATICS AND SCIENCE TEACHERS CONSIDER COHERENCY IN CURRICULUM DECISION MAKING

A Dissertation
Submitted to the School of Education

Duquesne University

In partial fulfillment of the requirements for the degree of Doctor of Education

By
Mona Baniahmadi

August 2022
WHAT DOES IT MEAN TO BE COHERENT?

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ABSTRACT

WHAT DOES IT MEAN TO BE COHERENT?
MATHEMATICS AND SCIENCE TEACHERS CONSIDER COHERENCY IN CURRICULUM DECISION MAKING

By
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August 2022

Dissertation supervised by Dr. Amy M. Olson

This qualitative study investigates teacher and administrator perceptions of what it means for a curriculum to be coherent, strategies they have for establishing coherence of the diverse curricular resources available, and the difficulties teachers may face in understanding coherence and implementing potentially coherent curricula. This study uses the Danielson Model of Effective Teaching and the Tripartite Model of Curriculum as frameworks to examine the ways coherence is understood and implemented in the classroom. The study collected open-ended survey, focus groups, and individual interview data from 12 participants who identify as administrators, mathematics teachers, and science teachers in secondary grades at a rural school and a suburban school through a semi-structured protocol. The data were analyzed holistically across all the participant responses and were grouped by themes using a selective reading approach. The results of
the data analysis identified some themes that were aligned with the literature including characteristics of a coherent curriculum, advantages of using a coherent curriculum for teachers, and teachers’ perceptions of advantages for students’ learning. Also, several additional new themes were uncovered including teacher strategies, teachers’ autonomy, teacher collaboration, administrator ideas for supporting teachers, and teacher evaluation. Some of the important findings of the study are that the teachers and administrators reflected on time and funding for curricular resources as the biggest barriers they face in designing and implementing a coherent curriculum. More so, both mathematics and science teachers described the need for collaboration, funding, and feedback from administrators. In addition, all of the teacher participants indicated they had high levels of autonomy in choosing and enacting their curriculum; however, they described that a lack of funding/resources limited their autonomy to supplement the curriculum in practice and they still need to seek permission from administrators and comply with a curriculum review process within and beyond the school.
DEDICATION

This dissertation is dedicated to my family members. Special gratitude to my supportive and loving parents, Hossein and Mitra, whose good examples have taught me to work hard for the things that I aspire to achieve. Their example has empowered me to persist, regardless of challenges and conflicts. I am who I am because of my parents.

I also dedicate this work to my beloved husband, Sajad, who held my hands every step of the way. He has been a constant source of encouragement and support during the challenges of my doctoral program and life.

Last but not least, I dedicate this dissertation to my only sister, Mina, and my only brother, Mohammad Ali, who have never left my side. Both of them have been my best cheerleaders.
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LIST OF ABBREVIATIONS

CCSS: Common Core State Standards
CCSSM: Common Core State Standards for Mathematics
FRL: Free or Reduced Lunch
IEA: International Association for the Evaluation of Educational Achievement
IES: Institute of Education Sciences
LP: Learning progression
NCES: National Center for Education Statistics
NCTM: National Council of Teachers of Mathematics
NGSS: Next Generation Science Standards
NRC: National Research Council
SES: Socio Economic Status
TIMSS: Trends in International Mathematics and Science Study
U.S: United States
WEF: World Economic Forum
OTL: Opportunity To Learn
CHAPTER 1
MOVING FROM A PROBLEM TO A PROBLEM OF PRACTICE

INTRODUCTION

Curriculum development and design play a critical role in the effectiveness of education (Eris & Kilicoglu, 2019). A high-quality curriculum which is the total educational goals and experiences that students face in a school or other educational institutions (Adentwi, 2005; Abudu, & Mensah, 2016), creates explicit guidelines for what they should learn and do at each grade level. Recently researchers focused on curriculum coherence based on the understanding that when students experience new lessons and activities within a coherent framework, their learning is enhanced by connections and dependencies between each lesson or activity (Darling-Hammond et al., 2005; Drake & Sherin, 2009). A curriculum coherence increases the depth of students’ learning and retention of knowledge and supports teachers to make connections between ideas and instructional activities which leads to students’ success (Chalk, 2020; Baniahmadi & Olson, 2021; Moon, Camburn, Sebastian, 2021). Since there might be limited definitions of what it means for a curriculum to be coherent (Newmann et al., 2001; Schmidt et al., 2007; Bryk, 2010; Pietarinen, Pyhältö, & Soini. 2017), it is essential to create and operationalize one, especially as teachers today are overwhelmed with various curricular resources that may not be well-aligned to each other or to key ideas students need to master (Baniahmadi & Olson, 2021; Pepin et al., 2013; Sawyer et al., 2020; Giorgio-Doherty et al., 2021).

We know that curriculum coherence is important for student learning. However, very little is known about what teachers think coherence is, how they conceptualize it, and what strategies they use to increase curriculum coherence in their classrooms. This study is significant...
because it investigates teacher and administrator perceptions of what it means for a curriculum to be coherent, examines the degree to which those understandings align with the literature and with strategies teachers use, autonomy they experience, and barriers and supports they experience from administrators. This study intends to extend existing theoretical and empirical research through exploration of how practitioners think about and enact curriculum coherence.

My Areas of Expertise in Relation to the Problem of Practice

Conducting this study needed background knowledge on curriculum design and teacher education to better understand the concept of the research and solve the unforeseen problems that might occur during the research process. For me, as an educator whose educational background is connected to science and mathematics instruction, curriculum development as well as teacher preparation, it is critical to investigate the factors that influence the quality of curriculum coherence and curricular decisions that science and mathematics teachers need to make in diverse curriculum contexts. Considering my passion and motivation along with the capability of working hard in education, I gained valuable experiences in directing curriculum development teams and preparing teachers for productive instruction. When I was an educational director in my home country, Iran, I analyzed the important factors contributing to the effectiveness of the pre-K-12 education system in preparing teachers and students for successful outcomes. In my opinion, to achieve a highly efficient educational system, teachers must be knowledgeable about student development to make the right decisions in designing their curriculum and daily instruction. Also, teachers should be supported with sufficient resources and professional development programs from administrators to implement a coherent curriculum. Incorporating technology in curriculum/instruction also can be very useful for learning and both teachers and students need to be proficient in using technology efficiently and ethically. For instance, the
Flipped Classroom is one of the modern systems that can reverse the traditional instructions and learning systems. Students can learn at home and practice in class. In this approach, online systems and technology are the main components. Students can use their tablets or smartphones for learning purposes. In my personal experience, when I was an elementary school teacher in Iran, I recorded short science and mathematics videos and used the recordings to teach the class materials. I was asking my students to watch and learn the course at home preferably with their parents. Then, we practiced the homework in class using games, teamwork, and smartboards. My students loved this, and they never seemed to get bored in my class. Educational leaders should develop methods to change the classroom into a better place for students, where they love to be.

In my native country, Iran, there is a unique national curriculum throughout the country. Teachers in each grade use the same textbooks and learning standards for their instruction at every school. Therefore, this common and coherent curriculum helps students to learn the same materials and knowledge throughout the country. Even if they change their schools in the middle of the academic year, they adjust to the new school setting quickly. I believe that the common curriculum plays a crucial role in-depth learning of students and increasing academic achievements. From the positions I held before, I have decided to learn more about the strengths and challenges within the field of education in the U.S. Currently, my graduate research assistant role has been helping me realize more about the differences between curriculum development processes in the U.S. in comparison with my native country. I hope that after earning my doctoral degree in Educational Leadership, I will be able, as an expert, to positively contribute to the field of curriculum development and instruction by leading decisions and actions.

My future plan is to continue conducting research in the field of curriculum development and instruction as a researcher and higher education faculty to help future educational leaders
and teachers to develop a high-quality, coherent curriculum in schools. Moreover, I aim to utilize my learnings and experiences to improve teachers’ curricular decision-making to manage the ever-increasing curricular resources and implement productive instruction in classrooms. My long-term goal is to contribute to the design of the mathematics and science curriculum in coherent ways that help students to build on their previous knowledge, make connections between the contents across grade levels, gain a deeper understanding of content and enhance their retention of knowledge.

**Statement of the Problem of Practice**

From the area of expertise, I mentioned above, I am drawing on a limited definition of curriculum. For the rest of this study by the word “curriculum”, I mean every resource that teachers have access to those influences the daily instruction which can include standards, pacing guides, textbooks, online resources, etc.

The recent COVID-19 pandemic impacted the education system, including teacher instruction and student learning, as well as the economy more broadly. The job market may be irrevocably changed with increasing opportunities to “work from home” and use technological means. In such an unprecedented time, education needs to respond through new curriculum and instructional methods, as well as a suitable technology, to help students adapt to the new normal. Students are expected to be able to successfully manage the ever-increasing resources of information, think critically when solving problems, and make life-changing decisions based on the information they have at their disposal. For example, according to the World Economic Forum (WEF) (2020), by 2025 more than 50% of the demanded skills and careers will need additional problem-solving skills, creativity, critical thinking, reasoning, and ideation skills. As the educational context shifts to accommodate these changes, curriculum design, and curricular
resources will continue to play significant roles in making sure all students from kindergarten through grade twelve achieve success.

Furthermore, Phang et al. (2020) state that science and mathematics are key curriculum areas that are fundamental requirements to our daily life because many careers need a basic understanding of them today and gradually more in the future. The Trends in International Mathematics and Science Study (TIMSS) has been running every four years, since 1995, to compare the mathematics and science achievements of U.S. students with students in other countries around the world. The TIMSS study has gathered international data about curriculum and contexts for schooling, and the research results of TIMSS have influenced the improvement and redesign of science and mathematics curricula around the world. The results of (TIMSS) in the United States (U.S.) provided evidence about the lack of a common, coherent curriculum, materials, and training that negatively affected U.S. teachers and students, especially in secondary grades (Schmidt & Prawat, 2006; Mullis et al., 2020).

According to Schmidt et al. (2004) and Mullis et al. (2020), TIMSS examined data from students in grades three and four, seven and eight, and 12 grades. The TIMSS findings revealed that in the fourth grade, students did well and scored above the international average in mathematics and science. However, the U.S. dropped in rankings in both mathematics and science in the eighth grade. The decline continued by the end of secondary schools, resulting in a startling placement near the bottom of the international distribution. Gonzales et al. (2008) described the results of TIMSS in 2007 as follows: the average mathematics scores for the U.S. fourth and eighth grades were a little bit high compared to 1995’s TIMSS scale average. In 2007, the average mathematics score of U.S. fourth grade was 11 points higher and the average mathematics score of U.S. eighth grade was 16 points higher than the 1995 average score.
However, in 2007, the average science scores of U.S. eighth and fourth grades were not measurably different from those in 1995. Later, the Institute of Education Sciences (IES) and the National Center for Education Statistics (NCES) (2021) highlighted the U.S. results of TIMSS in 2019, they report that the United States average score in mathematics at both grades has increased over the long term (from 1995 to 2019) but there are no significant changes between 2015 and 2019. Besides that, the U.S. average score in science showed no significant changes over the short term (from 2015 to 2019) and over the long term (from 1995 to 2019) in eighth grade. In fact, in fourth grade, the U.S. science average score in 2019 has decreased since 2015.

Further, TIMSS Advanced was conducted to evaluate and measure advanced physics and mathematics achievements in 12 grades, the final year of secondary school, in 1995, 2008, and 2015. The U.S. participated in the 1995 and 2015 TIMSS Advanced. The National Center for Education Statistics (NCES) (2019) reported an in-depth analysis of TIMSS Advanced 2015, which focuses on the results of the U.S. student average scores compare to students in other countries. According to NCES (2019), the U.S. students performed relatively well in terms of average scores in advanced mathematics and less well in physics. Overall, the U.S. student average scores and performance were below the TIMSS Advanced scale center points in advanced physics and mathematics in 12 grades (Provasnik et al., 2019). Therefore, according to the TIMSS results, we can conclude that student achievements and/or performance are not significantly increased over the long term in the U.S. within mathematics and science areas. Schmidt, Houang, and Cogan (2004) state that the findings of TIMSS help researchers examine student achievement within mathematics and science curricula. Because this is the curriculum-what is taught- that makes a significant influence on student learning outcomes.
Since 2010, Common Core State Standards (CCSS) were developed and 43 states as well as the District of Columbia adopted them (Schmidt & Houang, 2012). The main purpose of CCSS was to develop a more coherent, focused, and rigorous learning benchmark for students and teachers in U.S. schools (McDuffie et al., 2017; Schmidt & Houang, 2012). Although, in a research study conducted by McDuffie et al., (2017) about U.S. secondary school teachers’ perceptions of Common Core State Standards for Mathematics (CCSSM) three challenges were identified: 1) the standards are associated with high-stakes assessments and teacher evaluation. Since 2014, student achievements and growth scores account for teachers’ evaluations. The high-stakes nature of CCSS-based assessments often leads to a fragmented curriculum by reflecting test items rather than curricular concepts (Au, 2007; Palmer & Rangel, 2011; McDuffie et al., 2017); 2) “CCSS differs from previous standards in that the adoption of a common set of standards by so many states is unprecedented nationally, as prior to 2010, states had separate and widely varying sets of standards with respect to key dimensions such as content, rigor, coherence, and focus” (Carmichael et al., 2010; Porter et al., 2011; Reys, 2006; McDuffie et al., 2017), and 3) another challenge of “CCSS relates to the short time frame from CCSS’s development to implementation. Opportunities for input, testing, and revision of CCSS have been limited. In some states (e.g., New York, Tennessee, and Florida), CCSS was introduced to teachers at the same time they were asked to teach them, and in other places, there was only a 2- to 3-year window between adoption and implementation” (Rentner & Kober, 2014; McDuffie et al., 2017).

The researchers’ analyses showed that CCSSM can improve U.S. student mathematics achievements once implemented appropriately (Schmidt & Houang, 2012). Schmidt and Houang's (2012) data analyses indicated that the standards were poorly implemented in 13 states.
because of the high degree of challenges such as high levels of poverty and low definitions of proficiency on the state assessments, etc.

Schmidt and Houang (2012), and Shin et al. (2019) characterized the intended content of science and mathematics in the U.S. According to their data analyses: 1) The intended content is not very focused. For example, textbooks and state standards in the U.S. cover more content in each grade. Consequently, U.S. teachers have to teach more topics in the classroom, but less in-depth. 2) The intended content is highly repetitive. Teachers in the U.S. are reviewing the topic every year as if implementing a spiraling curriculum, but they are adding little depth when content is revisited (Schmidt & Houang, 2012). However, the intention of state standards was to in part rectify some of these issues. But, since its implementation, the problems remained (Schmidt & Houang, 2012; Shin et al., 2019). Schmidt, Wang, and McNight (2005) explained that “the presence of content standards is not sufficient to guarantee curricula that lead to high-quality instruction and achievement. An examination of the content topics covered in each grade in the U.S. shows a pattern in which topics enter and linger so that each grade typically devotes instructional attention to many more topics; in addition, each topic stays in the curriculum for more grades” (Schmidt, Wang, & McNight, 2005). Research showed that “curricula in the U.S. is a mile wide and an inch deep” (Schmidt, Houang, & Cogan, 2004; Schmidt & Houang, 2012).

Schmidt, Houang, and Cogan (2004) claim that one of the most significant features defining quality in the curriculum is coherency. Schmidt, Houang, and Cogan (2004) define “for a curriculum to be coherent a set of topics or contents must evolve from particulars to deeper structures inherent in the discipline. This deeper structure serves as a means for connecting the particulars. The evolution from particulars to deeper structures should happen during the school year within a particular grade level and as the student progresses across grades”. Their research
proves that “a curriculum coherence should be expressed over time as a logical sequence of
topics and performances and reflect the hierarchical nature of the disciplinary content from
which the subject matter derives. It is how and what students are taught should reflect not only
the topics that fall within a certain academic discipline but also the key ideas that determine how
knowledge is organized and generated within that discipline” (Schmidt, Houang, & Cogan,
2004). According to this description of coherence, it is more possible to build students’
understanding of the big ideas to ensure all students are mastered substantial content. Over the
years the curricula appear to be more rigorous in terms of content covered. Thus, it reflects a
logical structure. According to Schmidt and Prawat (2006) and Schmidt and Houang (2012),
there is a direct relationship between student performance on achievement tests and their
exposure to coherent content.

A common, coherent curriculum provides many benefits for students’ learning: 1) it
significantly enhances student learning by building an in-depth understanding of major contents
over time; 2) it decreases the differential achievement effects which are produced by various
quality curricula and standards in the U.S.; 3) as the research shows that part of the reason for the
SES achievement gap is due to a more fragmented curriculum in high poverty schools than low
poverty schools. Therefore, a coherent curriculum can improve this situation; 4) it helps teachers
work with their colleagues and share their experiences and goals; 5) and it is clear guidance for
preservice teachers on what to teach (Schmidt, Houang, & Cogan, 2004; Shin et al., 2019).

Research proved that “a coherent curriculum makes use of one of the firmest evidence-
based principles in education: that all new knowledge is constructed on the foundation of prior
knowledge” (Shin et al., 2019; Bransford, Brown, & Cocking, 1999). A coherent set of ideas and
scientific practices that build upon each other across years support learners to meet required
learning goals (Kesidou & Roseman, 2002; Shin et al., 2019). In addition, a “coherent curriculum supports the continuous growth in student understanding of core ideas as they experience varied learning tasks that integrate ideas across times (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014; Shin et al., 2019). Some studies showed that “middle school students who used coherent curriculum materials that focused on the particle nature of matter and how matter interacts developed explanations for these two central ideas” (Margel, Eylon, & Scherz, 2008; Shin et al., 2019).

One of the major goals of a coherent curriculum is to help students make connections between ideas to develop a deeper knowledge of disciplinary core ideas (National Research Council [NRC], 2012). The Next Generation Science Standards (NGSS) (the NGSS Lead States, 2013) and the Framework for K-12 Science Education (NRC, 2012) in the United States focus on a few core ideas of science in order to build knowledge across years. Therefore, “students apply these understandings to make sense of phenomena, solve problems, and make decisions in an increasingly technological global economy, and for their personal wellbeing as citizens” (Fortus & Krajcik, 2012; Shin et al., 2019). Although, research indicates that “current science programs rarely use coherent curricula in spite of the educational merits” (Kesidou & Roseman, 2002; Roseman et al., 2008; Shwartz et al., 2008; Shin et al., 2019). “Most current U.S. science curriculum materials were not designed to help learners make connections between ideas within and among disciplines, nor to help them develop meaningful understanding” (Krajcik et al., 2012; Shin et al., 2019). According to NRC (2009) “most materials published in the United States often contain a broad range of disconnected ideas that are given equal priority in terms of curriculum coverage”. Some research studies conducted a systematic review of the United States high school and middle school curricula and found that materials usually (a) “focus on numerous
topics at a superficial level, (b) do not take into consideration students’ prior knowledge, (c) lack concise and thorough explanations of phenomena, and (d) fail to provide students with an opportunity for developing their own explanations of phenomena” (Kesidou & Roseman, 2002; Shin et al., 2019). NRC (2012) states that engaging students in coherent practices and implementing coherent curricula need more time and effort in classrooms. However, teachers mostly are concerned about the number of concepts they have to teach in a limited amount of time and perform high degree of responsibility they may hold.

In conclusion, school administrators should support teachers with the required resources to move toward designing and implementing a more coherent curriculum to take advantage of its benefits. Because there could be a possibility for some schools where there is a lack of coherent curriculum that leads to creating gaps in students’ learning. Research demonstrated that the capability of learning new knowledge depends on an ability to connect previous knowledge to new things. Relevant prior knowledge provides students a greater opportunity for understanding the new content (Schmidt, Houang, & Cogan, 2004; Hirsch, 2010; Shin et al., 2019). Hence, the fragmented curricular landscape should be repaired to allow teachers to determine key concepts and skills, emphasize main content, reflect on student misunderstandings, and make a plan to guarantee the success of students in the next grade (Weber, 2019) because in the lack of clear goals and learning plans, students will not be able to develop their understandings and build on future lessons (Wiggins & McTighe, 2005, p. 21.; Weber, 2019).

Social Justice Implications of the Problem of Practice

When considering reasons for educational inequities, researchers often turn to the curriculum (Giorgio-Doherty et al., 2021). An unfocused curriculum plays an essential role in the learning gap between students from high and low socioeconomic backgrounds (Schmidt et al.,
1999; Schmidt et al., 2007; Schmidt et al., 2015; Giorgio-Doherty et al., 2021). However, addressing curriculum gaps is not as simple as identifying an excellent curriculum and mandating its use (Giorgio-Doherty et al., 2021).

In a research study conducted by Giorgio-Doherty et al. (2021) the survey results indicate that students from low-income families faced more inequities during the COVID-19 pandemic. They looked across schools by the percentage of students eligible for free or reduced lunch (FRL) and found that the schools with higher levels of FRL generally faced greater inequities and the opportunity gap between students of low and high socioeconomic status have exacerbated. Further, their research asserted that teachers who work in lower-income school districts have less access to professional learning programs and curricular resources to supplement their curriculum in coherent ways (Giorgio-Doherty et al., 2021). Therefore, policymakers and administrators should provide enough resources and professional learning opportunities for teachers in schools that serve students from less wealthy backgrounds.

In addition, research proved that there is a direct relationship between socioeconomic status (SES) and opportunity to learn (OTL) which influence student learning outcomes (Schmidt et al., 2015). Students from high SES schools have more opportunities to learn important lessons and receive high-quality instruction (Kaushal, Magnuson, & Waldfogel, 2011; Boyd et al., 2009; Schmidt et al., 2015). Also, curriculum and instructional content exposure play major roles in educational inequalities. A research study conducted by Schmidt et al. (2015) indicated that opportunity to learn (OTL) plays a significant role in student achievements. “Opportunity to learn (OTL) rests on the logical proposition that students’ ability to learn a subject is dependent on whether and for how long they are exposed to it in school” (Schmidt et al., 2015). There are some factors such as school resources, teacher quality, standardization, school autonomy, class
size, and more importantly curriculum and educational content coverage that influence student learning. Some studies found a direct relationship between mathematics and science instructional content coverage and student learning outcomes (Sousa & Armor, 2010; Willms, 2010; Schmidt et al., 2015). Furthermore, other scholars highlighted that curricular differentiation leads to unequal student learning outcomes. For example, separating students into different classes with different content exposure even in the same school reflects inequalities in student learning outcomes (Chudgar & Luschei, 2009; Brown et al., 2013; Schmidt et al., 2015). Schmidt and McKnight (2012) argued for “the existence of inequalities in OTL and highlighted that part of the apparent role of SES was related to the systematically weaker content offered to lower-income students that rather than ameliorating educational inequalities, schools were exacerbating them”. Thus, research indicated that OTL has a strong relationship to student achievement and students from affluent schools or high SES have more opportunities to learn important lessons and receive high-quality teachers. This relationship holds across U.S. schools. (Kaushal, Magnuson, & Waldfogel, 2011; Boyd et al., 2009; Schmidt et al., 2015).

Highlighting all of this from a social justice perspective, we can declare that socioeconomic factors could have a strong relationship with student achievements. Also, the student's poor performance could be because of the lack of a coherent curriculum in schools. A curriculum that is vertically and horizontally coherent helps students to experience common knowledge and skills at the same grade. The lack of a coherent curriculum holds back the learning process, especially for marginalized students who chronically and systematically are not granted adequate educational resources (Hirsch, 2010; Giorgio-Doherty et al., 2021). As Hirsch (1995) (2010) mentioned “a systemic failure to teach all children the knowledge they need in order to understand what the next grade has to offer is the major source of avoidable injustice in
our schools. It is impractical for a teacher to reach all children when some of them lack the necessary prior knowledge. In this situation, the most important responsibility of a teacher is to make sure that all students within that school gain the background knowledge and skills they will require at the next grades” (p. 11). Consequently, incoherent curricula in schools might be one of the reasons for the huge performance gaps, especially in students systematically disadvantaged by barriers to OTL.

**The Danielson Framework as a Conceptual Framework**

This study used the Danielson framework (Danielson Group, 2013) as a conceptual framework. The study particularly focused on Danielson as a way to examine coherence processes through instruction and instructional planning in ways that are made explicit to teachers and administrators through evaluation procedures. Teachers regardless of what content area they teach, are going to think about the coherency in the ways to be evaluated as well. Danielson Framework is used all across the country to evaluate teachers.

For the purpose of this study, I focused on components 1e and 1a to frame coherence and its effects on curricular decision-making by teachers. The way coherency appears in the Danielson framework is in two areas: 1e) the alignment between the lesson and the learning goals of the lessons, and 1a) the alignment across intra- and interdisciplinary content relationships (i.e., coherence across big ideas and coherence across subject areas).

**The Tripartite Model of Curriculum as the Theoretical Framework of the Study**

I use the Tripartite Model of Curriculum to examine the ways coherence changes across what was intended by the curriculum designers and what was implemented in the classroom by teachers. This framework demonstrates the hierarchy, complexity, and interaction between
standards, textbooks, curriculum goals, and teachers’ perspectives in the implementation of the curriculum.

International Association for the Evaluation of Educational Achievement (IEA) conducted large-scale studies of educational outcomes and learning opportunities in different subject areas such as science and mathematics (TIMSS) to better understand the connections between; (a) the intended curriculum (what policy requires); (b) the implemented curriculum (what is taught in schools); and (c) the achieved curriculum (what students learn). The Third International Mathematics and Science Study (TIMSS) included a major investigation of the curriculum intended for and implemented in the classrooms of over 40 countries (Taguma, Shirai, & Anger, 2016). The TIMSS was created to examine the educational systems which goal is to transfer educational experiences to learners. The tripartite model of curriculum, conceptualized through earlier studies, was the foundation for all aspects of the TIMSS (Schmidt et al., 1996; Taguma et al., 2016). The model provides a conceptual map that links important aspects of the curriculum as it plays out in schools. It demonstrates the hierarchy, complexity, and linkage between standards, textbooks, curriculum goals, and teachers’ perspectives in the implementation of curriculum (adapted from Schmidt et al., 1996). This model makes an analytical distinction between curriculum as system goals, curriculum as instruction, and curriculum as student achievement. These dimensions are known, respectively, as the intended, implemented, and attained curriculum (Taguma, Shirai, & Anger, 2016).

**Intended Curriculum**

The *intended curriculum* refers to the official statements that determine what students are expected to learn. Typically, these are “educational system’s goals such as national standards” (Eberle, 2010), as well as state and district curriculum standards or guides. Textbook publishers
often rely on these official documents to turn standards into lessons and accompanying exercises for students that may be used in classrooms (Taguma, Shirai, & Anger, 2016).

**Implemented curriculum**

Teachers use textbooks and other supplemental resources to create educational goals and experiences for students. These classroom instructional experiences are referred to as the *implemented curriculum* which is the taught curriculum. Knowing what content is actually taught in classrooms will help reform efforts go beyond the implementation of new instructional practices and materials and include identifying the coherence and connectedness of the lessons (Eberle, 2010). Research proved that “Teachers will significantly alter the implemented curricula to make it more congruent with their own teaching orientation and belief systems” (Cronin-Jones, 1991; Schmidt et al., 1996; Eberle, 2010). Therefore, the implemented curriculum is varied from class to class even when teachers utilize similar instructional materials (Eberle, 2010). One main reason for the various implemented curriculum is that a lot of teachers may not have enough content knowledge and competency for teaching, or their content knowledge are not adequately coherent across the disciplines (Abd-El-Khalick & Boudaoude, 1997; Arzi, White, & Fensham, 1987; Eberle, 2010). “In the intended and implemented curriculum, coherence has a purpose; it aims at developing coherent knowledge in the attained curriculum. In the attained curriculum, coherence is the purpose: students’ coherent knowledge” (Goodlad, 1979; Van den Akker, 2003; Sun, 2014).

**Attained Curriculum**

Finally, what students have learned and their knowledge: ideas, constructs, and schemas are referred to as the *attained curriculum* (Schmidt et al., 1996; Eberle, 2010). The *attained curriculum* refers to “what the learners actually acquired from their interaction with the teachers
in the cognitive, psychomotor and affective domains. The attained curriculum indicates the knowledge, understanding, skills, and attitudes that learners actually acquired as a result of teaching and learning that is authentically assessed through different approaches and/or demonstrated in practice. It is the result of what is achieved at the end of learning and teaching. The attained curriculum defines the student’s competencies, academic achievement, attitudes, and belief indications” (Houang & Schmidt, 2008; Anikweze, & Ugodulunwa, 2020).

**Potentially Implemented Curriculum**

In the tripartite model, a crucial bridging curriculum representation is introduced, i.e., the *potentially implemented curriculum*. Therefore, the potentially implemented curriculum shows the link between the intended curriculum and the implemented curriculum. In the model, textbooks and any curricular resources that teachers utilize in their daily instruction represent the potentially implemented curriculum. They play an essential role in impacting teachers’ beliefs and might be the source of teachers’ instruction and knowledge (Adams & Krockover, 1997; Eberle, 2010). Hence, the translation process from the intended to the implemented is made explicit, as the salient role of textbooks and materials becomes distinguishable. The three-level model of curriculum representations is extended to four levels.

**Figure 1.1**

*The Tripartite Model of Curriculum*
The Goal of the Study

The purpose of this study is to investigate (a) teachers’ and administrators’ perceptions of the qualities that make curriculum coherent; (b) the autonomy and barriers mathematics and science teachers experience in implementing coherent curriculum, and (c) ways that administrators act in support of teachers’ curriculum implementation. This study hopes to provide valuable insights to consider when supporting teachers’ skills in designing and implementing curriculum in coherent ways. However, engaging administrative stakeholders in addition to teachers is a priority in order to explore the context for teachers’ curricular efforts. This qualitative study collects data from participants who identify as administrators, mathematics teachers, and science teachers in secondary grades at public schools in the eastern U.S. in order to better understand the range of decisions about curriculum coherence teachers make. This study gives me the opportunity to ask the teachers questions about their instructional intentions and methods toward crafting a coherent curriculum. Thus, I hope to generate a better understanding of the nature of the teachers’ instructional decision-making and beliefs about curriculum coherence as well as support they need from administrators and barriers mathematics and science teachers experience in implementing a coherent curriculum.
Contextual information on the definition of a coherent curriculum, as well as mathematics and science teachers’ decision-making on designing and implementing curriculum coherence, will be provided in Chapter 2. The context, method, and design of the study and data collection tool will be outlined in Chapter 3. Results and analysis of the research study will be available in Chapter 4. Eventually, the detailed findings, recommendations, future implications, and limitations of the study will be discussed in Chapter 5.
CHAPTER 2
A REVIEW OF THE LITERATURE

INTRODUCTION

In order to make education meaningful and relevant to society, it depends on how the curriculum is developed. A curriculum is the total educational goals and experiences that students face in a school or other educational institutions (Adentwi, 2005; Abudu, & Mensah, 2016). Curriculum development and design play a critical role in the effectiveness of education (Eris & Kilicoglu, 2019). Research indicated that teachers’ knowledge and skills play a significant role in achieving educational objectives. Teachers should have sufficient knowledge and competencies in creating learning goals and planning instructional activities to reach desired learning and behaviors in students and lastly assessing the effectiveness of all these factors on students (Kuzgun, 1991; Eris & Kilicoglu, 2019).

There are various ways to select and use new curricular resources and it varies with different parameters such as knowledge of the teacher, availability of the resources, training, etc. (Gueudet & Poisard, 2018). Over the last few years, teachers’ use of curricular resources was shifting from traditional, published curricula toward different types of online teacher-created resources (e.g., Gewertz, 2014; Monahan, 2015; Ross, 2015). The widespread teachers’ access to online materials made it easier for them to share the curricula resources across states through the adoption of the mathematics and science standards. Also, the COVID-19 pandemic has pushed teachers to use online resources more. However, research evidence proved that if teachers are increasingly turning to online materials that were created by other curriculum developers (e.g., Baniahmadi et al., 2021; Gewertz, 2014; Monahan, 2015; Ross, 2015), they still are responsible
for creating an alignment and coherency between their contents within grades as well as across grades level to meet the needs of their students (Baniahmadi et al., 2021).

Research demonstrated curriculum standards and education policies in different countries strive to design more curriculum coherence (e.g., NCTM, 2006; Baniahmadi et al., 2021). “A coherent curriculum is one that has a sense of unity and connectedness, relevance and pertinence so the ideas have a sense of a larger purpose” (Beane, 1995; Eberle, 2010). Since there might be limited definitions of what it means for a curriculum to be coherent (Newmann et al., 2001; Schmidt et al., 2007; Bryk, 2010; Pietarinen, Pyhältö, & Soini. 2017), it is essential to create and operationalize one, especially as teachers today are overwhelmed with various curricular resources that may not be well aligned together or to key ideas students need to master (Baniahmadi & Olson, 2021). Furthermore, students need to experience the learning activities within a coherent framework to be able to successfully solve problems and make the right decisions for the ever-increasing resources of information.

**The Rationale for Increasing Curricular Coherence**

Research over the past two decades has recorded teachers’ use and shifting of curricular resources (e.g., Choppin, 2011; Remillard, 2005; Drake & Sherin, 2009). However, what remains understudied is how teachers’ curriculum use and modification result in a set of lessons that have a coherent sequence and structure. We know that curriculum coherence is important for student learning. However, very little is known about what teachers think coherence is, how they conceptualize it, and what strategies they use to increase curriculum coherence in their classrooms. This study is significant because it investigates teacher and administrator perceptions of what it means for a curriculum to be coherent, examines the degree to which those understandings align with the literature and with strategies teachers use, autonomy they
experience, and barriers and supports they experience from administrators. This study intends to extend existing theoretical and empirical research through exploration of how practitioners think about and enact curriculum coherence.

**Definition and Characteristics of Coherent Curriculum**

This part of the study discusses the definitions and characteristics of coherent curriculum from different perspectives and experiences, including different forms of coherent curriculum, coherence framed around teachers’ experience, advantages of coherence curriculum for students’ learning, coherence according to mathematics education literature, and coherence according to science education literature.

According to The Glossary of Education Reform website (2014) the term coherent curriculum refers to an academic program that is (a) aligned across subject areas, lessons, courses, and grade levels, (b) well organized and purposefully designed to facilitate learning, and (c) free of academic gaps and needless repetitions. In most cases, coherence is therefore operationalized as alignment of learning standards and teaching.

In a nutshell, curriculum coherence makes clear the logical sequence of topics and/or how the logical sequence determines the ordering of a series of topics. “Researchers value coherence of content because they believe that a coherently arranged curriculum makes it possible for a student to see the subject as a whole, to understand the logical connections and deep structures, and to use that understanding for more efficient problem-solving and better retention of knowledge and procedures” (Cuoco, & McCallum, 2018).

**Different Types of Coherent Curriculum**

Mathematics and science education researchers view coherence as an alignment. Whether that is from grade-to-grade, year-by-year: *Vertical Alignment*, from teacher-to-teacher, or
classroom-to-classroom: *Horizontal Alignment*, from lesson-to-lesson: *Chronological Alignment*, and/or connection between subject areas which is *Multidisciplinary Alignment*. Curriculum alignment prepares students with opportunities to synthesize new materials and build on their prior knowledge.

*Vertical Coherence*

There are two major types of coherent curriculum: (a) Horizontal coherence; (b) Vertical coherence. A curriculum that is vertically aligned helps students to connect what they learn in one grade level to the next grade level. In a vertically aligned or vertically coherent curriculum teaching is logically sequenced so that students' skills and knowledge will make progress to prepare them for higher-level challenges and works (The Glossary of Education Reform, 2014). A well-designed, vertically aligned curriculum flows. At first, students receive the skills foundation they need, and teachers reinforce the skills across classes and grades. A vertically aligned curriculum brings cohesion to the class. It helps schools meet their goals and make better decisions (Chalk, 2020). One way for vertical alignment to be developed is through opportunities for teachers who teach the same content to collaborate across grade levels (Baniahmadi & Olson, 2021).

*Horizontal Coherence*

A curriculum that is horizontally aligned or horizontally coherent occurs when teachers work within and across subject areas within grade level. For instance, teachers at the same grade level might meet to align their learning activities and assessment practices with their curricular goals. Horizontal teams focus on coordinating instruction and assessment to evaluate students’ progress and achievement according to grade-level standards (The Glossary of Education Reform, 2014; Baniahmadi & Olson, 2021). One of the benefits of horizontal alignment is that
every student who enrolls in the same grade level or takes the course within the school learns similar knowledge and receives the same instruction. Also, horizontal alignment improves instruction and communication between teachers as they exchange their experiences and ideas (Chalk, 2020; Banahmadi & Olson, 2021).

As described in the following parts, research demonstrates that horizontal and vertical alignments improve student success by (a) making knowledge more meaningful; (b) setting clear expectations; (c) decreasing unnecessary repetition; (d) addressing gaps in learning, and (e) sparking professional growth (Chalk, 2020).

**Decreasing Unnecessary Repetition.** Some lessons share similar foundational knowledge. A vertically aligned curriculum needs teachers to think and enact beyond the grade level or classroom walls. They should collaborate with their colleagues to develop a high-quality curriculum that builds from foundational knowledge at each level. If teachers make decisions independently, they may not know what is taught in other classrooms. Consequently, the materials may repeat over and over at the same level (Chalk, 2020), rather than “spiraling” to productively build deeper learning when content is revisited (Banahmadi & Olson, 2021).

**Addressing Gaps in Learning.** Vertical and horizontal alignments in curriculum assist teachers to determine students’ weaknesses and struggle to pay more attention to them. Therefore, teachers don’t miss any main skills to teach. Most importantly, they can organize their curriculum to see where timing doesn’t match up between basics and next level of learning, or where they are thin on lessons (Chalk, 2020; Banahmadi & Olson, 2021).

**Making Knowledge More Meaningful.** Sometimes students have opportunities to see connections across subject areas or to see how content from one area (e.g., mathematics) is part of learning in another area (e.g., science). This connectivity gives students opportunities to
examine content with more depth and develop a deeper knowledge of the topic. Seeing content in other subject areas also allows students to use reasoning and representation norms from different domains, thereby applying their information in different ways, from many perspectives (Chalk, 2020; Baniahmadi & Olson, 2021).

**Setting Clear Expectations.** Vertical and horizontal alignments are the practices in planning and coordination. When developing the alignments, curriculum maps are used to assure students make progress throughout the year, from basic to more complex skills as needed. These maps not only help teachers to plan before students arrive in the class but can also be shared to serve as a communication and an opportunity for parents and students to know what to expect (Chalk, 2020; Baniahmadi & Olson, 2021).

**Sparking Professional Growth.** Students’ improvement and progression depend, in part, on a teacher’s professional development. Efforts to vertically and horizontally align a curriculum and to support that alignment in practice provide opportunities for teachers to gather together to share their ideas and experiences and try new methods. Teachers’ collaboration around a mapped and aligned curriculum provides a way to see what others are doing and what is working best in their classrooms (Chalk, 2020; Baniahmadi & Olson, 2021).

From the perspective of vertical and horizontal coherence, a coherent curriculum is one in which students’ learning builds on their previous knowledge and lessons are not repetitive or redundant across grade levels and subject areas. Teachers know about the materials and standards that are taught in the previous grades and subsequent grade levels. In an incoherent curriculum, in contrast, teachers might decide independently about what students learn, without collaborating with other teachers, basing what they teach on consistent learning expectations or considering what students learned in previous grades and will need to learn in subsequent grades.
As a result, students may not receive appropriate lessons throughout their academic grade levels, and they will not meet the academic expectations (The Glossary of Education Reform, 2014). To sum up, vertical coherence and horizontal coherence require teachers to collaborate with their fellows to align their learning activities and assessments and consequently develop a high-quality, coherent curriculum for enhancing student achievements.

**Coherence Framed around Teachers’ Experience**

Teachers’ knowledge and skills play a significant role in designing and implementing a coherent curriculum. Remillard (2005) states that “curriculum use refers to how individual teachers interact with, draw on, refer to, and are influenced by material resources designed to guide instruction” (p. 212). This perspective considers that teachers have an important role within a unique instructional context, as they interpret, adapt, and implement the curriculum. Teachers need to be responsive to the needs and ideas of their students (Hammer, Goldberg, & Fargason, 2012; McNeill et al., 2018). However, there might be some obstacles or challenges teachers perceive to implementing curriculum in coherent ways. The greatest challenge for teachers in terms of coherence is to understand the underlying curriculum structure, understand the storyline and big ideas of the materials, become familiar with the materials, and be prepared to make instructional and curricular decisions that maintain or enhance the coherence of this storyline. In addition, teachers should be prepared to adjust, adapt, and modify the materials for existing students. Work to support these teachers informed by prior work in mathematics and science education related to curriculum storylines (e.g., NextGen Storylines work in science education), curriculum vision (e.g., Darling-Hammond et al., 2005; Drake & Sherin, 2009), and educative curriculum (e.g., Davis & Krajcik, 2005). However, in contexts in which teachers are gathering and curating resources from a variety of sources, the central challenge is to develop a
structure that will create coherence across these various resources and inform both instructional and curricular decisions.

One of the practices demonstrated to improve a coherent curriculum is teacher collaboration. Teachers collaborate with each other and with curriculum design team at schools to design and plan instruction, implement the task, evaluate student work, reflect on student needs, and provide coherency in instruction and curricular goals for students (Larson, 2016). Collaborative design improves teachers’ knowledge and competencies and consequently improves implementation of a coherent curriculum which leads to increasing teachers’ ownership of curriculum (Lewis, Perry, & Hurd, 2009).

The active involvement of teachers in collaboratively designing curriculum materials is becoming a more prominent educational practice (Vescio, Ross, & Adams, 2008). Teachers’ active involvement in collaborative curriculum design increase teachers’ ownership of the curriculum, promotes the harmonization and the coherence of enacted curriculum and enhances teachers’ curricular collaboration (Penuel, McWilliams, et al., 2009). The active involvement of teachers can only be effective when teachers themselves feel the need to change their practice, are convinced that their effort will bring about that change, and install that change (Becuwe et al., 2015; Morris & Hiebert, 2011). Therefore, one of the significant elements that contribute to the design of curriculum coherence is teachers’ collaboration (Voogt, et al., 2011). Research proved that to support curriculum coherence, at first teachers should receive support to make connections between experience and ideas and develop coherent instructional activities to improve students’ learning (Bransford, Brown, & Cockling, 2000).

In conclusion, teachers require specific guidelines on how to use curriculum resources and how to make connections between the lessons to improve coherency. Otherwise, they may
confront so many challenges and create fragmented learning experiences for their students. Moreover, instruction and communication between teachers improve as they exchange their experiences and ideas when teachers who teach the same course meet across grade levels or teachers at the same grade level meet to align their learning activities and curriculum.

**Advantages of Coherence Curriculum for Students’ Learning**

Recently researchers focused on curriculum coherence based on the understanding that when students experience new lessons and activities within a coherent framework, their learning is enhanced by connections and dependencies between each lesson or activity (Darling-Hammond et al., 2005; Drake & Sherin, 2009). A coherent curriculum helps learners to make connections to their immediate lives in tangible ways (Ennis, 2008). They perceive curriculum coherence not only as valuable but also as enjoyable, filling a need they identify and accept. According to Ennis (2008) “coherence is related to students’ perceptions of connectedness, both internally among curriculum topics and externally in their lived experiences. The perception of connectedness stems from the teacher’s careful selection and presentation of topics within a context, encouraging in-depth learning and leading to student acknowledgment of content meaningfulness and value”. The curriculum coherence must contain scientific inquiry; beyond that, inquiry skills of teachers without content knowledge do not advance students’ mastery of scientific inquiry (Gabel, 2006; Jin et al., 2019). “Coherence can be illusive and dependent on educational participants’ subjective perspectives” (Ennis & McCauley, 2002). Lee (1996) and Solmon (2003) explored the cognition role in students’ learning. The evidence shows that teachers can promote student learning and engagement when they purposefully and constantly help them make connections between the principles, topics, and skills and then apply their learning, building on previous knowledge both in life and school. One theory that could increase
subject matter value and student engagement is a coherent curriculum (Beane, 1995). It focuses directly on alignment within the curriculum that impacts students’ perceptions of value and meaning (Ennis, 2008).

The lesson learned from some research studies is that a coherent curriculum must not be treated in a strict manner for disciplinary structure; instead, it should consider prior knowledge and experiences of students (Sikorski & Hammer, 2017). “Teaching students, a list of statistical recipes is not enough to make them statistically literate. Students also need to see the coherence in the concepts they learn and in the basic principles underlying data analysis” (Moore, 1997; Tarr & Shaughnessy, 2007). Hence, a curriculum coherence advances students’ deep understanding of the important concepts (Bransford et al., 2000; Shwartz et al., 2008), makes authentic connections to real lives, engages with instruction in meaningful ways, and perceives the value of the learning.

Coherence According to Mathematics Education Literature

The study investigates coherence in Mathematics and Science education. Although, there are differences in how mathematics educators and science educators talk about coherency. This study uses the National Council of Teachers of Mathematics (NCTM) (2014) broad definition of curriculum as the “program used to help students meet the standards, including instructional materials, activities, tasks, units, lessons, and assessments” (p. 70). The study points out a National Council of Teachers of Mathematics position statement in response to the increasing prevalence and use of Open Educational Resources which highlights that “a coherent, well-articulated curriculum is an essential tool for guiding teacher collaboration, goal-setting, analysis of student thinking, and implementation” (NCTM, 2016, p. 1). The statement went on note that, “coherence means that connections are made from one year to the next, from one idea to another,
from one representation to another… There is coherence pedagogically, logically, conceptually, in terms of learning science and with the real world” (p. 1). This suggests that coherence means connections not only across mathematical topics, but also across mathematical practices, representations, and strategies. In prior teaching and professional development work with teachers, the construct of coherence has been made accessible in part through the notion of the sequence (s) that characterize students’ mathematical learning over time.

**Pedagogical Coherence**

Research studies highlighted the idea of pedagogical content knowledge. Pedagogical content knowledge refers to knowledge of pedagogical strategies specific to a content domain. It needs teachers to have great subject matter knowledge and the strong ability to utilize the subject matter knowledge in connecting their instructional practices (Shulman, 1986, 1987; Chen, & Li, 2010).

**Logical Coherence**

The Merriam-Webster dictionary defines coherence as “the quality or state of cohering as (a) systematic or logical connection or consistency, (b) integration of diverse elements, relationships, or values”. In this definition, more focus is on the quality of logically integrated or connected components, not the process. Instructional coherence must include a sequence of events that are related to one another and afford a more representation of coherence and effectiveness in student understanding (Fernandez et al., 1992; Chen, & Li, 2010).

**Conceptual Coherence**

(NCTM) (2016) developed a new curriculum that is coherent from different aspects. “First, the content grows and builds upon itself in ways that align with research on how students develop and retain mathematical understanding. This includes attention to the hierarchical
structure of the discipline. Coherent mathematics programs also help students make sense of
mathematics by situating the mathematics in problem-solving contexts so that students learn
mathematics in order to answer meaningful questions in real-world or mathematical contexts.
Explicit attention is paid to promoting students’ conceptual understanding of mathematics so that
the mathematics itself makes sense to students. By linking mathematical topics within and
among mathematical domains, mathematics appears as a unified discipline rather than as a
collection of topics. This is emphasized further through careful attention to cross-grade
articulation of mathematical ideas and skills. Additionally, consistent approaches in the use of
tools, instructional strategies, assessment, and accessibility, as well as careful attention to lesson
design create programs that seamlessly integrate a wide array of components into a coherent
whole and facilitate the development and maintenance of a classroom culture with consistent
student expectations” (NCTM, 2016, P. 2).

According to some researchers, instructional coherence could help students to promote
their mathematical reasoning and insights. Students can build on their prior mathematical
knowledge, make connections with the new ones, and create a profound understanding of
mathematical concepts through the coherence structure of the lessons and related activities (Chen
& Li, 2010). It is worth mentioning that causally connected practices are not adequate to achieve
coherent lessons, either for a sequence of lessons or a single lesson. In order to improve learners’
mathematics knowledge, teachers also should have coherent mathematics knowledge and skills
to implement a curriculum coherence (Chen & Li, 2010). Many research studies have indicated
that one of the substantial characteristics of mathematics class instruction is coherence (e.g.,
Hiebert et al., 2003; Shimizu, 2007; Stigler & Perry, 1988; Wang & Murphy, 2004) and that
coherent mathematics lessons lead to students’ profound mathematics understanding.
In conclusion, clearly, having a well-articulated, high-quality, coherent curriculum at the school is even more important in the age of open education resources because it is the curriculum that establishes the learning goals in a coherent progression and helps teachers to see and understand the multiple pathways that students take through the progression (NCTM, 2016, P. 2). More importantly, coherence in mathematics education makes the subject memorable for students and helps them to integrate the subject or contents with other disciplines.

**Coherence According to the Science Education Literature**

Science educators are interested in the arrangement between conceptual ideas and how the concepts get together. Also, they talk about coherency in terms of students learning in science, which is the connection between students’ prior knowledge and their new ideas based on the instruction. One major element that appears to the learning of science is that there is connection and coherency inside the contents of science. The responsibility of teachers is that they should make connections between ideas of science and provide coherent learning experiences to improve students’ understanding. The importance of this idea highlighted by some science educators and researchers (Bransford, Brown, & Cockling, 2000; Bybee, 2003; Farber, 2000; Jackson & Davis, 2000; Rutherford, & Ahlgren, 1990; Smith et al., 2004; Wilson, 1998). Research studies demonstrate that “learning of scientific knowledge occurs under different conditions of prior knowledge” (Chi, 2008; Jin et al., 2019). When former knowledge is missing, learning is conceived as adding new knowledge. If prior knowledge is incomplete, learning contains filling the gaps. Learning under these two conditions is a process of knowledge enrichment, which does not involve restructuring existing knowledge (Jin et al., 2019).

Eberle (2010) defined coherence in science as a collection of ideas and insights that are connected to each other and with unifying concepts that are hierarchically determined from
elementary to high school, they can represent a coherent structure. Bybee (2003) argues for a conceptual approach to coherence by stating that, “coherence occurs when a small number of basic components are defined in a system, organized in conceptual relationship to each other, and other components are based on or derived from those basic components” (p.350). A conceptual approach to a more coherent curriculum explains how a coherent curriculum may assist learners to gain a profound understanding of the essential ideas (Shwartz et al., 2008). More so, coherence is related to students’ understandings of alignments or connectedness, both externally in their real-world experiences and internally among curriculum topics. However, students’ understanding of conceptual alignments or connectedness has been shown to “stem from the teacher’s careful selection and presentation of topics within a context, encouraging in-depth learning and leading to student acknowledgment of content meaningfulness and value” (Ennis, 2008). This suggests that conceptual connections may relate to ideas raised in both domain content knowledge and evaluation perspectives.

Research shows that there are lacking opportunities for classroom teachers to make conceptual connections in science in order to help students learn. For this reason, so many reform efforts emphasize enhancing teachers’ content knowledge (Eberle, 2010). Eberle (2010) states that beginning teachers show a weaker quality of classroom discussions among the student and teacher. They discuss alternative concepts in science with their students, also represent a disintegrated and disconnected content because of their insufficient confidence in their subject area knowledge. Consequently, new teachers are marked as having lower content preparations (Eberle, 2010). Studies revealed that teachers involve in incoherent and fragmented learning experiences with students if they don’t select proper ideas that make larger concepts, and don’t think about achieving their learning goals (Schmidt, McKnight, & Raizen, 1997; Eberle, 2010).
Learning progression (LP) research has been revealed as a vital area for science education. To gain a clear explanation of student development, science educators and researchers create LPs that have several progress variables. Progress variables include skills, competencies, and abilities that are essential for students’ achievement and are targeted by the instruction and curriculum (Wilson, 2009; Jin et al., 2019). In a research study conducted by Jin et al. (2019) three types of coherences considered for an LP to be effective in enhancing student learning: 1) “developmental coherence of productive learning across time; 2) horizontal coherence across instruction, curriculum, and assessment, and 3) vertical coherence between classroom assessments and large-scale assessments. Developmental coherence is about the nature of learning. It entails an LP addressing the logical structure of science disciplines, students’ prior knowledge and experiences, and the integration of knowledge and practices. In contrast, horizontal coherence and vertical coherence are about the approaches used to promote productive learning for all students” (Jin et al., 2019). It is important to mention that the foundation for vertical and horizontal coherences is developmental coherence (Fulmer, Tanas, & Weiss, 2018).

Science researchers emphasized two important ideas about curricular coherence: 1) curricular coherence should not be treated strictly as a matter of disciplinary structure; instead, it must take into account students’ prior knowledge and experiences (Sikorski & Hammer, 2017; Jin et al., 2019), 2) and a “coherent curriculum should include scientific inquiry; more important, teaching inquiry skills separately from content knowledge does not lead to students’ mastery of scientific inquiry” (Gabel, 2006; Jin et al., 2019). Knowledge and inquiry should be integrated because inquiry (practices) use as a means to construct and apply knowledge. In NRC Framework (NRC, 2012) and NGSS (the NGSS Lead States, 2013), scientific inquiry is specified
in scientific practices. The relationship between knowledge and practices is conceptualized in the NRC’s vision for science education “students, over multiple years of school, actively engage in scientific practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields” (NRC, 2012, pp. 8-9; Jin et al., 2019).

The National Research Council (2012) presents a Framework for K-12 Science Education that describes fundamental practices and concepts for new standards and suggested shifts in K-12 science education. The framework defines three dimensions of science disciplines: core ideas, science practices, and crosscutting concepts (NRC, 2012). Reiser, Novak, and McGill (2017) discussed that meeting the vision of the framework in schools and classrooms needs significant changes in instructional strategies and teaching materials to support curriculum coherence. One clear and important goal expressed in the framework for K-12 science is paying more attention to the lack of a coherent curriculum in U.S. K-12 education. The framework emphasizes “the need for greater coherence that is, a sense of unity in K-12 science education. Too often, standards are long lists of detailed and disconnected facts, reinforcing the criticism that science curricula in the United States tend to be “a mile wide and an inch deep” (Schmidt, McKnight, & Raizen, 1997; National Research Council, 2012, p. 10; Reiser, Novak, & McGill, 2017). This framework determines three criteria to support coherence: (1) “organizing learning goals around a developmental progression …designed to help children continually build on and revise their knowledge and abilities, starting from their curiosity about what they see around them and their initial conceptions about how the world works; (2) focusing on a limited number of core ideas; and (3) integrating knowledge and practices” (National Research Council, 2012, p. 11). Considering coherence from student perspectives highlights criteria (1) and (3) of the framework: students build new knowledge incrementally from their primary conceptions and
engage in science practices to make progress in solving problems or responding to questions (Reiser, Novak, & McGill, 2017). In a summary, one key factor that appears in the learning of science is that there is connection and coherency within the contents of science. The responsibility of teachers is that they should make conceptual connections between ideas of science and provide coherent learning experiences for students to improve their successful outcomes.

The Danielson Framework as a Conceptual Framework

This study particularly is bringing in the idea of Danielson which is a generic subject taught process of coherence with the Tripartite Model of Curriculum that examines the ways coherence changes across what was intended by the curriculum designers and what was implemented in the classroom by teachers. Teachers regardless of what content area they teach, are going to think about the coherency in the ways to be evaluated as well. Danielson Framework is used all across the country to evaluate teachers. The way coherency appears in the Danielson framework is talking about two areas: 1) the alignment between the lesson and the goals of the lessons, and 2) the alignment across intra- and interdisciplinary content relationships which means coherence across big ideas and coherence across subject areas.

The Danielson Framework for Teaching Evaluation Instrument (Danielson Group, 2013) provides a definition of coherency that may especially influence teacher beliefs. The Danielson Framework is widely used as an element of teacher evaluation systems, and as such, has significant practical implications for teachers. For the purpose of this study, I chose components 1e and 1a to explain coherency and its effects on curricular decision-making by teachers. Framework Component 1e: Designing Coherent Instruction may provide one way to operationalize coherence that is accessible to teachers and meaningful in that it relates to their
evaluation outcomes. In the Danielson Framework, coherence is described in terms of a sequence of instructional activities, with special attention paid to alignment with learning goals. Importantly, teachers demonstrate their expertise with coherence through curricular decision-making about lesson and unit plans, learning activities, use of resources, and grouping strategies. However, the framework does not provide insight into what is important in determining sequence beyond accessing academic standards and goals. Instead, Component 1a: Demonstrating Knowledge of Content and Pedagogy suggests that distinguished teachers develop coherence across intra- and interdisciplinary content relationships, with special attention paid to awareness of potential student misconceptions and pedagogy that will address those misconceptions.

Thus, one way to ensure curricula coherence is accessible to teachers and can help teachers reach meaningful student learning outcomes is to help teachers conceptualize decision-making about curricular resources during planning to ensure that the instruction students receive is coherent in terms of content and pedagogy.

The Tripartite Model of Curriculum as a Theoretical Framework

In order to further explore the difference between the intended and implemented curriculum in the curricular landscape, this study uses the Tripartite Model of Curriculum to examine the ways coherence changes across what was intended by the curriculum designers and what was implemented in the classroom by teachers. This framework demonstrates the hierarchy, complexity, and interaction between standards, textbooks, curriculum goals, and teachers’ perspectives in the implementation of the curriculum.

International Association for the Evaluation of Educational Achievement (IEA) conducted large-scale studies of educational outcomes and learning opportunities in different subject areas such as science and mathematics (TIMSS) to better understand the connections
between; (a) the intended curriculum (what policy requires); (b) the implemented curriculum (what is taught in schools); and (c) the achieved curriculum (what students learn). The Third International Mathematics and Science Study (TIMSS) included a major investigation of the curriculum intended for and implemented in the classrooms of over 40 countries (Taguma, Shirai, & Anger, 2016). The TIMSS was created to examine the educational systems which goal is to transfer educational experiences to learners. The tripartite model of curriculum, conceptualized through earlier studies, was the foundation for all aspects of the TIMSS (Schmidt et al., 1996; Taguma et al., 2016). The model provides a conceptual map that links important aspects of the curriculum as it plays out in schools. It demonstrates the hierarchy, complexity, and linkage between standards, textbooks, curriculum goals, and teachers’ perspectives in the implementation of curriculum (adapted from Schmidt et al., 1996). This model makes an analytical distinction between curriculum as system goals, curriculum as instruction, and curriculum as student achievement. These dimensions are known, respectively, as the intended, implemented, and attained curriculum (Taguma, Shirai, & Anger, 2016).

**Intended Curriculum**

The *intended curriculum* refers to the official statements that determine what students are expected to learn. Typically, these are “educational system’s goals such as national standards” (Eberle, 2010), as well as state and district curriculum standards or guides. Textbook publishers often rely on these official documents to turn standards into lessons and accompanying exercises for students that may be used in classrooms (Taguma, Shirai, & Anger, 2016).

**Implemented curriculum**

Teachers use textbooks and other supplemental resources to create educational goals and experiences for students. These classroom instructional experiences are referred to as the
implemented curriculum which is the taught curriculum. Knowing what content is actually taught in classrooms will help reform efforts go beyond the implementation of new instructional practices and materials and include identifying the coherence and connectedness of the lessons (Eberle, 2010). Research proved that “Teachers will significantly alter the implemented curricula to make it more congruent with their own teaching orientation and belief systems” (Cronin-Jones, 1991; Schmidt et al., 1996; Eberle, 2010). Therefore, the implemented curriculum is varied from class to class even when teachers utilize similar instructional materials (Eberle, 2010). One main reason for the various implemented curriculum is that a lot of teachers may not have enough content knowledge and competency for teaching, or their content knowledge are not adequately coherent across the disciplines (Abd-El-Khalick & Boudaoude, 1997; Arzi, White, & Fensham, 1987; Eberle, 2010). “In the intended and implemented curriculum, coherence has a purpose; it aims at developing coherent knowledge in the attained curriculum. In the attained curriculum, coherence is the purpose: students’ coherent knowledge” (Goodlad, 1979; Van den Akker, 2003; Sun, 2014).

Attained Curriculum

Finally, what students have learned and their knowledge: ideas, constructs, and schemas are referred to as the attained curriculum (Schmidt et al., 1996; Eberle, 2010). The attained curriculum refers to “what the learners actually acquired from their interaction with the teachers in the cognitive, psychomotor and affective domains. The attained curriculum indicates the knowledge, understanding, skills, and attitudes that learners actually acquired as a result of teaching and learning that is authentically assessed through different approaches and/or demonstrated in practice. It is the result of what is achieved at the end of learning and teaching.
The attained curriculum defines the student’s competencies, academic achievement, attitudes, and belief indications” (Houang & Schmidt, 2008; Anikweze, & Ugodulunwa, 2020).

**Potentially Implemented Curriculum**

In the tripartite model, a crucial bridging curriculum representation is introduced, i.e., the *potentially implemented curriculum*. Therefore, the potentially implemented curriculum shows the link between the intended curriculum and the implemented curriculum. In the model, textbooks and any curricular resources that teachers utilize in their daily instruction represent the potentially implemented curriculum. They play an essential role in impacting teachers’ beliefs and might be the source of teachers’ instruction and knowledge (Adams & Krockover, 1997; Eberle, 2010). Hence, the translation process from the intended to the implemented is made explicit, as the salient role of textbooks and materials becomes distinguishable. The three-level model of curriculum representations is extended to four levels. The Tripartite Model of Curriculum is presented in the Figure below.

*Tripartite Model of Curriculum*

![Tripartite Model of Curriculum](image)

*Note. Adapted from Schmidt et al., 1996*
According to the research study conducted by Anikweze and Ugodulunwa (2020), they used the Tripartite model of Curriculum to emphasize the importance of curriculum design on students’ graduation. Anikweze and Ugodulunwa (2020) state that curriculum should be tied to the quality of learning experiences since quality of learning is increasingly being recognized as a fundamental factor in achieving the goals of education. Curriculum design is identified as a vehicle for meeting challenges of global competitiveness. The need to support students to live in the ever-changing global world through provision of solid, relevant preparation at the secondary and tertiary levels of education has been stressed (Harrison, 2017). Therefore, we can claim that, indeed, high-quality education is the outcome of all aspects of measurable learning experiences, especially in essential life skills. Thus, the teacher’s constant challenge would be to narrow the gap between the implemented curriculum (what teacher has taught) and the attained curriculum (what learners have mastered).

The Connection between Danielson Framework and Tripartite Model of Curriculum

The Danielson framework represents a high-stakes, top-down, achievement policy-driven approach to coherence. The Tripartite Model represents a systemic approach to bridging the intended content focus and what happens in classrooms. We argue the Tripartite Model needs to account for policy at the potentially implemented level. Component 1e in the Danielson framework aligns with potentially implemented curriculum coherence. Instructional resources and implemented curriculum coherence, teacher planning, and decision-making make a bridge between the teacher’s knowledge of the curriculum and their decisions around lesson planning. Component 1a in the Danielson framework aligns with intended curriculum coherence standards, domain-specific content, and pedagogical knowledge.
Teachers’ Curricular Decision Making

Curriculum design “is a process which involves making basic decisions about who will partake in the curriculum decision-making process and how it will proceed” (Adentwi, 2005: 54; Abudu & Mensah, 2016). Teachers’ involvement in developing curriculum help in determining their requirements and addressing solutions to them (Maphosa1 & Mutopa, 2012; Abudu & Mensah, 2016). Therefore, teachers should have the opportunity to modify curriculum to meet the needs of students and match the requirements of schools and districts.

In a research study conducted by Abudu and Mensah (2016) two types of curriculum development processes are compared: centrally designed and decentralized. In a centrally managed or prescribed curriculum, there is less involvement between the classroom and the curriculum planner. Therefore, it is hard to find the right curricula for all schools (Stenhouse, 1975; Eunitah et al., 2013; Abudu & Mensah, 2016) while in the school-based curriculum or decentralized, teachers play an active and major role in curriculum development process (Maphosa1 & Mutopa, 2012; Abudu & Mensah, 2016). In a centrally designed system, teachers carry out and implement the curricula that they did not involve in planning. It leads to a high rate of curriculum rejection by teachers as implementers (Chitate, 2005; Oloruntegbe et al., 2010; Maphosal & Mutopa, 2012; Eunitah et al., 2013; Abudu & Mensah, 2016). Research proved that teachers play a main role in the educational system, and it is important that they play a central role in developing and planning the curriculum (Abudu & Mensah, 2016). The important reasons for teachers’ engagement in curriculum development process are indicated as “improving the existing curriculum, and increasing effectiveness as a teacher, feeling that one’s contributions and suggestions are helpful, and satisfaction from participating in decision-making that affects
one’s own work (Bowers, 1991; Abudu & Mensah, 2016). However, research demonstrates that teachers became less interested in involving in the curriculum development process because they have seen their efforts changed constantly by the school administrators or educational ministers (Elliott, 1994; Abudu, & Mensah, 2016).

**Teachers’ Barriers to Curriculum Design Process**

If sometimes teachers try to participate in curriculum development process, they face some barriers/obstacles (Abudu, & Mensah, 2016). The barriers they confront are included: (1) lack of information about the role teachers are to play is a critical obstacle/barrier to teachers’ involvement in curriculum development (Connelly & Ben-Peretz, 1997; Ramparsad, 2001; Mokua, 2010; Abudu & Mensah, 2016); (2) another barrier/obstacle to teachers’ participation in curriculum development process is their lack of expertise in curriculum design (Bowers, 1991; Ramparsad, 2001; Handler, 2010; Abudu & Mensah, 2016). According to some researchers, teachers don’t receive adequate training and professional development program to do this, and their limited knowledge is a barrier/obstacle to participating in curriculum development process (Bowers, 1991; Abudu & Mensah, 2016); (3) More so, the wide range of responsibilities or tasks teachers should perform limit their willingness to participate in curriculum design (Bezzina, 1991; Bowers, 1991; Chinyani, 2013; Abudu & Mensah, 2016). Therefore, “teachers undergo stress and there are competing priorities for the time. This suggests that the unavailability of adequate time at the disposal of the teachers serves as a barrier to their participation in curriculum design” (Abudu & Mensah, 2016); (4) Beyond that, teachers feel reluctant to participate in curriculum design process because they believe their efforts are not appreciated. “They feel not motivated to take part in curriculum development at the school or national level.
because their efforts are usually massaged regularly making it lose its originality” (Abudu, & Mensah, 2016).

The results of a research study conducted by Baniahmadi et al. (2021) during the COVID-19 pandemic revealed that teachers reported curricular decisions were primarily made by district leaders (60%), principals (41%), grade-level teams (39%), and school boards (17%), with few teachers reporting that they were completely in control of their curricular decisions (11%). Also, teachers from different geographic areas reported a range of control over their curriculum. For example, 16% of rural, 19% of suburban, and 29% of urban teachers reported they had no control over their curriculum. At the other end of the spectrum, 13% of rural, 12% of suburban, and 7% of urban teachers reported they had full control over their curricular decisions. Most teachers reported either “a bit” (35% rural, 40% suburban, 42% urban) or “a lot” of control (35% rural, 29% suburban, 23% urban).

As a result, teachers’ decision-making and autonomy over curriculum are crucial elements for enacting a high-quality curriculum in the classroom. Teachers should have the opportunity to modify curriculum to meet the needs of students and match the requirements of schools and districts. More importantly, educational leaders and administrators should provide better support for teachers to participate in inventing and developing their curricula.

Summary

Practitioners like Shwartz and colleagues (2008) provide some helpful suggestions for improving learning goal coherence: “(a) focus on the key concepts, (b) take students’ beliefs and prior knowledge into account, (c) engage students with relevant phenomena, and (d) support students’ understanding and reasoning skills”. Curricular coherence should not be treated strictly
as a matter of disciplinary structure; instead, it must take into account students’ prior knowledge and experiences (Sikorski & Hammer, 2017). Supporting a coherent curriculum must include the supporting teachers to make alignment between topics and provide coherent learning activities to improve students’ understanding (Bransford, Brown, & Cockling, 2000). Therefore, education reforms will not succeed without teachers who are immersed in the subjects they teach and who know how to foster both basic knowledge and advanced thinking and problem-solving among their students (Garet et al., 1999; Darling-Hammond, Flook et al., 2020).
CHAPTER 3
THE RESEARCH PROCESS

This chapter provides an overview of the methodology used in conducting the study, including context and the setting, participants of the study, and how the data were collected and analyzed. To maintain confidentiality, the name of the schools and the participants in the study are presented as pseudonyms.

Purpose of the Study and Research Questions

The purpose of this study was to investigate (a) teachers’ and administrators’ perceptions of the qualities that make curriculum coherent; (b) the autonomy and barriers mathematics and science teachers experience in implementing a coherent curriculum, and (c) ways that administrators act in support of teachers’ curriculum implementation.

The overarching research question which guided the design and implementation of this study was: How do mathematics and science teachers conceptualize and implement a coherent curriculum?

In order to answer this question, the following sub-questions guided the investigation:

1) What are teachers’ and administrators’ perceptions and experiences of qualities that make curriculum coherent?

2) What obstacles do teachers perceive in implementing a curriculum in coherent ways?

3) What can we learn about teachers’ autonomy to make decisions about their curricular resources?

4) What similarities and differences are there in the ways that mathematics and science teachers conceptualize and implement a coherent curriculum?
The existing body of research suggests that curriculum development and design are critical for the effectiveness of education (Eris & Kilicoglu, 2019) and that when students experience new lessons and activities within a coherent framework, their learning is enhanced by connections and dependencies between each lesson or activity (Darling-Hammond et al., 2005; Drake & Sherin, 2009). In summary, we know that curriculum coherence is important for student learning. However, very little is known about what teachers think coherence is, how they conceptualize it, and what strategies they use to increase curriculum coherence in their classrooms. This study is significant because it investigated teacher and administrator perceptions of what it means for a curriculum to be coherent, examined the degree to which those understandings aligned with the literature and with strategies teachers used, autonomy they experienced, and barriers and supports they experienced from administrators.

This study contributes to the existing literature about teachers’ use of curriculum. Curriculum coherence is believed to help learners build on previous knowledge as well as support teachers to make connections between ideas and ways of thinking in the content area and their instructional practices and learning activities (Baniahmadi & Olson, 2021). This study is intended to extend existing theoretical and empirical research through an exploration of how practitioners think about and implement curriculum coherence.

Identification of Stakeholders

This study includes administrative and instructional stakeholders (i.e., teachers). Administrative stakeholders are included because they are involved in policies that influence the design and delivery of coherent curriculum; may act to support teachers in building a solid understanding of appropriate pedagogical practices, skills, and knowledge; and are key decision-makers in providing access to curricular resources within schools. Two types
of administrative stakeholders in addition to instructional stakeholders (i.e., teachers) are included in this study.

**Principals**

They are often the administrators who provide access to curricular resources and determine teachers’ level of autonomy in making decisions about the provided resources. For example, a principal may require teachers to use the curriculum as presented (i.e., scripted curriculum), may provide teachers with the opportunity to modify and adapt a core curriculum as needed, or may provide very limited support and expect teachers to source their own resources. Most teachers work in a context somewhere in between in which they have some shared curricular resources and are expected to supplement these with things they find online or develop on their own or with their grade-level teams. Principals set the norms for these expectations. Also, principals serve as a supporter and facilitators of quality instructional practice to make sure teachers provide effective learning for students. They also may emphasize frameworks for effective practice (e.g., Danielson’s Framework for Effective Teaching or the Tripartite Model of Curriculum) or elements of those frameworks during the teacher evaluation process. What principals highlight in their evaluation may be especially important to teachers’ decision-making about the curriculum.

**District or School-Level Curricular Experts and Stakeholders**

A district or school curriculum design team, Curriculum Director, and/or Instructional Coach may manage the curricular resources and choices for schools and ensure that the curriculum meets the educational needs of the students. They may present their findings to a School Board, who then has some authority in choosing to adopt or not adopt the curriculum.
Also, they provide training and professional development for teachers to help improve their instruction and use of the curriculum.

**Teachers**

Teachers are the primary participants in this study. Teachers use curriculum resources (e.g., textbooks, materials from curriculum publishers, state standards, online resources) to develop and enact high-quality instruction. Depending on the level of autonomy, teachers may utilize existing curricular resources, modify resources they are provided, identify new resources, and/or design their own resources. In this study, teachers are the targeted population because they are the ones who are closely involved with curriculum implementation and student outcomes.

This study hopes to provide valuable insights to consider when supporting teachers’ skills in designing and implementing curriculum in coherent ways. Also, this study hopes to generate a better understanding of the nature of the teachers’ instructional decision-making and beliefs about curriculum coherence. However, engaging administrative stakeholders in addition to teachers is a priority in order to explore the context for teachers’ curricular efforts.

**Research Design and Procedures**

**Rationale for Design**

The methodology used in this study is qualitative. Qualitative research is philosophical in nature; it is guided by a researcher’s belief in how she/he/they “see the world and acts in it” (Denzin & Lincoln, 2011, p. 19). There are different approaches to collecting data for qualitative research. Focus groups and in-depth interviews are among the most utilized methods researchers use. Focus groups help researchers to learn about the topic from different perspectives of group participants. Also, focus groups foster collaborative talk on a particular issue that participants
may not be able to talk about in individual interviews. According to Casey and Kueger (2000), focus groups provide “a more natural environment than that of individual interviews because participants are influenced by others just as they are in real life” (p.11). This naturalistic environment may be especially useful in building knowledge within a community (e.g., as teachers in the same content area/school/district collaborate to share ideas).

However, sometimes participants may not be comfortable sharing their important or individual experiences in a group. That is why an individual interview is a good technique to draw in-depth information from individuals on specific topics, such as their personal lesson planning. In-depth interviews provide a more personalized opportunity for individuals, and this is a helpful method for getting people to talk about their opinions and experiences in qualitative research. Individual interviews provide rich data which can add to the depth of information and improve the trustworthiness of the study. Lastly, open-ended surveys would be another useful way to collect data in qualitative studies because individuals may not be able to participate in longer focus groups or interview sessions, especially during the COVID-19 pandemic, but they may be able to answer questions in their own time to express their feelings and provide more detailed information about their experiences.

Data Resources and Data Collection Methods

This qualitative study collected data from participants who identify as administrators, mathematics teachers, and science teachers in secondary grades at public schools in the eastern U.S. in order to better understand the range of decisions about curriculum coherence teachers make. This study was conducted in a state of the eastern U.S. where includes 787 school districts, 2,947 schools, and 125,028.25 full-time teachers. The number of students enrolled in schools is 1,704,396 and the percentages of their racial/ethnic background are mostly white
(63%), Black (15%), and Hispanic (13%). Regarding mathematics and science standards, this state has adopted the CCSSM but has not yet adopted NGSS (The Nation’s Report Card, 2020-21).

I selected teachers in secondary grades because they are content area experts. Mathematics and science teachers in those grades are specialized in their content area, taking additional coursework and meeting content area skills requirements before becoming teachers. I hypothesized they would be better prepared to talk about coherence within the framework of their content area than teachers who are generalists, consistent with the literature review, including big ideas and ways of thinking within the domain, across grade levels, and across lessons. Their expertise might prepare them to be aware of the content area’s scope and sequence and how these relate both horizontally and vertically. This study also gave me the opportunity to ask the teachers questions about their instructional intentions and methods toward crafting a coherent curriculum. Thus, I hoped to generate a better understanding of the nature of the teachers’ instructional decision-making and beliefs about curriculum coherence.

I selected two school districts, one suburban school, and one rural school in the same metro area. Both school districts have access to a wide variety of curricular resources for different reasons. The two sites also have higher (suburban) and lower (rural) curriculum budgets. The suburban school has extensive resources to support the purchase of a variety of curricular resources for teachers to use. The rural school does not have the same budget resources, but teachers are expected to source curricular resources to supplement the existing curriculum provided by the district in order to better meet their student’s needs. Another difference is that the suburban school is on a short cycle of curriculum development. Their curriculum development process happens twice annually. Development happens in a
multidisciplinary committee, and the teachers play a major role in curricular development and selection of curricular resources. Teachers propose, present, and adjust the curriculum. In contrast, the rural school is on a longer cycle of curriculum development, with curriculum committees that include principal, curriculum leaders, and teachers reviewing and proposing curricula every five years. Therefore, teachers are asked to think about curricular revision and alignment more rarely.

For the purpose of this study, I proposed collecting data from approximately 18 participants. I intended to recruit around 12 total teacher participants for participation in content-area focus groups and individual semi-structured interviews. This would include four teacher focus groups, one for mathematics and one for science teachers from each school district. Each focus group would attempt to include three teachers for a total of six teachers per school district. I also intended to recruit three administrators (including principals, district or school curriculum experts, and instructional coaches) from each district.

Participation in this study was completely voluntary. Teachers who agreed to participate in the focus groups had the opportunity but were not required, to participate in a follow-up individual interview to further explore decision-making associated with their individual lesson planning. In addition, I provided the questions for focus groups and interviews in advance for teachers. In this way, they might organize and prepare their thoughts. Participants who chose not to participate in the focus group and interview had the option to participate by emailing their responses to the questions in their own time.

Given the ongoing pandemic, I proposed to use Zoom to conduct both the focus groups and interviews. The purpose of the focus groups was to better understand teachers’ ideas about what makes the curriculum coherent. The focus groups were intended to take about an hour, and
no more than an hour and a half. Teachers had the opportunity but were not required, to participate in a follow-up individual interview that would take about half an hour. Therefore, the total time commitment for teachers was two hours or less. However, the majority of teachers did not have or could not find time during the workday to participate in the focus group and they chose to participate by responding to questions in their own time.

I followed up with teacher participants to schedule an individual interview via Zoom. The purpose of the interviews was to collect artifacts, such as lesson plans and curricular resources provided by the teachers during discussions based on the teacher’s decision-making with respect to specific lessons. I asked interview participants to share more details about their instructional strategies and curricular materials. During the interview, I asked teachers to share their lesson plans and/or curriculum resources they used in planning mathematics and science for a week to see how they supplemented them and how they moved from one to another. I made it clear to teachers that I am interested in their planning process more so than their formal written lesson plans. I asked them to talk about considerations for coherence and decisions they made to support coherent learning in their lesson planning.

Semi-structured questions from focus groups and interviews were aligned to the definitions of coherence found in the literature. In addition, I made efforts to create opportunities for participants to discuss what was missing from understanding of coherence based on the literature. Consequently, with focus group questions, individual interview questions, and artifact analysis, I was able to better understand teachers' practices.

Similarly, I sent an open-ended survey to three administrators (including principals, district or school curriculum experts, and instructional coaches) in each school. My mentor, based on experiences working with administrators, suggested that it will be difficult to
coordinate administrator schedules to allow for a focus group. Thus, an open-ended survey allowed busy administrators to participate on their own time. The purpose of the survey was to provide curricular context from an administrative perspective. I asked them about curricular resources they provided for teachers, teachers’ level of autonomy to make curricular decisions, and how they supported teachers in curricular decision-making.

**Instruments**

The study employed an open-ended survey, focus groups, and individual interviews with a semi-structured protocol. Using semi-structured questions allowed for an exploration of topics that relate to coherence and curriculum decision-making. The focus group questions included big ideas about coherence that guided teacher/school/grade level planning. Also, they asked about the major considerations of coherence for the literature and then provided an opportunity to find out what was missing. The interview questions asked teachers to explain detailed steps through the decisions they made to create the lesson plan and then asked specifically about the ways they considered coherence, such as factors influencing connecting the instructional materials. Open-ended survey questions for administrators included information about the level of support, resources, and autonomy that administrators provided for teachers’ curricula decision-making.

**Teacher Focus Group Questions.** The questions include big ideas about coherence that guide teacher/school/grade level planning.

1. Tell me about yourself and your experiences as a science/mathematics educator? [e.g., your role, years of experience, grade(s) you teach, expertise in your content area]
2. When someone says a curriculum has “coherence”, what does that mean to you? What experiences have you had that impacted your understanding of what makes a curriculum coherent?

3. From a teacher’s perspective, what are the advantages of a more coherent curriculum in comparison to a less coherent curriculum? What about from a student’s perspective?

4. How much autonomy do you have in choosing and modifying your curricular resources?

5. Who else is involved in the selection of the curriculum materials that you use?

6. How often do you collaborate with your colleagues to make decisions about the implementation of the curriculum? For example, do you work with colleagues to align your curriculum vertically and horizontally?

**Teacher Interview Questions.** These questions include detailed steps through strategies teachers use day-to-day as well as factors influencing connecting their instructional materials.

1. Can you show me examples of your lessons/what you did this week? What resources did you access to plan for this week?

2. What strategies did you use to make connections between lessons this week? What strategies do you use to make connections between units or across the year?

3. What strategies do you use when you want to connect what students learn in your class to what they learn in other grades? Can you show me any examples of resources you use to make these connections?

4. What, if any, difficulties do you have in implementing a coherent curriculum?
5. What kind of support would be helpful for you in designing and implementing a more coherent curriculum?

**Administrator Open-ended Survey.** The survey mostly includes detailed information about the level of support, resources, and autonomy that administrators provide for teachers in curricula decision-making. The questions are:

1. How much autonomy do teachers have in choosing their curriculum and selecting additional curricular resources?
2. How are the norms for selection of curriculum materials that teachers use set? Who is involved? What roles do they have?
3. What challenges/difficulties do you see teachers have in designing and implementing a coherent curriculum?
4. What support do you make available for teachers in designing and implementing a coherent curriculum?
5. How do you evaluate teachers’ use of curriculum in the classroom?

**Recruitment of Subjects**

Like other qualitative methods, the people who participated in this study were not selected randomly. Rather a purposeful sampling method was used. According to Dilshad and Ijaz Latif (2013), purposeful sampling helps the researcher collect rich information from stakeholders who may best have access to the required data. In order to ensure a purposeful sample, I worked with my program mentor to recruit teachers and administrators from the identified suburban and rural schools. My mentor is a former graduate of my doctoral program and worked with the faculties at both schools. She provided an email introduction between me and the school personnel. Following the introduction, I followed up with recruitment materials
for any interested potential participants. I sent potential participants an email introducing the project (Appendix A) and asked for their participation. I was available to answer their questions and supply the consent form asynchronously over email. After the participants confirmed their interest in the study, they were sent a consent form (Appendix B). The consent form included information about risks and benefits, compensation, and other conditions of participation. Participants were free to withdraw their consent and choose not to be scheduled for a focus group and/or interview and were free not to complete the questions they were sent. Once the consent form was signed and returned, I sought to schedule the focus groups and individual interviews with consenting participants via Zoom. At the same time, once the consent form was signed and returned by administrators who were interested to participate in the study, I sent the open-ended survey to them via email. I did not know the identity of potential participants prior to being contacted. Recruitment was conducted without regard for gender, race, or ethnic background. I hoped to get responses from 18 participants including six administrators and 12 teachers.

**COVID-19 Impact on Data Collection**

It is important to mention that the data collection process of this study took place during an unprecedented time when teachers and administrators were exceptionally busy and overwhelmed due to the impact of COVID-19 on schools. Therefore, I was disappointed but not surprised that I did not reach the intended sample size even after I sent a follow-up email two weeks after the first one. Although I provided the opportunity for teachers to participate via focus group and interview, the majority of teachers preferred to respond to the questions in their own time. Of these, only a subset of them scheduled a time for the follow-up individual interviews. Data were collected for a period of two months, from the end of September 2021 to the end of November 2021.
As noted, the majority of the teacher participants preferred to respond to the interview and focus group questions in written responses. However, some of the data were collected through Zoom. Participants were informed during consent procedures that Zoom sessions would be recorded to the Cloud, but video and audio recordings would not be downloaded, and only automatically generated transcripts would be used for analysis. Additionally, they were informed that video and audio files would be deleted after automatic transcription is complete. Also, participants were requested to use a pseudonym as their Zoom names to de-identify their statements in the transcripts. I kept any notes or files that link the participant to the pseudonym they chose or to their responses to open-ended questions in a zipped file on my computer. Further, I deleted the email they sent with their word document in order to remove the link between name and data.

**Final sample size**

I was able to collect data from 12 participants. The final sample included four responses from science teachers (three teachers from the rural school and one science teacher from the suburban school), four responses from mathematics teachers (two mathematics teachers in the rural school and two mathematics teachers in the suburban school), and four responses from administrators (three from the rural school and one from the suburban school). The participant introductions are presented in Table 3.1.

**Table 3.1**

*Participant Introductions*

<table>
<thead>
<tr>
<th>Rural School</th>
<th>Suburban School</th>
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<tbody>
<tr>
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<tr>
<td>Science Teachers</td>
<td>1. Bob: Bob has taught Biology and Microbiology for 17 years at the rural school.</td>
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<td></td>
<td>2. John: John has been a science teacher at the rural school for 17 years. For four years, John taught Honors Biology, Introduction to Biology, and Botany at the high school level. John also spent the last 13 years at the middle school level teaching Life Science and Physical Science. But his area of specialization is Biology.</td>
</tr>
<tr>
<td></td>
<td>3. Mary: Mary has been taught Chemistry, Physics, Botany, Astronomy, and Physical Science for 17 years at the rural school. Mary also served as the science department educational leader, where she was responsible for the science department budget, curriculum and leading/observing the teachers.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mathematics Teachers</th>
<th>1. Ted: Ted has been taught Mathematics and AP Calculus for 34 years at the rural school. Ted also serves as mathematics department head there.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Robert: Robert has been taught middle school Algebra, Mathematics, and Geometry for 17 years at the rural school.</td>
</tr>
<tr>
<td></td>
<td>1. Steve: Steve has been taught Mathematics for 18 years at the suburban school. Steve also serves as a high school mathematics curriculum leader there.</td>
</tr>
<tr>
<td></td>
<td>2. Dave: Dave had been taught Mathematics, Algebra, and Geometry for 15 years at the suburban school.</td>
</tr>
</tbody>
</table>
Administrators

1. Daniel:
Daniel is a middle school principal at the rural school. He has a master’s degree in Administration and Supervision. Daniel has been a middle school principal at the rural school for eight years. He also previously served as a high school principal at the same rural school for five years.

2. Lucia:
Lucia is a high school assistant principal at the rural school. She has a master’s degree in Educational Leadership. Lucia was previously a high school English teacher. She has been a high school assistant principal at the rural school for five years.

3. Jill:
Jill is a high school principal. She has a master’s degree in Administration and Supervision. Jill was previously a teacher for 11 years. She has served as a high school principal at the rural school for four years.

1. James:
James is a high school principal at a suburban school. He was previously a high school associate principal for four years and a teacher for eight years. James has been a high school principal at the suburban school for three years.

Data Analysis and Interpretation

Method of Analysis

In this study, the data consisted of transcripts of interviews, shared documents from the teachers, and responses to open-ended questions. The transcribed data and open-ended responses were grouped by themes using a selective reading approach. This allowed for statements to be highlighted and grouped with similar statements in other passages from transcripts. Open coding broke down the statements through analysis, comparison, and categorization. Description, opinions, interpretations, and events are grouped together by theme through constant comparison. Any artifacts provided by teachers were used as examples to illustrate what teachers
said or wrote. The artifacts analysis provided a deeper understanding of the teacher practices and verified the themes or results derived across the data.

**Trustworthiness**

I used the member checking method to make sure of the trustworthiness of the themes that were revealed during the study. Member checking increased the credibility, validity, and trustworthiness of research findings. I organized and summarized the transcripts and sent them to the participants to check the accuracy of their voices while providing the opportunity for them to add or reflect on their responses.

For the first level of the analyses, I compared and contrasted data from focus group and interview responses as well as open-ended surveys to analyze the responses through the general interpretive process of close reading. Then, I used a close reading process to identify key phrases, common patterns, and emergent themes (Miles, Huberman, & Saldana 2014). To check the trustworthiness of the data I took several passes through the information. Through a careful analyzing process and comparing the responses to examine the difference and similarities, I identified some themes that were aligned with the literature as well as several additional new themes.
CHAPTER 4
DATA ANALYSIS AND FINDINGS

INTRODUCTION

The purpose of this study was to investigate (a) teachers’ and administrators’ perceptions of the qualities that make curriculum coherent; (b) the autonomy and barriers mathematics and science teachers experience in implementing a coherent curriculum, and (c) ways that administrators act in support of teachers’ curriculum implementation.

The overarching research question which guided the design and implementation of this study was: How do mathematics and science teachers conceptualize and implement a coherent curriculum?

In order to answer this question, the following sub-questions guided the investigation:

1) What are teachers’ and administrators’ perceptions and experiences of qualities that make curriculum coherent?
2) What obstacles do teachers perceive in implementing a curriculum in coherent ways?
3) What can we learn about teachers’ autonomy to make decisions about their curricular resources?
4) What similarities and differences are there in the ways that mathematics and science teachers conceptualize and implement a coherent curriculum?

Final Data Sources

The data presented in this study were based on written responses to open-ended questions provided by teachers and administrators as well as transcribed audio recordings that were collected through the Zoom platform with mathematics and science teachers. The data include three transcribed audio recordings from interviews with one mathematics teacher and two
science teachers from the rural school. The interviews varied in length from 35 to 55 minutes. One mathematics teacher chose to respond to the interview questions in writing. Thus, in addition to the interview transcripts, two pages of written responses were included in the analysis of interview data.

In addition, the data include eight written responses to focus group questions that teachers provided. The mathematics and science teachers chose to respond to the focus group questions individually in writing instead of participating in the focus group discussion. Four responses were from science teachers (three teachers from the rural school and one science teacher from the suburban school) and four responses were from mathematics teachers (two mathematics teachers in the rural school and two mathematics teachers in the suburban school). Hence, eight pages of written teacher responses were included in the analysis. Finally, the data include four responses from administrators to the open-ended survey prompts (three from the rural school and one from the suburban school). This includes four pages of written responses from administrators.

Data Analysis

The data consisted of transcribed audio recordings that were collected through Zoom interviews, shared documents from the teachers, and responses to interview, focus group, and open-ended survey questions. To maintain confidentiality, the name of the schools and the participants in the study are presented as pseudonyms. The participants of the study were requested to use a pseudonym as their Zoom names to de-identify their statements in the transcripts. No questions about gender identity were asked. The participants are gendered in text based on the pseudonym names they provided. Gender was not used as a variable for analysis.
The transcriptions and open-ended responses were not analyzed based on the questions but rather they were analyzed holistically across all the participant responses. The transcribed data and open-ended responses were grouped by themes using a selective reading approach. This allowed for statements to be highlighted and grouped with similar statements in responses to other questions or in differing passages from transcripts. I took several passes through the data and used a close reading process to compare and contrast the participant key phrases and common patterns to examine the difference and similarities across the data. I identified some themes that were aligned with the literature as well as several additional new themes.

According to Saldaña (2013) “some methodologists advise that your choice of coding method(s) and even a provisional list of codes should be determined beforehand (deductive) to harmonize with your study’s conceptual framework, paradigm, or research goals” (p. 65). Three initial thematic areas were identified from the literature review: characteristics of a coherent curriculum, advantages of using a coherent curriculum for teachers, and teachers’ perceptions of advantages for students’ learning.

The responses shared by the participants required a closer look to uncover additional themes related to teachers’ experience in designing and implementing coherent curriculum. Through a meticulous analyzing process, new themes were revealed that were pertinent to the study. The additional themes uncovered were not unrelated to the ones derived from the literature review, but rather an extension of what had already been identified. The following themes were identified: teacher strategies, teachers’ autonomy, teacher collaboration, administrator ideas for supporting teachers, and teacher evaluation.
Findings of the Study

In the following sections, I addressed the research questions of the study according to the initial thematic areas and the additional themes that were identified. The first research question was addressed according to the following themes, characteristics of a coherent curriculum, advantages of using a coherent curriculum for teachers, teachers’ perceptions of advantages for students’ learning, teachers' strategies, teacher collaboration, administrator ideas for supporting teachers, and teacher evaluation. The second research question was addressed according to the data analysis about the challenges or obstacles the teachers faced in designing and implementing a coherent curriculum. The third research question used the theme of teachers’ autonomy to be addressed. The fourth research question discussed the similarities and differences between mathematics and science teacher perceptions in curricular coherence decision making. Finally, the connections of these themes to the conceptual framework and theoretical framework of the study are described.

Research question one: What are teachers’ and administrators’ perceptions and experiences of qualities that make curriculum coherent?

The results of the data analysis addressed the first research question in the following section. In order to respond to research question one, the themes were used to make connections between the findings and the research question. This question was addressed according to the following themes: characteristics of a coherent curriculum, advantages of using a coherent curriculum for teachers, teachers’ perceptions of advantages for students’ learning, teachers' strategies, teacher collaboration, administrator ideas for supporting teachers, and teacher evaluation. In addition, examples of teacher and administrator language drawn from interview
transcripts, focus group written responses, and open-ended survey responses are included throughout the following section.

**Characteristics of Coherent Curriculum**

The following section includes five characteristics of a coherent curriculum that were identified by mathematics and science teachers in this study. They identified characteristics of a coherent curriculum as: logical sequencing, alignment, students’ prior knowledge, discipline-specific knowledge, and teacher collaboration. Each of these is described in the following section and examples of teacher language drawn from interview transcripts and written responses are included.

**Logical Sequencing**

There are always concerns in educational research that there may be gaps between the academic theory and the knowledge of practitioners working in schools. In this study, it appears that the mathematics and science teachers described the characteristics of a coherent curriculum consistent with the ways that it was defined in the literature. In fact, three teacher participants (one mathematics teacher and two science teachers) indicated that coherent curricula make connections between contents/topics in a logical way. For example, Steve stated: “To me, coherence means that the curriculum was developed in such a way that everything fits together vertically. Each course builds on the prior knowledge of the previous one, without gaps or unintentional repetition of content” (Steve, mathematics teacher, suburban school, focus group response). Similarly, Bob explained: “To me, a coherent curriculum means that the topics within that curriculum transition and build upon each other in a logical way” (Bob, science teacher, rural school, focus group response). Also, Tracy remarked: “When I hear the term ’coherence’ it means to me that there is a well-designed and logical progression in content that makes its
implementation relevant and well thought out” (Tracy, science teacher, suburban school, focus group response). In terms of logical sequencing, three of the eight teachers used words such as “build on”, “logic”, and “progression” to describe what makes a curriculum coherent.

Alignment

According to the literature review, another major characteristic of a coherent curriculum is “alignment” across subject areas, lessons, courses, and grade levels (The Glossary of Education Reform, 2014). Surprisingly, only two of the teachers referenced this term, despite it being prevalent in the literature. Steve hinted at this when he mentioned content “fits together vertically” (Steve, mathematics teacher, suburban school, focus group response). This aspect of curriculum is usually called vertical alignment in the literature and refers to the sequencing of content across grade levels. In a vertically aligned curriculum teaching is logically sequenced so that students' skills and knowledge will make progress to prepare them for higher-level challenges. With vertical alignment, students build on their prior knowledge across grade levels and teachers are aware of the standards and materials that are taught in the previous grades and subsequent grade levels.

Dave was the only participant to explicitly use the word alignment. He described: “I thought about coherence in terms of alignment. Alignment to academic standards as well as to others teaching the same subject area” (Dave, mathematics teacher, suburban school, focus group response). Even here, Dave connected his idea of alignment to the standards to his understanding of logical sequencing, stating “Since I have taught multiple levels of courses, I understand the importance of coherence knowing that students sometimes switch levels. Having a coherent curriculum is important so that students who do have to transition to another level can do so
without much academic disruption” (Dave, mathematics teacher, suburban school, focus group response).

This connection between alignment and logical sequencing is further supported by how John discussed coherence as an “overarching” backbone of learning goals. For example, John described: “To me, a coherent curriculum means that the district has an overarching set of goals set from K-12 and those goals are supported by each grade level and subject. Even though each subject and grade levels have their own objectives they need to meet those ideas that are tied to the bigger curriculum goals” (John, science teachers, rural school, focus group response). Thus, the language of the teachers in this study overlaps alignment with some external references and logical sequencing of content topics, with teachers more likely to describe coherence as an aspect of logical sequencing rather than in terms of external references. Overall, three-quarters of the teachers across disciplines and school contexts (three mathematics, three science, three suburban, and three rural) suggested curriculum coherence makes clear the logical sequence of topics and/or how the logical sequence determines the ordering of a series of topics.

Two of the rural teacher participants mentioned the lack of vertical alignment as a challenge they face in the classroom to teach new lessons which leads to student confusion. In science, Mary highlighted: “...I get students that all went through middle school, but half of them have done lots of experiments and they know how to use a beaker or cylinder and the other half of them have never seen one. We have different teachers doing different things, and it makes it very difficult for me to create some kind of coherence, see when I have kids who've had such varied backgrounds, even though they're coming from the same school” (Mary, science teacher, rural school, interview transcript). Similarly in mathematics, Ted stressed this point and explained how important it is for students to understand the connections between the information
across grade levels. Ted described: “I think the greatest difficulty I face is that a lot of their previous math instruction has not been taught in a way where there were connections seen between topics. So, when I start showing the connections …I sometimes feel they are overwhelmed at first. It would be great to have a consistent message taught to them throughout their mathematics experience. Students often want a quick trick and ‘give me something that will give me the answer today’. They should be wanting to understand how the information is connected” (Ted, mathematics teacher, rural school, interview transcript). When asked about how administrators could better support teachers, Ted also spoke about vertical alignment. Ted pointed out that having a more coherent instruction/curriculum between grades (vertical alignment) in the school could be the greatest support for teachers: “I think the greatest support is getting previous levels of math instruction to be taught in a way that allows for students to see the relevance of the material taught and projects that apply real-world situations to what they are learning” (Ted, mathematics teacher, rural school, interview transcript).

**Students’ Prior Knowledge**

A related concept may be “building on” prior knowledge. Two of the teacher participants highlighted the importance of building on students’ prior knowledge and increasing the depth of students’ learning as other characteristics of the coherent curriculum. As Tracy remarked: “A coherent curriculum allows one to effectively build on students’ prior knowledge and set them up with skills for what they will encounter next” (Tracy, science teacher, suburban school, focus group response). Also, Steve, highlighted: “...Each course builds on the prior knowledge of the previous one, without gaps or unintentional repetition of content” (Steve, mathematics teacher, suburban school, focus group response). In both these examples, building on prior knowledge is linked to effectiveness or efficiency and ideas about making sure students are prepared for next
steps with neither gaps nor repetition. John’s ideas about alignment, specifically that “each subject and grade levels have their own objectives” (John, science teachers, rural school, focus group response) are also part of this model where content is taught once and in particular courses or grades.

**Discipline-Specific Knowledge**

The logical sequencing and alignment ideas functioned to narrow when and in which courses content was taught. However, building on prior knowledge was also linked by three teachers to ideas about mathematics and science as disciplines. For example, a science teacher, Tracy, invoked this idea of coherence in science curriculum as connecting beyond the content of the class: “Coherence leads to purpose. If there is not a coherent curriculum then the big picture can be lost.” (Tracy, science teacher, suburban school, focus group response). Similarly, Mary emphasized continuity in the domain relevant learning: “A coherent curriculum, meaning one that offered students a continuous opportunity for learning content and skills related to science, both increasing the depth and breadth of their learning” (Mary, science teacher, rural school, focus group response). Ted also described the “cumulative” nature of both content areas: “In Math and Science, they are both cumulative subjects that require an understanding of previous knowledge to be successful in future concepts” (Ted, mathematics teacher, rural school, focus group response). Furthermore, Ted made connections between content and ways of thinking: “Students need to not only have content knowledge but be able to see connections between content to solve real-world problems and think in a scientific manner” (Ted, mathematics teacher, rural school, focus group response) and to the idea that: “A coherent curriculum is one where all of the pieces of the curriculum interact with each other to tell an overarching story” (Ted, mathematics teachers, rural school, focus group response).
Across the areas of logical sequencing, alignment, and building on prior knowledge, there are agreements between what teacher participants said and what was mentioned in the literature review about these characteristics of the coherent curriculum. In the literature review, a coherent curriculum is defined as one that is well organized and purposefully designed to build on previous knowledge, free of academic gaps and needless repetitions, in order to facilitate student learning. A coherent curriculum “makes it possible for a student to see the subject as a whole, to understand the logical connections and deep structures, and to use that understanding for more efficient problem-solving and better retention of knowledge and procedures” (Cuoco, & McCallum, 2018). Overall, from the teachers’ perspectives, the main purpose that connects logical sequencing, alignment, and discipline-specific knowledge is to build on prior knowledge and skills to prepare students for future levels of learning.

Teacher Collaboration

Three teacher participants (two rural and one suburban) explained how one of the significant characteristics of a coherent curriculum is the ways it enhances opportunities for teacher collaboration. All three explained how creating a coherent curriculum gives teachers more opportunities to collaborate and share ideas and resources with each other, but the purpose of this collaboration was different for the three teachers. For example, Mary stated: “With a coherent curriculum, teachers continually work with the other fellow teachers to evaluate the relevance and ability of the curriculum to meet the needs of our students once they leave school” (Mary, science teacher, rural school, focus group response). For Mary, the purpose of collaboration is to better meet the needs of her students. Furthermore, Mary references goals beyond the classroom, i.e., “once they leave school”. Mary’s comments are student-centered and similar to how Chalk (2020) argued the purpose of teacher collaboration for a coherent
curriculum is to help teachers to think and enact beyond grade level or classroom walls. Chalk (2020) warns that if teachers make decisions independently, they may not know what is taught in other classrooms. Consequently, the materials may become incoherent (i.e., lack logical sequencing and alignment) and repeat over and over at the same level instead of building from students’ foundational knowledge (Chalk, 2020).

Mary’s framing is very different from that explained by the other two teachers who spoke about collaboration as an important characteristic of a coherent curriculum. For example, Robert expressed: “To me, coherence means to be on the same page. Our school has been making strides to achieve coherence in our curriculum. The math teachers have been collaborating to create the same Quarterly Exams given at the end of the 9-week grading period. All of the math teachers’ classrooms are actually moved next to each other as well, giving us more opportunities to share ideas and touch base with each other more frequently” (Robert, mathematics teacher, rural school, focus group response). Dave’s remarks were very similar to Robert’s: “it is important to have coherence between teachers who teach the same course. My colleague and I who teach academic geometry share a Canvas page (like Blackboard) and use similar resources. While our styles are very different, we make sure to cover the same material and use common assessments, which is a very important practice” (Dave, mathematics teacher, suburban school, focus group response). Note that in their two responses, the framing is about standardization. In fact, they use the terms “same”, “similar”, and “common” six times across the two statements.

Contrary to this idea of standardization in implementation, the literature focuses more on collaboration in curricular design. For example, Voogt et al (2011) highlighted that one of the significant elements that contribute to the design of curriculum coherence is teachers’ collaboration. Similarly, Larson (2016) argues that teachers should collaborate with each other at
schools to design and plan instruction, implement the task, evaluate student work, reflect on student needs, and provide coherency in instruction and curricular goals for students. This focus on collaborative design provides opportunities for teachers to share their instructional strategies, resources, and assessment methods which leads to improving teachers’ knowledge and competencies and consequently promoting the harmonization of enacted curriculum and improving implementation of coherent curriculum (Lewis, Perry, & Hurd, 2009). In this study, three teachers spoke about the importance of teacher collaboration, but only one focused on design while the other two focused on standardization of implementation.

Advantages of Curriculum Coherence

The following section explains the advantages of a coherent curriculum for teachers, the disadvantages of a less coherent curriculum (as well as the implications for advantages), and what teachers perceive the advantages for students are. Where appropriate, connections between what teacher participants said and the research literature are described here. In addition, examples of teacher language drawn from interview transcripts and written responses are included throughout the following section.

Advantages of Coherent Curriculum for Teachers

According to the literature, there are two main benefits to using a coherent curriculum for teachers. First, Chalk (2020) points out that one of the benefits of a coherent curriculum from a teacher’s perspective is that the teacher can expect every student who enrolls in the same grade level or takes the course within the school comes into a course prepared with the prerequisite foundational knowledge (i.e., logical sequencing that builds on prior learning). Related to these expectations, teachers are better prepared to identify areas where students may have gaps in foundational knowledge.
Second, Chalk argues that a curriculum that is vertically and horizontally coherent (i.e., aligned) supports teachers by sparking professional growth through structuring opportunities for teachers’ collaboration. In essence, the curriculum map provides a way for teachers who teach the same content to collaborate across grade levels (Baniahmadi & Olson, 2021) and for teachers at the same grade level to align their learning activities and assessment practices with their curricular goals (The Glossary of Education Reform, 2014; Baniahmadi & Olson, 2021). The alignment structures and improves communication between teachers as they exchange their experiences and ideas (Chalk, 2020). The teacher's responses suggest that mathematics and science teachers recognized these two advantages of a more coherent curriculum in comparison to a less coherent curriculum.

In addition to the comments about teacher collaboration being a key characteristic of a coherent curriculum, the teachers also spoke about being better prepared to understand students’ preparation for learning. In fact, the most significant advantage the teachers reported in using a coherent curriculum was helping teachers to know what knowledge, skills, and abilities students should have. Steve cited this advantage directly, writing: “From a teacher's perspective, coherence is important because it allows the teacher to know what the students know and can do prior to his/her course” (Steve, mathematics teacher, suburban school, focus group response). Similarly, Robert explained: “An advantage from a teacher’s perspective to having a more coherent curriculum would be that all students should have the same prior knowledge when entering my classroom from the previous years of school, no matter which school or teacher they had” (Robert, mathematics teacher, rural school, focus group response). Furthermore, Robert reflected on the advantages of a coherent curriculum by asserting that a coherent curriculum provides opportunities for students to gain similar educational experience and knowledge and be
on the same page” for next grade levels. Robert expressed: “Having a more coherent curriculum would eliminate half of the class knowing the material that the other half has never seen before. All students will be on the same page when entering the next grades” (Robert, mathematics teacher, rural school, focus group response). Further, Dave acknowledged this point by saying: “I think the advantages are that students receive a similar knowledge and educational experience no matter who they have as their teacher” (Dave, mathematics teacher, suburban school, focus group response). Dave’s and Robert’s language again highlights the importance of standardization in their conceptualization of coherence. Like Steve, they argue that a coherent curriculum supports consistency in student learning across classes, ensuring students have had the opportunity to master foundational content before moving on in the logical sequence.

In contrast, Mary’s perspective is more nuanced. She agreed with Dave, Robert, and Steve that, “The advantages are that as a teacher, we know what skills students should have…”, However, consistent with her remarks about teacher collaboration as a means of meeting student needs, Mary continued on to say a coherent curriculum helps teachers understand “… what they [students] actually have because teachers would be able to discuss the students’ abilities based on a shared coherent curriculum. We will then be able to move forward knowing the appropriate level to meet the needs of each kid” (Mary, science teacher, rural school, focus group response). Mary is the only teacher who explicitly stated that there may be gaps between the curriculum map and what students learned, but she also felt that having a coherent curriculum makes it easier for teachers to identify and collaborate to fix those gaps.

An additional advantage was raised by Ted, John, and Bob, who all indicated that an advantage of having a coherent curriculum is that it makes teaching easier. Ted expressed this as clarifying what content needed to be taught. He wrote: “I feel that having a coherent curriculum
is helpful in that it sets a framework of what is taught and then you flesh out the framework from there” (Ted, mathematics teacher, rural school, focus group response). To Ted, the major advantage of having a coherent curriculum is that it eases the planning process by providing a framework from which the teacher works.

For John and Bob, a coherent curriculum is easier to work with because it is results-focused. Like Ted, John used the term “framework” to describe the expectations for content coverage, but he also suggested that the framework supplies expectations for results. John discussed: “When you have a coherent curriculum, you have a shared sense of expectations and a shared sense of outcomes. It allows teachers to build a framework they trust to reach a specific result” (John, science teacher, rural school, focus group response). Bob was also results-focused, arguing: “From a teacher’s perspective, a coherent curriculum makes teaching those topics much easier because you can see the growth in your students as they progress through the material” (Bob, science teacher, rural school, focus group response). According to John and Bob, coherence acts as a measure along which student progress can be tracked and learning goals are defined.

**Disadvantages of a Less Coherent Curriculum**

Additional insight into the teachers’ perceptions of the advantages of a coherent curriculum is their discussion of some of the difficulties they encounter when curriculum is not coherent. In fact, half of the mathematics and science teachers in this study discussed the disadvantages when a coherent curriculum is lacking. These disadvantages fall into two groups.

One set of disadvantages identifies the difficulties teachers experience with assessment, and in particular, grading when students are not motivated to perform well. For example, Tracy wrote: “Also, a lack of coherence can lead to student disinterest and low motivation to perform”
“Less coherent curriculum can cause issues in terms of grading and assessment practices. This can negatively impact a student’s academic experience and cause stress. The students appreciate that we stay on the same page. Without this coherence, sometimes teachers can have many students put into their sections if they are “fun” or “easier” than another teacher, which causes issues in terms of scheduling and equity” (Dave, mathematics teacher, suburban school, focus group response). It is interesting to note that this is the only time any of the 12 participants (eight teachers and four administrators) used the term “equity” and that the use refers to workload equity for teachers rather than equitable opportunities to learn for students as is more common in the literature.

Another set of disadvantages occurs when problems arise because previous teachers do not have enough structure or did not stick closely to the structure other teachers expect. For example, John wrote: “If the curriculum is not tied together each teacher is only worried about their own individual class goals” (John, science teacher, rural school, focus group response). Steve also worried about teachers’ individual approaches, writing: “From a teacher's perspective, when a curriculum is less coherent, the teacher may have to take some extra time to go over topics that aren't necessarily in the scope of his/her course because students don't have the necessary background” (Steve, mathematics teacher, suburban school, focus group response). There are clear parallels between Steve’s comment here and Dave’s comment about “equity” earlier. The concern these two teachers express is about workload, specifically about having to reteach content that was another's teacher’s job and being responsible for covering their own content and securing student achievement in their own class.
Research demonstrates that with an incoherent curriculum, teachers may decide independently about what students learn, without collaborating with other teachers, basing what they teach on consistent learning expectations, or considering what students learned in previous grades and will need to learn in subsequent grades. As a result, students may not receive appropriate lessons throughout their academic grade levels, and they will not meet the academic expectations (The Glossary of Education Reform, 2014). The literature positions the disadvantage in terms of lost opportunities to learn or failure to meet academic expectations. The teachers’ participants added to this that it also impacts teachers through workload equity issues, including inequitably distributed difficulties in motivating students to meet academic expectations and inability to progress to content or goals they planned or will be held accountable to reaching.

Teachers’ Perceptions of the Advantages of Coherent Curriculum for Students

According to Chalk (2020) a curriculum that is vertically and horizontally coherent supports student success by (a) reducing unnecessary repetition; (b) addressing gaps in learning; (c) making knowledge more meaningful; (d) setting clear expectations. As demonstrated so far, most of the teachers in this study provided responses that show this traditional focus on vertical and horizontal alignment within a content area. However, researchers have also focused on more student-centered ways coherence impacts student learning. When students experience new lessons and activities within a coherent framework, their learning is enhanced by connections and dependencies between each lesson or activity (Darling-Hammond et al., 2005; Drake & Sherin, 2009). In effect, students learn how to learn within a content domain. Coherency in the curriculum also aids students in making connections in tangible ways to their immediate lives (Ennis, 2008). As noted above, from the teachers’ perspective in this study, a coherent
curriculum follows a “logical progression”. Bob adds to this, writing: “From a student's point of view, it follows a logical progression that makes common sense” (Bob, science teacher, rural school, focus group response). This idea of logical sense as common sense sequencing flips from mastering the content area or developing domain area knowledge and skills to thinking in terms of students and what will make sense to them. This is also picked up by John who wrote, “Students look at education from a class-to-class perspective instead of an entire education perspective. They just want to finish a class and move on” (John, science teacher, rural school, focus group response). John also highlighted the importance of a coherent curriculum for students to see how each grade and topic are tied together and move toward a specific goal by explaining: “... If you have a coherent curriculum students will be able to see how each grade and class are tied together and then work towards a specific outcome” (John, science teacher, rural school, focus group response). For both Bob and John, an advantage of a coherent curriculum for students is that the curriculum makes sense to them even if they do not have or do not want to develop a “big picture” understanding of the content area.

Bob’s and John’s ideas are closely related to concepts about a student-centered purpose for framing the learning. From the majority of teachers’ perspectives, a coherent curriculum helps students to better understand why they are learning the materials and how knowledge is transferable or will become useful to them in the future. Mary highlighted this point by explaining: “Students will better be able to achieve and understand why they are learning material if they know it is going to be useful in their following coursework” (Mary, science teacher, rural school, focus group response). Also, Tracy claimed: “students need to know what they are learning and why. They need to see how skills and knowledge are transferable to help them follow their dreams” (Tracy, science teacher, suburban school, focus group response). By
the same token, Ted not only emphasized on students will be able to better understand why they are learning the materials, but also he reflected on “longer retention of knowledge” and seeing the “purpose behind their learning” by explaining: “From a student's perspective, understanding what they are learning and why it is important allows them to retain the information longer and see the purpose for what they do” (Ted, mathematics teacher, rural school, focus group response). The teacher's responses around “why,” “how,” and “purpose” demonstrate an alignment with the literature. According to the literature, a more coherent curriculum could help students gain a deeper understanding of the important ideas and purpose in lessons at each grade level that leads to better retention of knowledge (Bransford et al., 2000; Shwartz et al., 2008), make authentic connections to real lives, engage with instruction in meaningful ways, and perceive the value of the learning. The teachers in this study explicitly discussed retention and meaningful connections, but their perception of the value students would take from the learning is framed in transactional ways and directly related to the next step in the current course or course sequence. Although similar to the ways they spoke about sequencing more generally, the comments here are more about student achievement and less about mastery of the content area or understanding of the big ideas of the domain.

**Teacher Strategies**

This part of the study discusses the strategies teachers use to make connections between lessons in a week or units across the academic year within the same course and strategies teachers use to make connections between students’ learning across the grades. In answering questions about their individual strategies, teachers were provided with the opportunity to share examples of curricular materials and lesson plans that were used during a week of teaching. These examples allowed teachers to show places they connected the mathematics and science
Teacher Strategies to Make Connections Within a Course

In the study, the mathematics and science teachers were asked to reflect on the strategies they used to make connections between lessons in a week or units across the academic year within the same course. They highlighted two main ideas: the importance of relating or “tying together” lessons to make a “story” and using “real-life examples” as strategies to make connections between lessons and units. There is overlap in the language teachers used throughout this section, however, all of the teachers did not use the same approaches to implement these strategies. The examples provided made the differences clear.

Ted described his strategy of tying the lessons together and making a story to improve student understanding. Ted’s responses regularly use the language of tying together concepts and the story as a metaphor for the content area domain. When he talks about tying things together, he argues that those connections remind students about and build on prior learning. As Ted explained: “I am constantly making connections between lessons. To me, math and physics are a story. Previously learned material is needed to tell the story” (Ted, mathematics teacher, rural school, interview transcript). Ted also considers mathematics and science to be different parts of the same story where learning one of them is required for knowing the one by stating: “…There are connections between math concepts and science concepts… and it is not a series of formulas or rules that are set apart from each other. They are intertwined. So, this week I tied things we are doing now to lessons learned a week ago …or even years ago.” In addition to the need for prior learning, Ted acknowledged that as a storyteller he needs to be entertaining. He reflected, “I am constantly looking for applications of the math and science I teach that are
relatable to students and have interesting components to them” (Ted, mathematics teacher, rural school, interview transcript). In addition, Ted highlighted that tying the lessons together helps students to understand the logical sequence and purpose of their learning. Ted reported “...Students need to know why things work and not just learn tricks to solve problems that seem like magic. I use strategies that continuously make me say things like remember when we did…” (Ted, mathematics teacher, rural school, interview transcript). Ted also shared the scenarios and a video that were used to teach and connect the mathematics and science lessons together in the previous week during his interview (See Appendix C).

John also used the language of “tying together” previously learned content to new lessons and provided an example of the resources that were used for a week to teach biology lessons to show the connections. In his example, he utilized a virtual lab as a strategy to help students solidify their understanding. (See Appendix D). John reported: “Luckily, this lesson is the culmination of the first nine weeks and ties together everything we covered from cellular chemistry to the parts of the cell. Each day of this lesson brings in topics we already covered and ties them together. It culminates with this lab and the discussion of dehydration and how it affects each student” (John, science teacher, rural school, interview transcript). In this description, John also indicates that his goal is to personalize the content for each student. This use of real-life connections is also central to comments made by Robert below, though he takes a different approach to do so.

Mary used similar language to “tying together” to explain how she makes connections. She talked about “wrapping back around” as a strategy to connect the prior knowledge to current lessons in order to improve student understanding. Mary described: “One of the strategies, I think, is having them use the material that they had previously learned. And so
again we're restarting the next part of the unit, but they're still utilizing the material that we did in the earlier part of the unit. I also think that kind of wrapping back around and looking at those objectives helps to make those connections because they can physically see how all these things are right, they're all on the same list” (Mary, science teacher, rural school, interview transcript).

In this comment, Mary also highlighted wrapping back around helps students to “physically see” how the materials relate together. In addition, Mary emphasized the importance of connecting ideas by saying: “…so, to me that really is what brings that connection between not only one lesson from day to day and from week to week but also within the whole unit” (Mary, science teacher, rural school, interview transcript).

Interestingly, Mary mentioned the connection that in her words "wraps around" or "carries over" is the skills students learn and within and use across units. Mary stated: “…So again within the units, a lot of what we do carries over creating experiments, collecting data and graphing will continue throughout the rest of the year and I always tell them that, if you can't do this, you're done with physics, you can’t move forward. Because I want them to understand that these are strategies that we use to create the equations for physics” (Mary, science teacher, rural school, interview transcript). In addition, she later remarked: “…so I think it's just that continual use of the skills that provide that connection” (Mary, science teacher, rural school, interview transcript).

In contrast, Robert illustrated the importance of real-life examples as a strategy to make connections between previously learned lessons and current ones to enhance student perceptions. Robert discussed: “When showing students how to solve and graph inequalities, I had them practice solving equations as a warm-up (which they already have learned in a previous lesson). I use a lot of real-life examples to try to familiarize the students with our current topic” (Robert,
mathematics teacher, rural school, responded to the interview questions in writing). Robert continued by providing an example: “...For example, with the inequalities, I used an example of a see-saw and showed the students how one side is greater than the other, and therefore it is heavier and tips to that side. I try to relate prior knowledge to all of my lessons as much as possible to help the students make a better connection with the new material” (Robert, mathematics teacher, rural school, responded to the interview questions in writing). In this example, Robert demonstrates an understanding of real-life connections as something the student might have seen before outside the classroom. In drawing the attention of students to the direct visual connection, he makes connections differently than John, who suggested he wanted students to see the science concept in action in their lives. Robert also shared the websites that were used in the class to review the previous lessons and practice mathematics concepts (See Appendix E).

**Teacher Strategies to Make Connections Between Students’ Learning Across the Grades**

The teacher participants were also asked about the strategies they used to connect students’ learning in their class to other grades. The prominent theme that emerged across the teacher responses was a retrospective approach of reviewing content from previous grades in the current grade, primarily by locating curricular resources for content in previous courses or by creating regular opportunities to ask questions or engage in activities about previous content. Ted described provided an example: “I often review material from previous years and then apply it to the new situation. For instance, in calculus we last week took the derivative of a logarithm. I first went back to explain that a logarithm is really an exponent. So, the laws of logarithms follow exponent rules in algebra. I also show that the exponent rules in algebra follow the order of operations that they learned earlier in math (See his example in Appendix F).
Ted continued: “I pull resources from the internet of previously learned concepts. I then use AP resources to help with the present calculus problems. Also, in physics, I use several Interactives from Physics Classroom and other websites (See Appendix F for links to the interactive websites he uses for this purpose) to either tie the lesson together or establish the pattern that leads to the rules of physics” (Ted, mathematics teacher, rural school, interview transcript). Note that Ted’s comments again use the “tying together” language. Like previous comments made by both him and by John and like the comments about “wrapping back around” made by Mary, this language is used to reference making connections to previously learned material. However, this time Ted is referencing material learned in previous courses with different teachers.

John relied both on question asking and curricular resources to review content from previous grade levels. John said: “I try to start each lesson with a ‘Bell Ringer Question’. This is usually a question that has the goal of pulling out prior knowledge” (John, science teacher, rural school, interview transcript). Bell ringer questions are usually small activities or assignments students do when they first enter the classroom. They are a way of setting the expectation that when students come in, they start working immediately. They are sometimes called warm-ups. Bell ringers are generally used to remind students about what they were working on in a previous class, a strategy to address the connections between lessons. John also uses this strategy to connect back to content from previous grades. He intentionally starts every class with an activity that is supposed to connect to content students learned in previous courses rather than the current content. John gets material for his bell ringer activities by referencing curricular resources from previous grade levels. He explained: “The main resource I use is our book series. Because it is
used in grades 4-8 and I have access to each grade level, I can look at all materials covered over that four-year span” (John, science teacher, rural school, interview transcript).

Mary’s approach is less formal than John’s. Instead of activities, she relies on question asking at the beginning of units (i.e., informal preliminary assessment) as a strategy to review prior knowledge for students. Mary explained: “I like to ask the students questions, usually start a topic by asking them what they know about the topic which brings on a lot of the information from previous years for me to better understand what they know and what they don't” (Mary, science teacher, rural school, interview transcript).

More formally, Mary also reflected on using the resources already in her classroom to create hands-on activities that allow her to make connections. Mary stated: “There are all kinds of stuff within my classroom that allows students to see those connections. For example, I have got plants, lights, an incubator… we use them, and we talk about when we learned about lights. I don't know other than just the general resources that are available in my classroom. I don't have a book and I don't have a special worksheet. I'm often more of the like... let's do something, instead of just…here's a worksheet and here's the book” (Mary, science teacher, rural school, interview transcript).

Despite the teachers identifying collaboration as a key characteristic of a coherent curriculum, surprisingly, only Robert emphasized the importance of collaborating with fellow teachers as a strategy to help build connections between what students learned in previous grades and new lessons. Robert discussed: “In the past, I used to have some of the same students in 6th grade all throughout 8th grade, which made making connections from previous grade levels much easier. Now, our school district mostly has a different teacher for each grade and course, making it a little more difficult to know how they learned a lesson the previous year. I have had
enough experience teaching with a fellow colleague and know the strategies he uses, so it helps me understand what methods of instruction were used last year, so I can relate our current lessons to them easier. For example, the 7th-grade math teacher draws shapes around different terms to help students visually when simplifying and combining like terms” (Robert, mathematics teacher, rural school, responded to the interview questions in writing).

The teacher participants in this study discussed the strategies used to make retrospective connections to previous courses/grade levels such as “tying together” lessons to make a “story”, using “real-life examples”, and using in-class activities and question-asking to review content from previous courses/grades. They spoke and wrote about different approaches to implementing these strategies and also provided examples of the lesson plans that were used in a week to make connections between students' prior knowledge with current ones. A finding consistent across the teachers is that their approaches were exclusively about how to connect their current content with previous courses/grades. No teachers discussed strategies that indicated they were looking forward or finding ways to help connect with students’ future learning.

**Content Area and Teacher Collaboration**

The following part discusses teacher collaboration as an opportunity for the mathematics and science teachers to share ideas and resources in order to design and implement a coherent curriculum. Also, it includes the difference between mathematics and science teachers' collaborations within grades and across grade levels to align the curriculum horizontally and vertically. Additionally, the teachers and administrators reflected on difficulties they face in collaboration and discussion as well as support teachers need to design and implement a coherent curriculum. The examples of teacher and administrator language drawn from interview
transcripts, focus group written responses, and open-ended survey responses are included throughout the following section.

One practice shown to improve curricular coherence is teachers working collaboratively with one other and with the curriculum design team at the school level “to plan instruction, implement the task, predict student work, respond to student learning needs, and provide consistency in curricular goals and instruction for students” (Larson, 2016). Teacher collaboration is an important characteristic of a coherent curriculum that is highlighted by the teachers’ participants several times.

A surprising finding was that the science teachers in this study claimed to rarely collaborate. As Mary described: “Unfortunately, we rarely collaborate. It always seems to be a conquer and divide task when given alignment” (Mary, science teacher, rural school, focus group response). As Bob explained, the collaboration between science teachers was limited to a few times per year “We have set times throughout the year that are put aside to collaborate to see what is working and what isn't” (Bob, science teacher, rural school, focus group response). These two comments point to time pressure and a need to “divide and conquer” the needed work given so little time was set aside for teacher collaboration.

However, many of the science teachers did discuss more informal conversations with the same grade teachers and they rarely meet with the other grade level teachers. John declared: “I work with the other middle school science teachers, but I rarely meet with the other grade level teachers. Our curriculum is not vertically aligned” (John, science teacher, rural school, focus group response). Also, Tracy alluded: “While teaching physics, my collaboration was typically informal conversations with my fellow physics teachers at the same grade level” (Tracy, science teacher, suburban school, focus group response). These informal collaborations within-grade or
course content may explain why so little work was done to look forward or connect current content with content in future courses or grades.

The mathematics teachers, on the other hand, asserted more collaboration with the teachers who teach the same course or same grade level and with teachers in other grades. Ted explained: “We have had several meetings and there is the discussion between teachers teaching the same course to help with the horizontal alignment. We have recently put together a curriculum framework that goes k-12 in which I met with every teacher grade k-12 in mathematics, and we looked at vertical alignment issues” (Ted, mathematics teacher, rural school, focus group response). Similarly, Steve claimed: “We have a curriculum recommendation process that happens twice a year. We don't always review curriculum, but the opportunity of collaboration is always there” (Steve, mathematics teacher, suburban school, focus group response).

More so, the mathematics teachers’ participants highlighted the value of teacher collaborations in creating horizontal alignment. They clearly expressed that teachers who teach the same course within the same grade level do collaborate and share ideas with each other to make sure they are on the same page. Robert expanded on this point by saying: “There are only a few math teachers in our building, and we do collaborate and touch base with each other to make sure we are on the same topics. We align ourselves with the same topics, but differ in what worksheets, homework assignments, and quizzes we use” (Robert, mathematics teacher, rural school, focus group response).

The mathematics teachers in the study also reflected on “time” as an issue for collaboration and sharing ideas to allow teachers to do a better job of the alignment. For example, Dave described: “I communicate frequently with teachers of the same level. We,
Fortunately, have a common planning time, but that is not the case for most teaching teams. I communicate less often with those of different levels, and it is more informal simply because we don’t have the time to do so” (Dave, mathematics teacher, suburban school, focus group response). Likewise, Ted emphasized the importance of time for collaboration to make alignment within grades and across grade levels: “...We need to have more time set aside to allow us to do a better job of the alignment, and as teachers change assignments, we should be periodically going over the vertical alignment so that everyone has a better idea of how these courses affect each other ...and students' understanding” (Ted, mathematics teacher, rural school, focus group response). The content area difference in collaboration existed across the urban and suburban schools. What seemed to differ between mathematics and science was time. The mathematics teachers at the suburban school had a common planning time, which none of the science teachers had. At the rural school, the teachers did not have a common planning time, but they did meet regularly. The science teachers, in contrast, did not have the same time set aside to develop horizontal and vertical connections.

As noted above, one of the biggest difficulties for the science teacher participants was the unavailability of “time” to collaborate with their colleagues to design a coherent curriculum. John reflected on this challenge by saying: “The biggest difficulty in implementing a coherent curriculum is that we don't have one. We rarely if ever meet with teachers not in our building or discipline to design curriculum. I will reach out occasionally for opinions but with a full schedule, it is difficult to find the time to collaborate in any meaningful way” (John, science teacher, rural school, interview transcript). Moreover, Mary said: I think a difficulty really is the opportunity to have communication with my colleagues. I think time could be the reason we don't collaborate here” (Mary, science teacher, rural school, interview transcript). Research
showed that the huge responsibilities teachers have to execute limit their willingness to take part in curriculum development (Bezzina, 1991; Bowers, 1991; Chinyani, 2013). Therefore, “teachers undergo stress and there are competing priorities for the time. This suggests that the unavailability of adequate time at the disposal of the teachers serves as a barrier to their participation in curriculum design” (Abudu & Mensah, 2016).

In the study, the administrators also were asked about the challenges/difficulties teachers confront in designing and implementing a coherent curriculum. Interestingly, the administrators also remarked making “time” for collaboration and discussion with colleagues and administrators to receive feedback is a challenge for teachers in designing and implementing a coherent curriculum. Lucia wrote: “Making time for collaboration and meaningful discussions interdepartmentally as well as with curriculum leaders and administrators is a challenge. It is also important to prepare, review, and support teachers with data, but it can also be a challenge to find time and resources for this. Just as well, regular walkthroughs and observations are challenging, but an important aspect of ensuring a coherent curriculum is in place. Unfortunately, many things can inhibit time to do so in a school day” (Lucia, assistant principal, rural school, open-ended survey response). Similarly, James discussed the limitation of time as a challenge for teachers to collaborate and design a coherent curriculum: “Implementation of a coherent curriculum can be challenging, as individual teachers do not have built-in time for K-12 dialogue. Their curriculum leaders have these conversations on their behalf. In terms of ensuring the integrity of a course from teacher to teacher (implementing curriculum with fidelity), an emerging PLC structure for grades 9-12 will help, but we aren’t there yet. We do require common assessments in all courses, which does help with aligning outcomes. A PLC structure that is more routine is implemented in grades K-8” (James, principal, suburban school, open-ended survey response).
The mathematics and science teachers were asked about the helpful support they need in designing and implementing a more coherent curriculum. Having more “time” to collaborate with other teachers was a theme that repeatedly surfaced in all teachers’ responses. Ted highlighted the importance of having in-service time to collaborate with fellow teachers in order to share ideas and design a vertical coherent curriculum. Ted declared: “It would be great if we had in-service time that would allow for the many hours of collaboration necessary to show the importance of why meaningful curriculum matters and share ideas with one another. Vertically align from k-12 with talks each step along the way and have the ability for elementary teachers to see what high school teachers are doing and vice versa” (Ted, mathematics teacher, rural school, interview transcript). Also, Robert remarked: “Time would be the most valuable in building a more coherent curriculum for sure! With such a lack of substitute teachers in our district, we find ourselves covering other classes during our planning periods, leaving less time in the day to collaborate with other teachers. Even if that wasn’t an issue, it’s rare to have the same planning period as another teacher in the same department at the same time to collaborate” (Robert, mathematics teacher, rural school, responded to the interview questions in writing). In the same way, John explained: “I think most teachers would need some type of in-service training on the topic. It is not something discussed in our district. The most important thing though is time. This is not an easy process and time is a valuable commodity, especially after what we have been going through the last two years during the pandemic” (John, science teacher, rural school, interview transcript). Further, Mary stated: “I think another kind of support would be just give us the opportunity to create a goal as a department and then time to work on the goal. Even if it’s just something little” (Mary, science teacher, rural school, interview transcript). It is interesting to see all of the teachers who mentioned providing time as helpful support are from
the rural school. All of them broadly discussed they need more time to collaborate with their colleagues and share ideas and resources, to attend in-service training, and to work on creating the goal.

In this study, what the science teachers discussed was different from what the mathematics teachers explained about their collaboration with other colleagues. The science teachers claimed they rarely collaborate, and their collaboration is more informal conversations with the same grade teachers, and they rarely meet with the other grade level teachers. On the other hand, mathematics teachers asserted more collaboration with the teachers who teach the same course or same grade level and with teachers in other grades.

The mathematics and science teachers in the study reflected on “time” as an issue for collaboration and sharing ideas to allow teachers to do a better job of the alignment. The mathematics teachers at the suburban school had a common planning time, which none of the science teachers had. At the rural school, the teachers did not have a common planning time, but they did meet regularly. The science teachers, in contrast, did not have the same time set aside to develop horizontal and vertical connections. Interestingly, the administrators also remarked making “time” for collaboration and discussion with colleagues and administrators to receive feedback is a challenge for teachers in designing and implementing a coherent curriculum. Further, all of the teachers from the rural school mentioned providing time as helpful support. All of them broadly discussed they need more time to collaborate with their colleagues and share ideas and resources, to attend in-service training, and to work on creating the goal.

**Administrator Ideas for Supporting Teachers**

The following section discusses the support administrators make available for teachers in designing and implementing a coherent curriculum. They identified time, funding for curriculum
resources, monitoring data and curriculum process as well as providing Professional Development opportunities as the best supports that make available for teachers to design and implement a coherent curriculum. The examples of the administrator language drawn from open-ended survey responses are included in the following section.

In the study, the administrators were asked about the support they make available for teachers in designing and implementing a coherent curriculum. As a matter of interest, the majority of the administrators emphasized “time”, “funding for curriculum resources”, as well as “monitoring data and curriculum process” as the best support that makes available for teachers to design and implement a coherent curriculum. Daniel outlined: “Time, funding for adequate curriculum, co-planning, access to data to inform curriculum changes that may be needed, a person that can be dedicated to ensuring that curriculum is reviewed regularly” (Daniel, principal, rural school, open-ended survey response). Similarly, Lucia highlighted: “Providing a timeframe for our scheduling process that includes the program of studies early in the year allows for time to assess and monitor what is currently working or not working. Funding for curriculum and curriculum research is essential as well as professional support to research and evaluate the most up-to-date and successful offerings we can provide. In short, time, funding, data review, and a research-based approach” (Lucia, assistant principal, rural school, open-ended survey response). Furthermore, James explained: “Several times per year curriculum leaders meet as a K-12 curriculum team. This allows for conversations that are vertical. Several times per month curriculum leaders facilitate department meetings. This allows for conversations that are horizontal. A key step in the curriculum recommendation process is the involvement of curriculum leaders that represent a K-12 perspective, allowing for coherent design” (James, principal, suburban school, open-ended survey response).
Another administrator additionally pointed to providing professional development opportunities for teachers as support. Jill discussed: “I have worked with the previous Curriculum Director to provide Professional Development opportunities for teachers. I am also available for teachers to talk about ideas for resources. Since the comfort level of teachers varies, I often share ideas from the teachers who are finding resources to the teachers who need more support and guidance” (Jill, principal, rural school, open-ended survey response).

Teacher Evaluation

The following section includes the approaches administrators used to evaluate teachers’ use of curriculum in this study. They identified “observations/walkthroughs” and “students’ mastery or student data” as approaches to evaluate teachers’ use of curriculum. The examples of the administrator language drawn from open-ended survey responses are included.

The administrator participants in the study were asked about the approaches to evaluate teachers’ use of curriculum. The main ideas that emerged from all of their responses were “observations/walkthroughs” and “students’ mastery or student data” as approaches to evaluate teachers’ use of curriculum. James as a high school principal referenced walkthroughs, differentiated supervision projects, and student data for evaluating teachers’ use of curriculum as well as assessing students’ growth and achievement. James described: “Our supervision & evaluation model includes up to four walkthroughs per year. This allows a glimpse into how teachers use curriculum. We also use differentiated supervision, so in addition to walk-throughs, teachers complete a curriculum-related project, allowing supervisors to understand the thinking, development, and implementation considerations that matter to a teacher. Finally, all teachers work on a curriculum project for two days each summer; these projects are developed by and facilitated by teachers, and administrators play a part in watching the progress of and evaluating
this work. Finally, student data, including but not limited to final exams, Keystones, AP, IB, and NOCTI scores all help us assess curriculum and students’ growth & achievement” (James, principal, suburban school, open-ended survey response).

Further, Jill as a high school principal acknowledged the value of observation/walkthrough and evident in students’ mastery as approaches to assessing teachers’ use of curriculum. Jill explained: “There are still common assessments for each subject and grade level. So, ultimately, the appropriate use of curriculum materials should be evident in the students' mastery of the curriculum content on assessments. I also provide feedback to teachers through walkthrough observations and formal observations” (Jill, principal, rural school, open-ended survey response).

Daniel the middle school principal also discussed the importance of observations/walkthroughs and meaningful discussion approaches for evaluating teachers’ delivery of content. However, he highlighted “time” as an issue for observation. Daniel wrote: “I wear multiple hats during a day/week/month/year. If I had the time, then I would regularly be in classrooms weekly/monthly to observe content delivery. Finding this time to do observations/walkthroughs is often difficult. I do meet with my departments monthly to help with guiding questions and have uncomfortable conversations sometimes when I know that content is not being taught similarly across the same subject/course. For example, Reading 7 content should be the same across the building, no matter who is teaching the course. Teachers’ delivery of content can vary, but the content and skills being taught should be the same” (Daniel, principal, rural school, open-ended survey response).

Lucia as a high school assistant principal highlighted these approaches by explaining: “Observations, meaningful discussions, student engagement as it correlates to successfully
meeting standards and benchmarks (which in and of themselves are terms that need to be defined) are a few means of doing this. Department heads are an integral part of the ongoing conversation to evaluate curriculum because they can collaborate and discuss within their departments without an administrator present at all times” (Lucia, assistant principal, rural school, open-ended survey response).

As noted above, Daniel mentioned “time” limitation as an issue for classroom observation and walkthrough to evaluate teachers’ delivery of content. Daniel also broadly expressed limited follow-up with teachers, regular observation, and walkthroughs can lead to a lack of coherent curriculum and create gaps in student learning. He described: “What gets monitored – gets done! If administrators are not requiring quarterly/common assessments, and regularly following up with teachers, getting into classrooms to observe and ensure that eligible content is being delivered consistently, then what happens is a lack of coherent curriculum, which creates gaps in student learning as students get older” (Daniel, principal, rural school, open-ended survey response). As Lucia emphasized on this thought by writing that “…Regular walkthroughs and observations are challenging, but an important aspect of ensuring a coherent curriculum is in place” (Lucia, assistant principal, rural school, open-ended survey response).

The administrator participants in the study referenced observations/walkthroughs, differentiated supervision projects, and students’ mastery or student data as approaches to evaluate teachers’ use of curriculum as well as assessing students’ growth and achievement. One of them mentioned “time” limitation as an issue for classroom observation and walkthroughs to evaluate teachers’ delivery of content. They also broadly expressed limited follow-up with teachers, regular observation, and walkthroughs can lead to a lack of coherent curriculum and create gaps in student learning.
Research question two: What obstacles do teachers perceive in implementing a curriculum in coherent ways?

The findings of the data analysis addressed the second research question in the following section. In this section, the difficulties teachers faced in designing and implementing a coherent curriculum are discussed. They include the lack of “time” to collaborate with their colleagues, lack of funding and limitation of physical resources, and the lack of coherent curriculum/instruction. Also, in this section, the administrator's reflections on teachers’ challenges are discussed. In addition, examples of teacher and administrator language drawn from interview transcripts, and open-ended survey responses are included throughout the following section.

The data demonstrated the mathematics and science teachers in this study faced some difficulties/challenges in designing and implementing a coherent curriculum. Two of the rural teacher participants mentioned the lack of vertical alignment as a challenge they face in the classrooms to teach new lessons which leads to student confusion. One science teacher expressed that when different teachers do different things, it is very difficult to create coherent instruction/curriculum. Therefore, students transition to the next grade level with different educational backgrounds even though all of them are coming from the same school. Also, a mathematics teacher pointed out that the greatest difficulty is a lot of previous instruction has not been taught in a coherent way, then teaching new lessons leads to student confusion. In addition, he highlighted it is important for students to understand the connections between the information across grade levels through coherent instruction.

Furthermore, two science teachers, both from the rural school, described a lack of funding and limitation of physical resources as another difficulty they face to supplement the
curriculum (i.e., textbook series) in practice. They remarked on the limitation of physical resources especially when students need to make connections between their lesson and real-world experience. More so, the teachers reflected on budgeting and ordering supplemental resources as an issue in the rural school if their students want to do an experiment in the middle of the year. Both teachers highlighted the limited funding and resources in the rural school. They talked about requests at their school as something that could be considered by the curriculum leader, but the likelihood that supplies would be funded for an individual teacher, much less a wider group of teachers, was less certain than was the case in the suburban school district. The need for agreement and permission to use the resource budget is centered throughout the responses of teachers from the rural school.

One of the biggest difficulties for the science and mathematics teachers was the unavailability of time to collaborate with their colleagues to design a coherent curriculum. The mathematics teachers in the study reflected on “time” as an issue for collaboration and sharing ideas to allow teachers to do a better job of the alignment within grades and across grade levels. The mathematics teachers asserted they communicate frequently with the same grade level teachers and communicate less often with those of different levels, because of time limitations.

The content area difference in collaboration existed across the urban and suburban schools. What seemed to differ between mathematics and science was time. The mathematics teachers at the suburban school had a common planning time, which none of the science teachers had. At the rural school, the teachers did not have a common planning time, but they did meet regularly. The science teachers, in contrast, did not have the same time set aside to develop horizontal and vertical connections.
As noted above, one of the biggest difficulties for the science teacher participants also was the unavailability of “time” to collaborate with their colleagues to design a coherent curriculum. The science teachers claimed that there is a lack of a coherent curriculum in their school. Because the teachers don't have time to meet with each other to share ideas and collaborate in any meaningful way. Research showed that the huge responsibilities teachers have to execute limit their willingness to take part in curriculum development (Bezzina, 1991; Bowers, 1991; Chinyani, 2013). Therefore, “teachers undergo stress and there are competing priorities for the time. This suggests that the unavailability of adequate time at the disposal of the teachers serves as a barrier to their participation in curriculum design” (Abudu & Mensah, 2016).

In the study, the administrators also were asked about the challenges/difficulties teachers confront in designing and implementing a coherent curriculum. Interestingly, the administrators also remarked making “time” for collaboration and discussion with colleagues and administrators to receive feedback is a challenge for teachers in designing and implementing a coherent curriculum. Also, they broadly mentioned follow-up with teachers, regular observation and walkthroughs as well as supporting teachers with data and resources are other challenges that lead to the lack of a coherent curriculum.

**Research question three: What can we learn about teachers’ autonomy to make decisions about their curricular resources?**

The findings of the data analysis addressed the third research question in the following section. This part examined the amount of autonomy (freedom) mathematics and science teachers have for choosing and modifying their curricular resources, limitation on curriculum autonomy, administrator perspectives about the amount of autonomy teachers have in selecting their curriculum resources, people who are involved in the selection of the curriculum materials
at the school level, the norms and policies for the selection of curriculum materials, and the COVID-19 impact on curricular resources. In addition, examples of teacher and administrator language drawn from focus group written responses, and open-ended survey responses are included throughout the following section.

**Autonomy in Choosing and Modifying Curricular Resources**

Mathematics and science teachers in this study discussed the amount of autonomy they have for choosing and modifying their curricular resources. Interestingly, all of the teacher participants described their autonomy in choosing their curricular resources and course objectives as ‘full’ or ‘a lot’. Across content areas, the teachers highlighted having a great deal of freedom allowing them to try new resources and see if they meet student needs or not. For example, Ted expressed: “I have a great deal of autonomy in choosing my resources” (Ted, mathematics teachers, rural school, focus group response). As Bob wrote: “I have full autonomy. We have the freedom to try new things to see what works and what doesn't. We can then pass that information along to our colleagues building a stronger staff” (Bob, science teacher, rural school, focus group response).

Bob’s response also provides an example of the collaboration teachers engaged in. Here Bob shares resources and his opinion on those resources with peers. This facet of collaboration at the rural school was further expanded on by Robert, who explained: “In my building, the math teachers and math department have gathered together to make decisions on which textbook or supplemental resources we would like to use, such as IXL.COM and other workbooks” (Robert, mathematics teacher, rural school, focus group response).

Tracy described her autonomy in terms of modifications of existing resources, she wrote, “I have a lot of autonomy to modify curricular resources. I am changing support materials all of
the time. As new resources are available, I incorporate them. If they have a cost associated with them, I put in a request. If I am interested in changing the main curricular resources like a textbook, I propose it to our curriculum panel for approval” (Tracy, science teacher, suburban school, focus group response). Tracy’s response also provides insight into how curricular resources are chosen and implemented at her suburban school site. Given the school has resources to spend on curriculum, she is able to “put in a request” if she finds something she wants to try. She is also able to propose resources to the school’s curriculum panel for wider use by more teachers. In addition to what Tracy discussed, Steve further described the curriculum choice process at the suburban school: “I have a lot of autonomy in choosing resources. I'm also the math curriculum leader and have a lot of influence in math curriculum choices” (Steve, mathematics teacher, suburban school, focus group response). As can be seen across these two examples, the teachers at the suburban school experienced a lot of freedom in choosing and purchasing curricular resources.

An unexpected consequence of the high degree of autonomy that teachers experienced was that they saw their curriculum as lacking in coherence. John stated this most explicitly when he wrote, “Because we don’t have a coherent curriculum, we have a lot of say over how we modify and choose our curriculum” (John, science teachers, rural school, focus group response). John’s comment underscores a common experience for the teachers. Choices about curriculum, especially supplemental resources, and decisions about how to modify the curriculum provided by the school/district were left to the individual teacher. A potential implication of this is that teachers may hold a high degree of responsibility in establishing coherence across a range of resources and modifications.
Further, the administrators underlined that a high degree of teacher autonomy in selecting curricular resources and different styles of teaching leads to an incoherent curriculum. Jill explained: “Teachers have different teaching styles and different ideas about quality curriculum materials. As we moved toward more teacher autonomy in selecting and using resources, many teachers expressed excitement and a feeling of empowerment to be able to use what they feel are appropriate resources to meet the needs of their students while others expressed frustration in not having a basal system to guide daily instruction” (Jill, principal, rural school, open-ended survey response). From the administrators’ perspectives, teacher autonomy can be frustrating for some teachers while it can be more empowering for other teachers to choose appropriate curricular resources and meet the needs of their students.

Limitations on Curriculum Autonomy

Although all participants in this study expressed a wide range of autonomy in selecting, changing, and incorporating the curricular resources, two science teachers, both from the rural school, described that a lack of funding/resources limited their autonomy to supplement the curriculum (i.e., textbook series) in practice. Mary wrote: “Currently, I have a wide breadth of autonomy in choosing and modifying curriculum, however, I have not requested particular resources. When I moved here, they gave me a book and they're like, here's the curriculum. I said it's a book that's not a curriculum. Also, they didn't give me the objectives, I made those. So, I think if there was some tangible thing, other than just a textbook that would be great” (Mary, science teacher, rural school, focus group response). Mary also remarked on the limitation of physical resources as a difficulty they face in the rural school. Especially when students need to make connections between their lesson and real-world experience. Mary alluded: “…Especially when you're trying to do more of that real-world learning where students are hands-on and
they're figuring things out. A lot of times they will come up with really great ideas for experimentation or expansion for making connections between things, but we just don't have the means to provide the resources to do those things. And so that's always an issue with the actual resources” (Mary, science teacher, rural school, interview transcript). More so, John reflected on budgeting and ordering supplemental resources as an issue in the rural school by explaining: “I have full autonomy in choosing our curriculum. But budgeting and ordering supplemental resources is an issue here. If I want my students to come up with a really great experiment that they want to do in the middle of the year, I need a budget to purchase items. I should send the request to the curriculum leader and the department for consideration” (John, science teacher, rural school, focus group response).

Furthermore, Mary explicitly expressed that providing funding and curricular resources are huge supports for teachers. Mary explained: “At the administrative level, I think that if they adjusted the way they do budgeting for us and the way that we do ordering would be a tremendous help. If I could have a budget and use that to go purchase experimental items for students. That would help tremendously” (Mary, science teacher, rural school, interview transcript). Mary and John both highlighted the limited funding and resources in the rural school. They talked about requests at their school as something that could be considered by the curriculum leader, but the likelihood that supplies would be funded for an individual teacher, much less a wider group of teachers, was less certain than was the case in the suburban school district.

The need for agreement and permission to use the resource budget is centered throughout the responses of teachers from the rural school. As Ted described: “There has been agreement on the purchasing of curricular materials by the math and science department. When new books are
purchased, we break into committees to look through the choices. We also meet to determine what electronic resources should be purchased as a department to help us move forward. The principals and technology coordinator have also been instrumental in pushing apps and training in using technology in the curriculum” (Ted, mathematics teacher, rural school, focus group response). Additionally, Mary alluded: “When making adjustments to curriculum, I run it by the science department but again have not had the need to seek out curriculum materials, beyond what I have written grants and received funding for” (Mary, science teacher, rural school, focus group response).

What was common across the school sites was that despite the large degree of freedom to choose the resources, teachers still needed to confirm with the curriculum leaders and go through a curriculum review process within and beyond the school. In this regard, Dave stated: “I have a large degree of freedom to modify as needed. I confirm with my curriculum leader, and we do have a curriculum review process, but we still have a lot of leeways” (Dave, mathematics teacher, suburban school, focus group response). The teacher responses across the two sites indicated agreement with the literature on potential limitations for teacher autonomy in the policy. Wright (2018) states that “although the curriculum makes certain room for teacher autonomy, it appears that the micro-management of the school and district educational authorities may undermine the autonomy of teachers in the classrooms”. In addition, both mathematics and science teachers discussed other people who are involved in the selection of the curriculum materials at the school level. These include administrators within and outside of the school and fellow teachers in their departments. Tracy outlined: “Fellow teachers teaching the same content, curriculum leader, principal, central office administration, and school board. Our district has a very clear-cut process for this” (Tracy, science teacher, suburban school, focus
group response). Dave reinforced this point by explaining: “Our department has always had a say in the text we use and materials as well as our curriculum leader. Also, those who teach the same sections and same level communicate regularly. I do try to touch base with those teaching different levels as well to see if they have any new curricular materials that could be modified for the academic level” (Dave, mathematics teacher, suburban school, focus group response).

Besides all of these individual decision-makers, one of the science teachers, additionally referenced more involvement of the administrators and the department in the selection of curriculum materials. Bob said: “Our administrative staff along with the entirety of the science department” (Bob, science teacher, rural school, focus group response).

However, three teachers (two mathematics teachers and one science teacher) emphasized the importance of teachers’ involvement in designing the curriculum. As John explained: “The three science teachers in my building have written the curriculum multiple times” (John, science teacher, rural school, focus group response). Moreover, Robert asserted: “Our school principal gave us teachers the opportunity to make the decision on what materials we think would be best to use” (Robert, mathematics teacher, rural school, focus group response). Also, Steve stressed this point by stating: “Myself and other teachers in the math department” (Steve, mathematics teacher, suburban school, focus group response).

Administrator Perspectives

In this study, the administrators in both rural and suburban schools also discussed the amount of autonomy teachers have in selecting their curriculum and additional-curricular resources. The administrators, who included principals and assistant principals, agreed with the teachers that teachers in their schools had “close to full autonomy” for choosing curricular resources, but as was evident in the teacher responses, there were policies and practices for
administrative discussion and review of teachers’ curricular decision making that varied across the two school sites. At the rural school, Lucia described the path through which curriculum goes to be approved: “Teachers have close to full autonomy for choosing curricular resources, but with departmental discussions and sometimes administrative review. As curriculum goes, department heads, department members, and administration review/discuss curricular additions. The school board approves a new curriculum” (Lucia, assistant principal, rural school, open-ended survey response). Jill explained how that pathway had evolved in recent years due to the ease of sharing curricular resources via technology: “Previously, the Curriculum Director asked for teacher representatives from each grade level to provide input and assistance with creating curriculum pacing guides and selecting curricular resources. More recently, teachers have had more autonomy to select and share resources through Google Drive folders” (Jill, principal, rural school, open-ended survey response). From these responses, it is clear that the teacher collaboration around supplemental resources described by the rural teachers is supported by administrators, but that there is still a school and district-wide process for making large curriculum decisions.

The process is more formalized and quicker in the suburban school. As James highlighted: “Twice annually our District engages in a curriculum recommendation process. Recommendations can be big or small – from developing an entirely new course to adopting a small resource in a particular course. The process is rigorous but allows change to happen in all content areas up to two times per year, rather than waiting for a curriculum cycle” (James, principal, suburban school, open-ended survey response). James expanded on this thought by highlighting the importance of teachers’ roles and voices in curricular decision-making. Also, he emphasized the autonomy that teachers have to make changes and recommendations through this
process by writing that “...Recommendations are primarily teacher-driven, which means that teacher’s voice is critical in all changes – the autonomy lies in teachers’ abilities and desire to make recommendations for review on a regular basis. We find both ability and desire to be high” (James, principal, suburban school, open-ended survey response). It is clear in this comment that the way James refers to teacher autonomy as the ability and desire to make recommendations is different from how teachers described their own autonomy and what other administrators described as teacher autonomy in selecting curricular resources.

**The Norms and Policies for Selection of Curriculum Materials**

The administrator participants in this study discussed the norms and policies for the selection of curriculum materials that teachers use in the schools. The administrators described the norms for the selection of curriculum in the state of Pennsylvania. They emphasized the importance of teacher autonomy in reviewing the content and standards, creating the curriculum map, and selecting the resources and instructional methods. More importantly, the administrators stressed that materials and curriculum processes should be monitored, reviewed, and assessed using student data to determine the impact on student learning. Daniel, the middle school principal, elaborated on the process and highlighted teachers have the autonomy to review the content, choose the resources, create a curriculum map, and decide how to deliver the content: ”When establishing the norms for curriculum in Pennsylvania, the first place to start is www.pdesas.org. Teachers have had in recent years the task of reviewing the eligible content that is to be taught at each level and creating a curriculum map that outlines when content is to be delivered. Teachers have autonomy in how content is delivered, and what resources can be used. At the middle school level, monthly department meetings are held in order to discuss where teachers are in regard to their curriculum, quarterly/common assessments, student data,
etc.” (Daniel, principal, rural school, open-ended survey response). Besides, Lucia as a high school assistant principal explained: “Teachers should know their content area, state standards, and eligible content in the state of PA. Curriculum mapping vertically and horizontally should occur, and when possible, should be reviewed K-12 for the entire scope and sequence of subjects. We have had a curriculum director whose primary role was principal making it challenging to provide full-time attention to curriculum needs. Materials should be monitored, reviewed, and reassessed regularly using a variety of data and researched-based effectiveness to determine the impact on student learning” (Lucia, assistant principal, rural school, open-ended survey response).

Jill, the high school principal, remarked on the importance of teacher autonomy in selecting and using resources with oversight from the administrators by stating: “There have recently been a few changes to this process. Previously teacher representatives, principal, and curriculum director would work together to select curriculum materials. More recently, there has been a move toward more teacher autonomy in selecting and using resources with oversight from the Curriculum Director and principal” (Jill, principal, rural school, open-ended survey response).

Further, James as a high school principal described the norms for the curriculum development process in the suburban school. He explained the hierarchical process of curricular decision-making as occurring twice a year in the suburban school. James wrote: “Norms are set by the stages of the process itself. Curriculum development is the foundation of our instructional program. There are two times during the school year that the formal curriculum development process takes place, January and June. The curriculum development process follows these steps: 1) Curriculum leaders and department chairs prepare recommendations as a result of ongoing
work with teachers, administrators, students, and parents; 2) Preliminary panel meetings are held and recommendations are reviewed by leadership teams at the elementary, middle school and high school levels; 3) At a final panel, the revised and/or edited recommendations are reviewed again by K-12 discipline teams and Central Office administrators; 4) The Assistant Superintendent and Director of Curriculum & Professional Development review the recommendations with a community curriculum input committee; 5) The Superintendent, Assistant Superintendent and Director of Curriculum & Professional Development prepare administrative reactions to the recommendations; 6) The recommendations are presented to the School Board for review and/or final approval” (James, principal, suburban school, open-ended survey response).

**COVID-19 Impacts on Curricular Resources**

Unexpectedly, only one mathematics teacher and one administrator in this study pointed out a shift to their curriculum due to COVID-19 online instruction during the 2020-2021 school year. Daniel, as an administrator, expressed: “Our school made efforts to purchase textbooks and curriculum 8 years ago at the secondary level; Department Heads and teachers were involved and brought into review textbooks and also met with reps; During the 2020-2021 school year most of our curriculum was shifted to Google Classroom, and a number of online resources and supplementals programs have been added to support teachers. So, teachers have the autonomy to select and share resources” (Daniel, principal, rural school, open-ended survey response). This comment clearly demonstrates the differences between the curriculum cycle in the two school districts. As Daniel wrote they chose the curricular resources eight years ago in the rural school, but James explained his school goes through the curriculum review process and chooses a new curriculum twice annually in the suburban school. In addition, this comment implies the rural
school district did not have adequate online resources to meet the remote needs of the 2020-2021 school year.

The only teacher to mention the impact of COVID-19 was Dave, a suburban mathematics teacher who asserted teachers used their increased freedom due to COVID-19 shifts to be more creative and to make decisions about their curricular resources and instructional activities during the pandemic. Dave wrote: “I have a large degree of freedom to modify as needed. The pandemic has allowed us to be as creative as needed in this regard. We have a new schedule that has cut down on our instructional minutes, so we have had to make cuts to the content we have covered. It will be interesting to see how these changes impact students moving forward and also encourage us to reflect on what skills are truly necessary for students” (Dave, mathematics teacher, suburban school, focus group response). It is interesting that Dave positions the reduction of instructional time and content as an opportunity for “creativity” and “to reflect on what skills are truly necessary for students”, particularly because Dave was the teacher who understood coherence to be about alignment to the standards and one of the teachers who understood coherence as standardization across sections of the same course.

In a summary, the mathematics and science teachers in this study discussed the amount of autonomy they have for choosing and modifying their curricular resources and course objectives as “full” or “a lot”. Across content areas, the teachers highlighted having a great deal of freedom allowing them to try new resources and see if they meet student needs or not. Although all participants in this study expressed a wide degree of autonomy in selecting, changing, and incorporating the curricular resources, two science teachers described that a lack of funding/resources limited their autonomy to supplement the curriculum (i.e., textbook series) in practice. Also, the teachers asserted despite the large degree of freedom to choose the resources,
there are policies and procedures in place that teachers must go through before enacting that autonomy (e.g., a curriculum review process within and beyond the school or a budget review process within the school). Moreover, the teacher participants talked about people who are involved in the selection of the curriculum materials at the school level. These include administrators within and outside of the school and fellow teachers in their departments.

The administrators in this study agreed with the teachers that teachers in their schools had “close to full autonomy” for choosing curricular resources, but as was evident in the teacher responses, there were policies and practices for administrative discussion and review of teachers’ curricular decisions making that varied across the two school sites. Furthermore, the administrators mostly spoke about teacher autonomy as having a voice or input in larger processes (e.g., making recommendations as part of the curriculum review process). The way they referred to teacher autonomy in action as the ability and desire to make recommendations is different from how teachers described their own autonomy or perceived freedom in selecting curricular resources. Further, the administrators described the norms for the selection of curriculum in the state of Pennsylvania. They emphasized the importance of teacher autonomy in reviewing the content and standards, creating the curriculum map, and selecting the resources and instructional methods in the curriculum development process.

One mathematics teacher and one administrator in this study pointed out a shift to their curriculum due to COVID-19 online instruction during the 2020-2021 school year. They claimed that teachers have enough autonomy to modify the curriculum and the pandemic provided an opportunity for teachers to be more creative in curricular decision making. Being creative and changing the instructional content could be an opportunity for them to see what skills are truly necessary for students.
Research question four: What similarities and differences are there in the ways that mathematics and science teachers conceptualize and implement a coherent curriculum?

The results of the data analysis addressed the fourth research question in the following section. In order to respond the research question four, I compared and contrasted the mathematics teachers’ and science teachers' responses through the general interpretive process of close reading to find the similarities and differences between their perceptions and experiences across both the rural school and suburban school. The mathematics and science teachers talked similarly for the most part. However, there were some differences in their responses. They discussed the characteristics of a coherent curriculum, the advantages of a coherent curriculum for teachers, what teachers perceive the advantages for students are, strategies teachers use to make connections between lessons, units, and students’ learning across the grades, and the challenges or obstacles the teachers face in designing and implementing a coherent curriculum similarly in most parts. But they described limitations to curricular autonomy and implementation and opportunities to collaborate differently.

The science and mathematics teachers identified characteristics of a coherent curriculum as logical sequencing, alignment, students’ prior knowledge, discipline-specific knowledge, and teacher collaboration. They reported similarly about the advantages of using a coherent curriculum as helping teachers to know what knowledge, skills, and abilities students should have prior to starting the current content, providing opportunities for students to gain similar educational experience and knowledge and be on the same page for next grade levels and making teaching easier for teachers. The teachers also highlighted the importance of a coherent curriculum for students similarly. They discussed it helps students to see how each grade and topic are tied together and move toward domain-specific goals. Also, a coherent curriculum
helps students to better understand why they are learning the materials and how knowledge is transferable or will become useful to them in the future.

In addition, the teachers mentioned similar strategies to make connections between lessons, units, and students’ learning across the grades. However, all of the teachers did not use the same approaches to implement these strategies. The mathematics teachers and science teachers described the strategies such as relating or ‘tying together’ lessons to make a ‘story’ and using ‘real-life examples’ as strategies to make connections between lessons and units. Furthermore, they reported using resources such as scenarios, videos, and virtual labs to teach and to connect the mathematics and science lessons together in the previous week. Moreover, the teachers used retrospective approaches of reviewing content from previous grades in the current grade, primarily by locating curricular resources for content in previous courses or by creating regular opportunities to ask questions or engage in activities about previous content in order to connect students’ learning in their class to other grades. A finding consistent across the teachers is that their approaches were exclusively about how to connect their current content with previous courses/grades.

All of the mathematics and science teachers broadly stated they had full or lots of autonomy in choosing their curricular resources. However, some of them discussed the limitations on teacher autonomy. For instance, the science teachers from the rural school pointed to the lack of funding/resources limited their autonomy to supplement the curriculum (i.e., textbook series) in practice. Furthermore, the mathematics teachers described that despite the large degree of freedom to choose the resources, they still need to confirm with the curriculum leaders and go through a curriculum review process. Interestingly, only one teacher, a mathematics teacher from the suburban school pointed out a shift to their curriculum due to
COVID-19 online instruction during the 2020-2021 school year. He asserted teachers used their increased freedom due to COVID-19 shifts in the amount of instructional time to be more creative and to make decisions about their curricular resources and instructional activities during the pandemic.

The mathematics and science teachers spoke and wrote differently about the amount of collaboration they have to share ideas and make decisions about curriculum. All of the science teachers in this study declared that they rarely collaborate with fellow science teachers. On the other hand, the mathematics teachers asserted more collaboration with the teachers who teach the same course within the same level and with teachers in other grades. More so, the mathematics teachers’ participants highlighted the value of teacher collaborations in creating horizontal alignment. They clearly expressed that teachers who teach the same course within the same grade level do collaborate and share ideas with each other to make sure they are on the same page.

The data showed that the mathematics and science teachers faced similar challenges/difficulties in the implementation of a coherent curriculum. However, the science teachers more often emphasized the limitation of funding and physical resources as the biggest difficulties, especially when students need to make connections between their lesson and real-world experience. The mathematics and science teachers in the study reflected on “time” as an issue for collaboration and sharing ideas to allow teachers to do a better job of the alignment. But what seemed to differ between mathematics and science was time. The mathematics teachers at the suburban school had a common planning time, which none of the science teachers had. At the rural school, the teachers did not have a common planning time, but they did meet regularly. The
science teachers, in contrast, did not have the same time set aside to develop horizontal and vertical connections.

All of the mathematics and science teachers in the study reported broadly on having more time to collaborate with other teachers as helpful support they need in designing and implementing a more coherent curriculum. Although, the mathematics teachers remarked having a more coherent instruction/curriculum between grades (vertical coherent) is the greatest support. In addition, the science teachers clearly expressed that providing funding and curricular resources, as well as classroom observation and feedback from administrators, are huge supports for teachers. Finally, the mathematics and science teachers reported similarly about the people who are involved in the selection of the curriculum materials at the school level. They mentioned administrators, the entire department, and teachers’ involvement in the selection and designing of the curriculum.

**Connections to the Frameworks**

In the following section, the connections of the themes to the conceptual framework and theoretical framework of the study are discussed. This study used the Danielson framework (Danielson Group, 2013) as a conceptual framework and the Tripartite Model of Curriculum as a theoretical framework. The study particularly focused on Danielson as a way to examine coherence processes through instruction and instructional planning in ways that are made explicit to teachers and administrators through evaluation procedures. This was supplemented with the Tripartite Model of Curriculum that examines a broader perspective on curriculum, and in particular, the ways coherence changes across what is intended by the curriculum designers and what is implemented in the classroom by teachers. The intended curriculum refers to the official statements that determine what students are expected to learn. Typically, these are “educational
system’s goals such as national standards” (Eberle, 2010), as well as state and district curriculum standards or guides. Textbook publishers often rely on these official documents to turn standards into lessons and accompanying exercises for students that may be used in classrooms (Taguma, Shirai, & Anger, 2016). Teachers use textbooks and other supplemental resources to create educational goals and experiences for students. These classroom instructional experiences are referred to as the implemented curriculum which is the taught curriculum. In the model, textbooks and any curricular resources that teachers utilize in their daily instruction represent the potentially implemented curriculum. The potentially implemented curriculum shows the link between the intended curriculum and the implemented curriculum. Finally, the attained curriculum refers to what students have learned in classrooms and their knowledge: ideas, constructs, and schemas.

**Connections to the Danielson Framework**

For the purpose of this study, I focused on components 1e and 1a to frame coherence and its effects on curricular decision-making by teachers. The way coherency appears in the Danielson framework is in two areas: 1e) the alignment between the lesson and the learning goals of the lessons, and 1a) the alignment across intra- and interdisciplinary content relationships (i.e., coherence across big ideas and coherence across subject areas). However, the teacher participants in this study were focused on alignment between lessons or concepts in the content, alignment across grade levels, and standardization across sections which is related to component 1a in the Danielson framework. They did not discuss coherence within lessons.

In 1a, coherence is described in terms of the alignment across intra- and interdisciplinary content relationships. The way the teacher participants discussed content relationships is within one of the characteristics of a coherent curriculum, specifically logical sequencing. Three teacher
participants (one mathematics teacher and two science teachers) indicated that coherent curricula make connections between content/topics in a logical way. For example, Steve stated: “To me, coherence means that the curriculum was developed in such a way that everything fits together vertically. Each course builds on the prior knowledge of the previous one, without gaps or unintentional repetition of content” (Steve, mathematics teacher, suburban school, focus group response). This emphasis on vertical alignment is consistent with interdisciplinary content relationships across courses.

Two of the teachers referenced another major characteristic of a coherent curriculum as “alignment” across interdisciplinary subject areas and interdisciplinary lessons, courses, and grade levels. This characteristic of the coherent curriculum is also aligned with component 1a because it talks about alignment across intra- and interdisciplinary content relationships. For instance, Dave explicitly used the word alignment to talk about alignment to standards. He described: “I thought about coherence in terms of alignment. Alignment to academic standards as well as to others teaching the same subject area” (Dave, mathematics teacher, suburban school, focus group response). Dave connected his idea of alignment to the standards to his understanding of logical sequencing, or interdisciplinary connections across courses or grades, stating “Since I have taught multiple levels of courses, I understand the importance of coherence knowing that students sometimes switch levels. Having a coherent curriculum is important so that students who do have to transition to another level can do so without much academic disruption” (Dave, mathematics teacher, suburban school, focus group response). Note, however, that Dave’s description also references standardization or “Alignment…to others teaching the same subject area” (Dave, mathematics teacher, suburban school, focus group response). This
idea of standardizing across sections is not referenced in Danielson, which focuses on individual teachers rather than teaching teams.

Further, the teachers identified discipline-specific knowledge as a characteristic of a coherent curriculum. In this theme, one of the science teachers highlighted having a coherent curriculum helps teachers to achieve the required purpose and the lack of a coherent curriculum leads to losing the big goal or big picture. Tracy invoked the idea of coherence in science curriculum as connecting beyond the content of the class by explaining: “Coherence leads to purpose. If there is not a coherent curriculum then the big picture can be lost.” (Tracy, science teacher, suburban school, focus group response). Her comments are connected to component 1a about intradisciplinary content relationships and coherence across big ideas. In addition, John discussed coherence as an “overarching” backbone of learning goals. For example, John described: “To me, a coherent curriculum means that the district has an overarching set of goals set from K-12 and those goals are supported by each grade level and subject. Even though each subject and grade levels have their own objectives they need to meet those ideas that are tied to the bigger curriculum goals” (John, science teachers, rural school, focus group response).

The teachers also discussed an advantage of a coherent curriculum for students, namely that the curriculum makes sense to them, and students can see the “big picture” and the “purpose behind their learning”. This “big picture” and “purpose” perspective may indicate elements of alignment across content relationships in Danielson’s framework. The teachers highlighted the importance of a coherent curriculum for students to see how each grade and topic are connected and move toward a specific goal by explaining: “… If you have a coherent curriculum students will be able to see how each grade and class are tied together and then work towards a specific outcome” (John, science teacher, rural school, focus group response). From John's perspective,
an advantage of a coherent curriculum for students is that the curriculum makes sense to them for understanding the content area.

The mathematics and science teachers reflected on the strategies they used to make connections between lessons in a week or units across the academic year within the same course to improve student understanding as tying together lessons to make a story. The teacher comments are aligned with component 1a about the interdisciplinary content relationships of the Danielson framework. For example, Ted explained: “I am constantly making connections between lessons. To me, math and physics are a story. Previously learned material is needed to tell the story” (Ted, mathematics teacher, rural school, interview transcript). Ted also considers mathematics and science to be different parts of the same story where learning one of them is required for knowing the one by stating: “...There are connections between math concepts and science concepts… and it is not a series of formulas or rules that are set apart from each other. They are intertwined. So, this week I tied things we are doing now to lessons learned a week ago …or even years ago.” In addition to the need for prior learning, Ted acknowledged that as a storyteller he needs to be entertaining. He reflected, “I am constantly looking for applications of the math and science I teach that are relatable to students and have interesting components to them” (Ted, mathematics teacher, rural school, interview transcript).

In a summary, the teacher participants in this study rarely discussed what happened within a lesson. For them coherence was between lessons, units, courses, and across grades which is more aligned with component 1a than 1e in the Danielson framework. They focused their understanding of coherence on the big picture or important concepts in science and mathematics. The teachers also made connections to prior learning and rarely discussed preparing students for future learning to build on those big ideas. They explained the purpose of
the learning in terms of the big ideas. But the connections within a lesson to today's activities or today’s learning objectives which is related to component 1e in the Danielson framework is largely absent from their discussion.

**Connections to the Tripartite Model of Curriculum**

In order to further explore the difference between the intended and implemented curriculum, this study used the Tripartite Model of Curriculum to examine the ways coherence changes across what was intended by the curriculum designers and what was implemented in the classroom by teachers. This framework demonstrates the hierarchy, complexity, and interaction between standards, textbooks, and curriculum goals on the one hand, and teachers’ perspectives and decision-making in the implementation of the curriculum on the other. This model makes an analytical distinction between curriculum as system goals, curriculum as instruction, and curriculum as student achievement. These dimensions are known, respectively, as the intended, implemented, and attained curriculum (Taguma, Shirai, & Anger, 2016). In the tripartite model, a crucial bridging curriculum representation is introduced, i.e., the potentially implemented curriculum. Therefore, the translation process from the intended to the implemented is made explicit, as the salient role of textbooks and materials becomes distinguishable. The three-level model of curriculum representations is extended to four levels. Given there was no student achievement data in this study, the focus remained on teachers’ perspectives on how they move from the intended to the implemented curriculum.

The *intended curriculum* refers to the “educational system’s goals such as national standards” (Eberle, 2010), as well as state and district curriculum standards that determine what students are expected to learn. The way mathematics teachers and science teachers in this study talked about alignment in Danielson 1a is similarly connected with the intended curriculum in
the Tripartite Model of Curriculum. As noted in the discussion of 1a, the teachers in this study, both in mathematics and science, thought about coherence as alignment between their instruction and the intended curriculum. They thought about this in terms of ensuring there is logical sequencing between big ideas and domain concepts and in terms of vertical alignment between courses and grades.

However, they found it challenging to achieve vertical alignment. For example, the teacher participants discussed the lack of alignment or coherent instruction across grade levels as a challenge they face in the classroom. Mary highlighted when different teachers implement the curriculum in various ways it is difficult to create coherent instruction across the grade levels. She stated: “...I get students that all went through middle school, but half of them have done lots of experiments and the other half of them have never done one. We have different teachers doing different things, and it makes it very difficult for me to create some kind of coherence, see when I have kids who’ve had such varied backgrounds, even though they’re coming from the same school” (Mary, science teacher, rural school, interview transcript).

Similarly in mathematics, Ted stressed this point and explained how important it is for students to understand the connections between the information across grade levels. Ted described: “I think the greatest difficulty I face is that a lot of their previous math instruction has not been taught in a way where there were connections seen between topics. So, when I start showing the connections ...I sometimes feel they are overwhelmed at first. It would be great to have a consistent message taught to them throughout their mathematics experience. Students often want a quick trick and ‘give me something that will give me the answer today’. They should be wanting to understand how the information is connected” (Ted, mathematics teacher, rural school, interview transcript). Note that both Ted and Mary focused on gaps in prior learning
as the difficulty they experienced in vertical alignment. Even though the intended curriculum was the same, teachers found it difficult to obtain vertical alignment because of differences in the implemented curriculum. This aspect of the vertical alignment is related to implemented curriculum in the Tripartite model of curriculum. As explained in the Tripartite model, teachers use textbooks and other supplemental resources to create educational goals and experiences for students. These classroom instructional experiences are referred to as the implemented curriculum which is the taught curriculum. Eberle (2010) states that “Teachers will significantly alter the implemented curricula to make it more congruent with their own teaching orientation and belief systems”. Therefore, the implemented curriculum is varied from class to class even when teachers utilize similar instructional materials (Eberle, 2010). This aspect is related to Mary’s and Ted’s comments: “when different teachers implement the curriculum in various ways it is hard to create coherent instruction across the grade levels” and “a lot of their previous math instruction has not been taught in a way where there were connections seen between topics”. The teachers’ participants in this study discussed there was no common ground to build forward from.

The teacher participants in this study also explained the importance of collaboration when teachers try to implement curriculum coherently, specifically teachers described the need to have more opportunities to collaborate with each other to plan their instruction and implement the tasks. However, the science teachers claimed to rarely collaborate and described their collaboration as more informal conversations with the same grade teachers. As John declared: “I work with the other middle school science teachers, but I rarely meet with the other grade level teachers. Our curriculum is not vertically aligned” (John, science teacher, rural school, focus group response). The mathematics teachers, on the other hand, asserted more collaboration with
the teachers who teach the same course or same grade level and with teachers in other grades. Ted explained: “We have had several meetings and there is the discussion between teachers teaching the same course to help with the horizontal alignment. We have recently put together a curriculum framework that goes k-12 in which I met with every teacher grade k-12 in mathematics, and we looked at vertical alignment issues” (Ted, mathematics teacher, rural school, focus group response). The way teacher participants in this study used teacher collaboration as a strategy to implement a coherent curriculum is related to aspects of the implemented curriculum in the Tripartite model, including instructional experiences, materials, and strategies that teachers use in their classrooms. As Robert emphasized, the importance of collaborating with fellow teachers as a strategy is that it helps build connections between what students learned in previous grades and new lessons. Robert further explained: “In the past, I used to have some of the same students in 6th grade all throughout 8th grade, which made making connections from previous grade levels much easier. Now, our school district mostly has a different teacher for each grade and course, making it a little more difficult to know how they learned a lesson the previous year. I have had enough experience teaching with a fellow colleague and know the strategies he uses, so it helps me understand what methods of instruction were used last year, so I can relate our current lessons to them easier. For example, the 7th-grade math teacher draws shapes around different terms to help students visually when simplifying and combining like terms” (Robert, mathematics teacher, rural school, responded to the interview questions in writing).

Further, two teachers highlighted sharing curricular resources as an important facet of teacher collaboration. For example, Robert expressed: “Our school has been making strides to achieve coherence in our curriculum. The math teachers have been collaborating to create the
same Quarterly Exams given at the end of the 9-week grading period” (Robert, mathematics teacher, rural school, focus group response). Dave’s remarks were very similar to Robert’s: “it is important to have coherence between teachers who teach the same course. My colleague and I who teach academic geometry share a Canvas page (like Blackboard) and use similar resources. While our styles are very different, we make sure to cover the same material and use common assessments, which is a very important practice” (Dave, mathematics teacher, suburban school, focus group response). Note that the way these two teachers discussed collaboration around resources rather than the implementation of those resources aligns with the potentially implemented curriculum in the Tripartite model. The *potentially implemented curriculum* shows the link between the intended curriculum and the implemented curriculum as designated in particular resources (e.g., by connecting materials to specific standards). In the model, textbooks and any curricular resources that teachers utilize in their daily instruction represent the potentially implemented curriculum rather than the implemented curriculum because different teachers could use/implement those resources differently. However, sharing resources may play an essential role in impacting teachers’ beliefs and impact teachers’ instruction and knowledge (Adams & Krockover, 1997; Eberle, 2010).

As mentioned above, the potentially implemented curriculum refers to any curricular resources that teachers utilize in their daily instruction. The teacher participants in this study discussed resources in terms of support (i.e., autonomy to choose) and constraints (i.e., budget). In particular, the science teachers from the rural school described a lack of funding and limitation of physical resources as a difficulty they face to make connections between their lessons and real-world experience. More so, they reflected on budgeting and ordering supplemental resources as an issue in the rural school if their students want to do an experiment in the middle of the year.
In addition, mathematics and science teachers in this study discussed the amount of autonomy. They highlighted having a great deal of freedom allowing them to try new resources and see if they meet student needs or not. However, two science teachers, both from the rural school, described that a lack of funding/resources limited their autonomy to supplement the curriculum (i.e., textbook series) in practice. Mary wrote: “Currently, I have a wide breadth of autonomy in choosing and modifying curriculum, however, I have not requested particular resources. When I moved here, they gave me a book and they're like, here's the curriculum. I said it's a book that's not a curriculum. Also, they didn't give me the objectives, I made those. So, I think if there was some tangible thing, other than just a textbook that would be great” (Mary, science teacher, rural school, focus group response). Mary also remarked on the limitation of physical resources as a difficulty they face in the rural school. Especially when students need to make connections between their lesson and real-world experience. Mary alluded: “…Especially when you're trying to do more of that real-world learning where students are hands-on and they're figuring things out. A lot of times they will come up with really great ideas for experimentation or expansion for making connections between things, but we just don't have the means to provide the resources to do those things. And so that's always an issue with the actual resources” (Mary, science teacher, rural school, interview transcript). More so, John reflected on budgeting and ordering supplemental resources as an issue in the rural school by explaining: “I have full autonomy in choosing our curriculum. But budgeting and ordering supplemental resources is an issue here. If I want my students to come up with a really great experiment that they want to do in the middle of the year, I need a budget to purchase items. I should send the request to the curriculum leader and the department for consideration” (John, science teacher, rural school, focus group response). To make connections in the Tripartite model, this means the
teachers have a lot of autonomy in the potentially implemented curriculum stage which is applying and modifying different curricular resources in their daily instruction. However, there are limitations in providing the resources which are related potentially implemented curriculum. As Mary highlighted: “When I moved here, they gave me a book and they're like, here's the curriculum. I said it's a book that's not a curriculum. Also, they didn't give me the objectives, I made those”. The school provided a textbook for teachers that is aligned with the intended curriculum, but it was not enough. It is not all of the curricular resources the teachers need to implement a coherent curriculum.

In a summary, the mathematics and science teachers in this study mostly focused on the intended curriculum which is standards, domain-specific content, and big picture goals. The teachers thought about coherence as alignment between their instruction and the intended curriculum. They thought about this in terms of ensuring there is logical sequencing between big ideas and domain concepts and in terms of vertical alignment between courses and grades. There were some places where the teachers discussed the potentially implemented and implemented curricula which are curricular resources and classroom instructional strategies. The teachers' participants talked about collaborations as a strategy to share ideas and resources to implement a coherent curriculum. Also, they talked about curricular resources in terms of budget limitation and autonomy. But they did not talk about it in terms of coherence to the big picture, to the daily lessons, or building on prior knowledge.

**Chapter Summary**

This chapter discussed the research findings as they pertained to the themes of characteristics of a coherent curriculum, advantages of using a coherent curriculum for teachers, and teachers’ perceptions of advantages for students’ learning. After a careful and thorough data
analysis process, the following additional themes were revealed: teacher strategies, teachers’ autonomy, teacher collaboration, administrator ideas for supporting teachers, and teacher evaluation. This chapter used the themes of the study to address the research questions. Finally, the last section discussed the connections of these themes to the conceptual framework and theoretical framework of the study. The following chapter will provide the overall discussion of findings, limitations of the research, the implications for future research as well as recommendations for moving forward.
CHAPTER FIVE

DISCUSSION OF FINDINGS AND RECOMMENDED ACTIONS

INTRODUCTION

The purpose of this study was to investigate (a) teachers’ and administrators’ perceptions of the qualities that make curriculum coherent; (b) the autonomy and barriers mathematics and science teachers experience in implementing coherent curriculum, and (c) ways that administrators act in support of teachers’ curriculum implementation. This qualitative study collected data from participants who identify as administrators, mathematics teachers, and science teachers in secondary grades at public schools in the eastern U.S. in order to better understand the range of decisions about curriculum coherence teachers make. The data presented in this study were based on written responses to open-ended questions provided by teachers and administrators as well as transcribed audio recordings that were collected through the Zoom platform with mathematics and science teachers. A total of 12 participants responded to the open-ended survey, focus group, and interview questions. They included four responses from science teachers (three teachers from the rural school and one science teacher from the suburban school), four responses from mathematics teachers (two mathematics teachers in the rural school and two mathematics teachers in the suburban school), and four responses from administrators (three from the rural school and one from the suburban school). The transcribed data and open-ended responses were grouped by themes using a selective reading approach. Also, the data was analyzed using close reading to compare and contrast the participant key phrases and common patterns. Some themes were identified that were aligned with the literature as well as several additional new themes.
Discussion of the Findings

The following section discussed and summarized the main findings of this study according to the thematic areas including characteristics of a coherent curriculum, advantages of using a coherent curriculum for teachers, and teachers’ perceptions of advantages for students’ learning, teacher strategies, teacher collaboration, administrator ideas for supporting teachers, teacher evaluation and teachers’ autonomy.

Five characteristics of a coherent curriculum were identified by mathematics and science teachers in this study. They identified characteristics of a coherent curriculum as logical sequencing, alignment, students’ prior knowledge, discipline-specific knowledge, and teacher collaboration. Further, the advantages of a coherent curriculum for teachers, the disadvantages of a less coherent curriculum (as well as the implications for advantages), and what teachers perceive the advantages for students are, emerged as findings in the study.

The most significant advantage the teachers reported in using a coherent curriculum was helping teachers to know what knowledge, skills, and abilities students should have prior to starting the current content. Furthermore, they reflected on the advantages of a coherent curriculum by asserting that a coherent curriculum provides opportunities for students to gain similar educational experience and knowledge and be on the same page for next grade levels. An additional advantage raised by the teachers is that they believed having a coherent curriculum makes teaching easier. They expressed this as clarifying what content needed to be taught. To them, the major advantage of having a coherent curriculum is that it eases the planning process by providing a framework from which the teacher works. The teachers explained a coherent curriculum is easier to work with because it is results-focused.
Half of the total number of mathematics and science teachers in this study discussed the disadvantages when a coherent curriculum is lacking. These disadvantages fall into two groups. One set of disadvantages identifies the difficulties teachers experience with assessment, and in particular, grading when students are not motivated to perform well. The teacher suggested less coherent curriculum can cause issues in terms of scheduling and equity. The teacher used the term ‘equity’ and that the use refers to workload equity for teachers rather than equitable opportunities to learn for students as is more common in the literature. Another set of disadvantages occurs when problems arise because previous teachers do not have enough structure or did not stick closely to the structure other teachers expect which leads to a lack of coherent instruction.

The teachers highlighted the importance of a coherent curriculum for students to see how each grade and topic are tied together and move toward domain-specific goals. The teachers asserted that an advantage of a coherent curriculum for students is that the curriculum makes sense to them even if they do not have or do not want to develop a ‘big picture’ understanding of the content area. This idea is closely related to concepts about a student-centered purpose for framing the learning. From the majority of teachers’ perspectives, a coherent curriculum helps students to better understand why they are learning the materials and how knowledge is transferable or will become useful to them in the future. The teachers not only emphasized students will be able to better understand why they are learning the materials but also, they reflected on ‘longer retention of knowledge’ and seeing the ‘purpose behind their learning’.

The mathematics teachers and science teachers also discussed different strategies and approaches to implement those strategies in order to make connections between lessons in a week or units across the academic year within the same course and across the grades. The
teachers described the strategies such as relating or ‘tying together’ lessons to make a ‘story’ and using ‘real-life examples’ as strategies to make connections between lessons and units. In addition, they reported using resources such as scenarios, videos, and virtual labs to teach and connect the mathematics and science lessons together in the previous week. Moreover, the teachers used retrospective approaches of reviewing content from previous grades in the current grade, primarily by locating curricular resources for content in previous courses or by creating regular opportunities to ask questions or engage in activities about previous content in order to connect students’ learning in their class to other grades. A finding consistent across the teachers is that their approaches were exclusively about how to connect their current content with previous courses/grades. No teachers discussed strategies that indicated they were looking forward or finding ways to help connect with students’ future learning.

Teacher collaboration is an important characteristic of a coherent curriculum that is highlighted by the teachers’ participants several times. Given this emphasis on the importance of teacher collaboration, a surprising finding was that the science teachers in this study claimed to rarely collaborate and the collaboration between science teachers was limited to a few times per year. Many of the science teachers did have more informal conversations with the same grade teachers, but they rarely had opportunities to meet with the other grade level teachers. The mathematics teachers, on the other hand, asserted more collaboration with the teachers who teach the same course or same grade level and with teachers in other grades. They explained they have several meetings and there are regular discussions between teachers teaching the same course to help with the horizontal alignment. Also, there are opportunities to meet with every teacher across grades in the school, and they look at vertical alignment issues.
The content area difference in collaboration existed across the urban and suburban schools. What seemed to differ between mathematics and science teachers was time to collaborate. The mathematics teachers in the study also reflected on ‘time’ as a barrier for greater collaboration and sharing ideas to allow teachers to do a better job of the alignment within grades and across grade levels. However, the mathematics teachers at the suburban school had a common planning time, which none of the science teachers had. At the rural school, the teachers did not have a common planning time, but they did meet regularly. The science teachers in both schools, in contrast, did not have the same time set aside to develop horizontal and vertical connections.

As noted above, one of the biggest difficulties for the science teacher participants was the unavailability of ‘time’ to collaborate with their colleagues to design a coherent curriculum. In short, the science teachers in the rural school claimed that the biggest difficulty in implementing a coherent curriculum is that they do not have one. The teachers rarely if ever meet with each other to design curriculum. With a full schedule, it is difficult for them to find the time to collaborate in any meaningful way. In the study, the administrators also discussed the challenges/difficulties teachers confront in designing and implementing a coherent curriculum. Interestingly, the administrators also remarked making ‘time’ for collaboration and discussion with colleagues and administrators to receive feedback is a challenge for teachers in designing and implementing a coherent curriculum.

More so, the mathematics and science teachers described the helpful support they need in designing and implementing a more coherent curriculum. The teachers highlighted the importance of having in-service time to collaborate with fellow teachers in order to share ideas and design a coherent curriculum. All of them broadly discussed they need more time to
collaborate with their colleagues and share ideas and resources, to attend in-service training, and to work on creating the goal.

In the study, the administrators also were asked about the support they make available for teachers in designing and implementing a coherent curriculum. There is an alignment between what the teachers want and what the administrators provide. The majority of the administrators expressed that providing enough time, funding for curriculum resources as well as providing Professional Development opportunities are the best supports that could make available for teachers in designing and implementing a coherent curriculum.

The administrator participants in the study also reported on the approaches to evaluate teachers’ use of curriculum. The main ideas that emerged from all of their responses were observations/walkthroughs and students’ mastery or student data as approaches to evaluate teachers’ use of curriculum resources and instruction. The administrators mentioned ‘time’ limitation as an issue for classroom observation and walkthrough to evaluate teachers’ delivery of content. It's unsurprising but still interesting that there is never enough time in schools. Everyone seemingly feels like time limits their ability to do the work. The administrators also expressed limited follow-up with teachers, regular observation, and walkthroughs can lead to a lack of coherent curriculum and create gaps in student learning. Therefore, while the administrators believe coherence is important, they don't have access to the data they would need to support teachers in order to improve a coherent curriculum.

In addition, mathematics and science teachers in this study discussed the amount of autonomy they have for choosing and modifying their curricular resources. Interestingly, all of the teacher participants described their autonomy in choosing their curricular resources and course objectives as ‘full or a lot’. The teachers highlighted having a great deal of autonomy,
allowing them to try new resources and see if they meet student needs or not. Although all participants in this study expressed a wide degree of autonomy in selecting, changing, and incorporating new curricular resources, two science teachers, both from the rural school, described that a lack of funding/resources limited their autonomy to supplement the curriculum (i.e., textbook series) in practice. Furthermore, the teachers in the rural school explicitly expressed that providing funding and curricular resources are important administrative supports for teachers. What was common across the school sites was that despite the large degree of autonomy to choose the resources, teachers still needed to confirm with the curriculum leaders and go through a curriculum review process within and beyond the school.

In the findings, the administrators in both rural and suburban schools also discussed the amount of autonomy teachers have in selecting their curriculum and additional-curricular resources. The administrators agreed with the teachers that teachers in their schools had close to full autonomy for choosing curricular resources, but as was evident in the teacher responses, there were policies and practices for administrative discussion and review of teachers’ curricular decision making that varied across the two school sites.

**Contributions to the Field of Educational Leadership**

This study explored what it means for a curriculum to be coherent in practice, how teachers attempt to make their curriculum coherent, why they believe it is important to do so, and the supports and barriers to teachers’ coherent curriculum design. As Eris and Kilicoglu (2019) state “curriculum development and design are critical for stimulating the effectiveness of education”. A high-quality coherent curriculum creates explicit guidelines for what they should learn and do at each grade level (Adentwi, 2005). Therefore, it is important to support teachers to design and implement the curriculum in coherent ways and understand the challenges teachers
face in implementing a coherent curriculum as well as the support they need from administrators. However, relatively little is known about how practitioners understand coherence or about their strategies for implementing it. Most of the literature is theoretical or examines the degree to which teachers are able to implement a single curricular resources (e.g., a textbook series) with fidelity. This study adds to the literature because it investigated teacher and administrator perceptions of what it means for a curriculum to be coherent and examined the ways teacher and administrator perceptions align with or do not align with theory and empirical research. This study also contributes to the field of educational leadership more generally by centering practitioners by focusing on teachers' voices and drawing more attention to how administrators and policymakers in school districts can support teachers and address teachers’ needs.

This study collected qualitative data from teachers and administrators to respond to the research questions. It was important to speak with both administrators and teachers in order to understand their perceptions of what it means for a curriculum to be coherent. It also was important to get enough information from them to understand if they are using the same words in the same way. What qualitative work gives us is the ability to hear people are not all saying the same things, even when they use the same language from the field. It is clear there are a few places in this study where administrators and teachers use the same language (e.g., autonomy) very differently. For example, the way administrators referred to teacher autonomy was different from how teachers described their own autonomy in selecting curricular resources. The administrators mostly talked about teacher autonomy as making changes and recommendations in curriculum development process. But it is clear that this is not how teachers thought of their
own autonomy. The teachers think they need full autonomy in choosing curricular resources and designing their curriculum.

In another example of this mismatch between the way language was used by the practitioners in this study and in the literature, several teachers talked about ‘alignment’ as standardization across classes instead of vertical alignment or horizontal alignment. Others thought about coherence in terms of alignment to academic standards and understanding logical sequencing across the grade levels.

A third example of unexpected use of language occurred when some of the teachers used the term ‘equity’ to reference workload equity for teachers rather than equitable opportunities to learn for students as is more common in the literature. The teachers had a teacher-centered idea about what equity is and it refers to their job. The teacher's concern was about workload, specifically about having to reteach content that was another's teacher’s job and being responsible for covering their own content and securing student achievement in their own class.

The findings from the study have implications for not only improving teachers’ strategies to make their curriculum coherent but also enriching school administrators’ experience in supporting teachers so that they can better deliver a coherent, student-centered curriculum that responds to all of their voices and needs. According to the findings in this study, there are concrete supports that administrators could make available for teachers in designing and implementing a coherent curriculum. First and most important to the participants, administrators need to find ways to provide additional time for teachers to collaborate and share ideas and resources and to work on creating educational goals. Also, administrators need to provide funding for curriculum resources and support teachers to more autonomously access that
funding, especially when teachers need to do more hands-on experience for students in the middle of the school year.

Moreover, the data indicated that teachers and administrators believed teachers had high levels of autonomy over their curriculum, but there were significant barriers to enacting that autonomy, including school and district policies and procedures that structure curriculum review cycles, difficulty applying for and receiving funding to supplement curriculum in between cycles, and difficulty finding time to collaborate between curriculum cycles.

Science teachers in the rural school believed the lack of physical resources for student experimental experiences creates gaps and inconsistencies in learning between courses, and incoherencies in developing the learning of science as a domain. Therefore, providing sufficient curricular resources when those resources are deemed important for developing coherent trajectories of learning is an important area that administrators should pay attention to in order to enhance curriculum coherence within the content area.

**Implications and Recommendations for the Field of Educational Leadership and Social Justice**

When considering reasons for educational inequities, researchers turn to the curriculum (Giorgio-Doherty et al., 2021). An unfocused curriculum plays an essential role in the learning gap between students from high and low socioeconomic backgrounds (Schmidt et al., 1999; Schmidt et al., 2007; Schmidt et al., 2015; Giorgio-Doherty et al., 2021). However, addressing curriculum gaps is not as simple as identifying an excellent curriculum and mandating its use (Giorgio-Doherty et al., 2021).

In a research study conducted by Giorgio-Doherty et al. (2021) the survey results indicate that students from low-income families faced more inequities during the COVID-19 pandemic.
They looked across schools by the percentage of students eligible for *free or reduced lunch* (FRL) and found that the schools with higher levels of FRL generally faced greater inequities and the opportunity gap between students of low and high socioeconomic status have exacerbated. Further, their research asserted that teachers who work in lower-income school districts have less access to professional learning programs and curricular resources to supplement their curriculum in coherent ways (Giorgio-Doherty et al., 2021). Therefore, policymakers and administrators should provide enough resources and professional learning opportunities for teachers in schools that serve students from less wealthy backgrounds.

Highlighting all of this from a social justice perspective, we can declare that socioeconomic factors could have a strong relationship with student achievements. Also, the student's poor performance could be because of the lack of a coherent curriculum in schools. A curriculum that is vertically and horizontally coherent helps students to experience common knowledge and skills at the same grade. The lack of a coherent curriculum could hold back the learning process, especially for marginalized students who don't have adequate access to educational resources (Hirsch, 2010; Giorgio-Doherty et al., 2021).

As the findings of this study showed the mathematics and science teachers in rural school districts faced some barriers in designing and implementing a coherent curriculum including the lack of curricular resources and access to funding for physical resources to provide experimental experiences for students during the school year to make connections between the lessons and real-life examples for students. Particularly the science teachers asserted that sometimes they could not do experimental practices to connect the lessons to real-life examples because they do not have the required resources or equipment. As an educational leader, I believe that the idea of
learning particularly in sciences is that the students should get more hands-on in authentic education. Because that is the place that improves student learning opportunities.

Another important challenge that teachers mentioned in the rural school was the lack of curricular resources. The teachers mentioned they only received textbooks as the curriculum without any supplemental curriculum. This is obvious that a textbook is not enough for teaching the lessons. Particularly in sciences that means it really restricts what students are able to do in practice the science. Thus, the administrators should provide required curricular resources for teachers to advance student learning opportunities and outcomes.

In this study, the educational leaders and administrators at both school sites agreed that having a coherent curriculum is important. There are some recommendations for educational leaders that can help teachers to resolve the issue at the school sites, particularly in the rural schools. In rural schools, one way that could really help teachers is to reduce school and district policies and procedures that structure curriculum review cycles so that teachers can make suggestions. Also, providing opportunities for teachers to have full autonomy in their curriculum to implement coherent instruction. Another recommendation for educational leaders is to provide individual budgets for teachers in rural schools to buy their required resources and don’t have to go through the big budgeting process to supplement the curriculum for their classrooms. In addition, educational leaders should create common planning time for teachers to collaborate and share ideas and resources with their colleagues, since the teachers did not have that in this study, particularly in science at the rural school.

In terms of equity issues, the teachers believed that there are advantages to having a coherent curriculum. It helps students to understand how grades are tied together and move toward the same outcomes to reduce learning gaps and unnecessary repetition of content. Also, it
makes knowledge more meaningful for students to see the big picture of learning the content. In this study, teachers clearly believed a coherent curriculum is better for student learning, but additional research is needed to examine how coherent implementation affects student learning. Another aspect to investigate could be to examine whether providing more time/budget improves student learning outcomes as teachers believe it would. In addition, research should look to understand what supports would allow teachers to craft a more coherent curriculum beyond additional time to collaborate and budget resources.

All of these factors have important impacts on student learning to improve equitable learning opportunities for students and reduce student achievement gaps. Examining all of the data through the lens of educational leadership and social justice allowed me to analyze the demands and obstacles the teachers experience across the schools and draw conclusions regarding the support they need to design high-quality, coherent instruction.

**Limitations**

The limitations of the study are identified as the following: first, this research study was conducted in the middle of the pandemic which was limited to meeting the teachers and administrators in person at the school buildings. Hence, the interview and focus group discussions were required to be conducted virtually via Zoom to make sure everyone was safe.

Furthermore, this study was conducted during the COVID-19 pandemic when school leaders and teachers were experiencing hard times and challenges in schools. This study first intended to collect data through focus groups and individual semi-structured interviews. The questions were provided in advance for participants to give them time to be prepared. But school personnel reported they were overwhelmed with their work responsibilities during the pandemic and most preferred to participate by sending written responses rather than set aside a block of
time to participate in interviews and focus groups. This had limitations for the depth of the data as well as the amount of data that was collected since I could not ask follow-up questions or probe responses. In addition, I had planned the focus group design to give teachers a chance to talk within content area specialty as a means to further explore differences in how mathematics and science teachers approached increasing coherence. However, the teachers did not have the chance to talk to each other during the focus groups, the data cannot be crossed for deeper results. It is possible that the participants’ preference for answering questions via written responses in their own time was due to the difficulties of teaching during the pandemic but given the repeated focus on time as a barrier for participants in this study, I would suggest future researchers carefully consider whether they will offer the option for written responses. If they do so, care will need to be taken to ensure the questions elicit the richest data possible in that format. Also, it is important to note that the artifacts teachers shared during the interview were not lesson plans. They were mostly the curricular resources they used in a week for their instruction. Therefore, there was a limitation for artifact analysis in order to get rich data.

In addition, this study was conducted at the beginning of the school year when the mathematics and science teachers worked remotely for most of the past year due to the COVID-19 pandemic, and the schools were transitioning back to in-person instruction. Anecdotally, administrators and teachers had a difficult time with the transition and meeting the needs of their students during the return to in-person schooling. These circumstances limited the number of people who participated in my study and the amount of time they were able to spend responding to the open-ended questions and participating in the focus group and interview discussions. Therefore, they were provided with some flexibility to respond to the questions in their own time, if they cannot participate in the focus group and interview discussions.
Also, this school year did not look much like other school years because of the COVID-19 situation. Teachers were moving back to the curriculum they had used in the past that may or may not have worked well in the previous remote year. Disruptions to opportunities to learn likely had impacts on what students knew or knew how to do and were prepared for in their current classes. The salience of this may have resulted in teachers focusing on that alignment across grade levels piece.

Moreover, one of the limitations of this study is that the racial demographics of the teachers are unknown. Also, I don’t know whether the racial demographics of the teachers were matched with the students they were working with. As the teachers discussed ‘equity’ as their workload rather than equitable opportunities to learn for students, it made that more difficult to understand the ways the teachers were using equity. Having this information would have helped to understand the ways teachers were talking about equity and interpretation disconnect.

Lastly, another limitation of this study is the imbalance across the two school sites. This study was conducted in a rural school district and an affluent suburban school district in the eastern U.S. But the participation of teachers and administrators in one district was far more than in another one. Most responses (eight) were received from the rural school district with only four responses from the suburban school.

I recognized the limitations of the small number of cases in this project. All of the factors mentioned above caused a small sample size for the study. My intention was to collect data from 18 participants in both school districts but only 12 people participated in the study. An additional reason could be that I did not have a former relationship with the teacher and administrator participants. Therefore, it limited the number of people who participated in my study.
Implications for Future Leadership Agenda and Growth

Conducting this study needed background knowledge on curriculum design and teacher education to better understand the concept of the research and solve the unforeseen problems that might occur during the research process. For me, as an educator whose educational background is connected to science and mathematics instruction, curriculum development as well as teacher preparation, it was critical to investigate the factors that influence the quality of curriculum coherence and curricular decisions that science and mathematics teachers need to make in diverse curriculum contexts. Considering my passion and motivation along with the capability of working hard in education, I gained valuable experiences in directing curriculum development teams and preparing teachers for productive instruction. When I was an educational director in my home country, Iran, I analyzed the important factors contributing to the effectiveness of the pre-K-12 education system in preparing teachers and students for successful outcomes. In my opinion, to achieve a highly efficient educational system, teachers must be knowledgeable about student development to make the right decisions about designing their curriculum and daily instruction. Also, teachers should be supported with sufficient resources and professional development programs from administrators to implement a coherent curriculum.

Doing my Doctorate degree in the school of education at Duquesne University where is rooted in the idea of social justice, equity, and ethics has inspired me to become an educational leader beyond the classroom. Throughout my time in the Ed.D. program, I engaged with a community of culturally diverse people who were equipped with ethics, intellectual discernment, and the courage to strive for improved social justice and equity in the education system. I am well-schooled in educational policy and politics, community-engaged leadership for social justice, and ethics and educational laws in the United States.
More so, during my doctoral program, I have collaborated on the NSF-funded project entitled "Co-Developing a Curriculum Coherence Toolkit with Teachers” where we collected survey data from 524 elementary (third to fifth grade) mathematics teachers and asked them about curricular resources they used across 46 states, before and during the Covid-19 pandemic, as well as the challenges they faced in working with students during the pandemic. In addition, we have explored the impact of red and blue state policies on curricular decision-making and teachers’ autonomy during the pandemic. As a graduate research assistant, I have taken an active role in designing the survey, collecting data, analyzing data with SPSS, interpreting the data, and writing conference proposals and journal papers to disseminate the findings. Also, I have worked on another project which is funded by the Woodrow Wilson National Fellowship Foundation, where we prepared teachers with backgrounds in the STEM fields: science, technology, engineering, and mathematics for teaching students from underserved communities at under-resourced secondary schools in urban environments. My principal responsibilities were to maintain constant communication with the induction coaches, and work on the research related to Woodrow Wilson Teaching Fellowship residency, mentoring beginning teachers, and induction programs. This includes developing focus group and interview questions, sending consent forms for participants, collecting data from field sites, reporting to the research team as well as building annotated bibliography for writing research papers.

Leveraging my multidisciplinary experiences, I have spent my time as a researcher to solidify my commitment to ways that improve teachers’ curricular decision making, promote teacher preparation for productive instruction and enhance educational equities for students. Through these projects, I acquired excellent expertise in quantitative and qualitative research
methods by developing research instruments, collecting quantitative and qualitative data, analyzing data, and writing conference proposals and research papers.

Last but not least, conducting this study has been a precious experience for me. It built a solid and deep knowledge about teachers’ and administrators’ perceptions of the qualities that make a curriculum coherent, the autonomy and barriers mathematics and science teachers experience in implementing a coherent curriculum, and the ways that administrators act in support of teachers’ curriculum implementation in U.S. schools. Furthermore, through this process, I learned important criteria to develop a scientific study, how to collect and analyze the data, how to solve the unforeseen problems that might occur during the research process and build arguments for supporting my perspectives as a scholar and educational leader. As a result, this research study plays a vital role in growing my thinking and leadership skills.

Regarding my leadership agenda, my future plan is to continue conducting research in the field of curriculum development and instruction as a researcher and higher education faculty to help future educational leaders and teachers to develop a high-quality, coherent curriculum in schools. Moreover, I aim to utilize my learnings and experiences to improve teachers’ curricular decision-making to manage the ever-increasing curricular resources and implement productive instruction in classrooms. My long-term goal is to contribute to the design of the mathematics and science curriculum in coherent ways that help students to build on their previous knowledge, make connections between the contents across grade levels, gain a deeper understanding of content and enhance their retention of knowledge. I believe a coherent curriculum plays a crucial role in the in-depth learning of students and increasing academic achievements.
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Appendix A

Recruitment Letter (Email)

Dear Teachers,

My name is Mona Baniahmadi and I am a doctoral student in Educational Leadership in the School of Education at Duquesne University. I am conducting a research study on what it means for curriculum to be coherent, how teachers use the diverse curricular resources available today in their lesson planning, and how administrators support teachers’ use of curriculum.

I would like to invite you to participate in my research study, which investigates your perceptions about (a) the qualities teachers and administrators believe make curriculum coherent (b) how mathematics and science teachers approach designing and implementing a coherent curriculum, (c) the kinds of curricular decisions that teachers need to make when using diverse curricular resources, and (d) the difficulties or barriers they may face in integrating diverse curricular resources.

Your input is valuable!

Your participation will include a focus group and opportunity to participate in a one-on-one follow up interview. Both the focus group and interview will be scheduled on Zoom at your convenience. If we cannot find a convenient time, I will be happy to send you the questions as a Word document to answer in your own time.

If you are interested in participating in this research study, please reach out to contact me. I will be happy to answer any questions you have about this research study or your rights as a research participant. You may contact me Mona Baniahmadi, 412-499-1038 and baniahmadim@duq.edu. You may also contact my advisor, advisor Dr. Amy M. Olson at 412-396-5712 and olsona@duq.edu. Additionally, you may contact Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board at (412)-396-4032, if you should have any questions about your rights as a research participant.

Thank you for your consideration of this opportunity.

Sincerely,
Mona Baniahmadi
Graduate Student, Department of Educational Foundations and Leadership
Recruitment Letter (Email)

Dear School Administrators,

My name is Mona Baniahmadi and I am a doctoral student in Educational Leadership in the School of Education at Duquesne University. I am conducting a research study on what it means for curriculum to be coherent, how teachers use the diverse curricular resources available today in their lesson planning, and how administrators support teachers’ use of curriculum.

I would like to invite you to participate in my research study, which investigates your perceptions about (a) the qualities teachers and administrators believe make curriculum coherent (b) how mathematics and science teachers approach designing and implementing a coherent curriculum, (c) the kinds of curricular decisions that teachers need to make when using diverse curricular resources, and (d) the difficulties or barriers they may face in integrating diverse curricular resources.

Your input is valuable!

Your participation will include completing a short set of 5 open-ended survey questions. I will email the questions as a Word document so that you can answer them in your own time.

If you are interested in participating in this research study, please reach out to contact me. I will be happy to answer any questions you have about this research study or your rights as a research participant. You may contact me Mona Baniahmadi, 412-499-1038 and baniahmadim@duq.edu. You may also contact my advisor, advisor Dr. Amy M. Olson at 412-396-5712 andolsona@duq.edu. Additionally, you may contact Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board at (412)-396-4032, if you should have any questions about your rights as a research participant.

Thank you for your consideration of this opportunity.

Sincerely,
Mona Baniahmadi
Graduate Student, Department of Educational Foundations and Leadership
Follow up Recruitment Letter (Email)

Dear Teachers,

Thank you for your interest in this study about teachers’ use of curriculum.

Please review the attached consent form. The consent form provides you with detailed information about this study to help you choose whether you want to participate. If you choose to participate, you can sign and return the form electronically.

Once you sign and return the consent form, I will contact you to schedule a focus group and/or individual interview (online by Zoom) to discuss your experiences. I will email you the questions in advance of the scheduled focus groups and interviews.

If you cannot attend or do not wish to attend the focus group, the open-ended questions can be provided to you over email for you to complete in your own time and email back.

Only the transcript or text of your responses will be used for analysis. No identifying information will be kept with the transcript or text.

If you have any questions, please do not hesitate to let me know. If you are ready to participate after reading the attached consent form, please sign and return it.

Thank you for considering participation.
I look forward to hearing from you.

Sincerely,
Mona Baniahmadi
Doctoral Student, Department of Educational Foundations and Leadership
Dear School Administrators,

Thank you for your interest in this study about teachers’ use of curriculum.

Please review the attached consent form. The consent form provides you with detailed information about this study to help you choose whether you want to participate. If you choose to participate, you can sign and return the form electronically.

Once you sign and return the consent form, I will send you the open-ended survey questions to response on your own time and email back.

Only the text of your responses will be used for analysis. No identifying information will be kept with the text.

If you have any questions, please do not hesitate to let me know. If you are ready to participate after reading the attached consent form, please sign and return it.

Thank you for considering participation.
I look forward to hearing from you.

Sincerely,

Mona Baniahmadi
Doctoral Student, Department of Educational Foundations and Leadership
Appendix B

Consent Form

DUQUESNE UNIVERSITY
600 FORBES AVENUE ♦ PITTSBURGH, PA 15282

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE:
What Does It Mean to Be Coherent?
Mathematics and Science Teachers Consider Coherency in Curriculum Decision Making

INVESTIGATOR:
Mona Baniahmadi
Doctoral Student, Educational Leadership
412-499-1038
Baniahmadim@duq.edu

ADVISOR:
Amy M. Olson, Ph.D.
Associate Professor, Department of Educational Foundations & Leadership
School of Education, Duquesne University
101C, Canzine Hall
Pittsburgh, PA
412-396-5712
olsona@duq.edu

SOURCE OF SUPPORT:
This study is being performed as partial fulfillment of the requirements for the doctoral degree in the School of Education at Duquesne University.

STUDY OVERVIEW:
Most existing research examines how teachers use a single curricular resource (e.g., a textbook) to plan their lessons. This study is significant because it explores how teachers today use diverse curricular resources. You are being asked to participate in this study because you have been identified as an effective mathematics or science teacher or administrator working in a Pittsburgh area public school. Your experiences could be valuable in assisting others in being more effective.

PURPOSE:
You are being asked to participate in a research project that is investigating (a) the qualities teachers and administrators believe make curriculum coherent (b) how mathematics and science teachers approach designing and implementing a coherent curriculum, (c) the kinds of curricular decisions that teachers need to make when using diverse curricular resources, and (d) the difficulties or barriers they may face in integrating diverse curricular resources.

In order to qualify for participation, you must be:
- An adult (age 18 or older).
- An active administrator, mathematics or science teacher
- Serving in Pittsburgh area public schools

PARTICIPANT PROCEDURES:

If you are a teacher and provide your consent to participate, you will be asked to participate in:
- one focus group of no more than 90 minutes with other teachers in your content area (i.e., mathematics or science) to discuss your ideas about curriculum coherence. Focus groups will be held via Zoom. Zoom sessions will be recorded to the Cloud, but only the automatically generated text transcripts will be used for focus group analysis. Video and audio recordings will not be downloaded from the Cloud. You may leave your video off when joining the Zoom meeting. You will be asked to use a pseudonym as your Zoom name to further protect your identity in the transcripts.

If you cannot attend or do not wish to attend the focus group, the open-ended questions can be provided to you over email for you to complete in your own time and email back. As with Zoom transcripts, only the text of your responses will be used for analysis. No identifying information will be kept with the text.

Teachers will also be asked to participate in one interview of no more than 30 minutes via Zoom. You can choose not to participate in this interview even if you have chosen to participate in the focus group or email questions. The purpose of this interview is for teachers to be able to share with the researcher their curricular materials and talk through their decision-making and lesson planning process. Like the focus group, the automatically generated text transcripts will be used for analysis. Video and audio recordings will not be downloaded from the Cloud. You may leave your video off when joining the Zoom meeting. You will be asked to use a pseudonym as your Zoom name to further protect your identity in the transcripts. In addition, you may choose to share documents with the researcher (e.g., lesson plans and materials). Any identifying information (e.g., teacher name, school) will be removed from documents prior to analysis.

The researcher will utilize a member checking process, which will give you the opportunity to confirm accuracy of focus groups and interview transcripts and interpretations, ensure your voice and experiences are accurately represented in the findings, and provide additive data that you feel may inform revisions. This will be done through email correspondence and Zoom meetings as needed. Your preference and availability for times and modes of communication will be a top consideration.

If you are an administrator, and provide your consent to participate, you will be provided five of open-ended survey questions over email for you to complete in your own time and email back.
Only the text of your responses will be used for analysis. No identifying information will be kept with the text.

**RISKS AND BENEFITS:**

There are minimal risks associated with participating in this study, but no greater than those encountered in everyday life. The benefits of participating in this study may include better understanding of the qualities of coherent curriculum and improving curricular decisions that teachers need to make when using diverse curricular resources.

**COMPENSATION:**

There will be no compensation for participating in this study. There is no cost for you to participate in this research project.

**CONFIDENTIALITY:**

Your participation in this study, and any identifiable personal information you provide, will be kept confidential to every extent possible, but the researcher cannot guarantee that other focus group participants will not recognize you or repeat a story you tell. In order to protect your confidentiality, you will be asked to choose a pseudonym for participation in Zoom and your name will never appear in any transcripts used for analysis. The researcher will not keep records connecting your name with the pseudonym you choose. Audio and video recordings will not be downloaded from Zoom and will be deleted after automatic transcription is complete. All written and electronic forms and study materials will be kept secure. All transcripts will be maintained on a password protected computer. Any written notes generated from the coding process will be kept in a locked filing cabinet. In addition, any publications or presentations about this research will only use data that is combined together with all subjects; therefore, no one will be able to determine how you responded. All files, written and electronic, will be destroyed three years after the data collection is completed.

**RIGHT TO WITHDRAW:**

You are under no obligation to start or continue this study. You can withdraw at any time without penalty or consequence by notifying the researcher by email (baniahmadim@duq.edu) that you do not want to continue. Due to the commitment to participant confidentiality, the researcher will only be able to destroy your transcripts if you provide the pseudonym you used.

**SUMMARY OF RESULTS:**

A summary of the results of this study will be provided to at no cost. You may request this summary by contacting the researcher via email. The information provided to you will not be your individual responses, but rather a summary of what was discovered during the research project as a whole.

**FUTURE USE OF DATA:**
Any information collected that can identify you will not be used for future research studies, nor will it be provided to other researchers.

COVID-19 CONSIDERATIONS:

I understand that the researcher running this study have put in place the following guidelines to address concerns related to COVID-19:

● All data collection will happen remotely using Zoom and/or email.

VOLUNTARY Consent:
I have read this informed consent form and understand what is being requested of me. I also understand that my participation is voluntary and that I am free to withdraw at any time, for any reason without any consequences. Based on this, I certify I am willing to participate in this research project.
I understand that if I have any questions about my participation in this study, I may contact Mona Baniahmadi, 412-499-1038, baniahmadim@duq.edu and advisor Dr. Amy M. Olson, olsona@duq.edu. If I have any questions regarding my rights and protections as a subject in this study, I can contact Dr. David Delmonico, Chair of the Duquesne University Institutional Review Board for the Protection of Human Subjects at 412.396.1886 or at irb@duq.edu.

_________________________                                  __________________
Participant’s Signature                                                                                 Date

_________________________                                  __________________
Researcher’s Signature                                                                                Date

Contact Information Form

Last Name
First Name
Phone Number
Email Address
Preferred Time(s) to Contact for Interview or/and Focus Group
Appendix C

Artifact

This artifact shared by Ted (Mathematics teacher) at the rural school during the interview.

This week in physics I did a lab on a CSI scenario where students had to take data from a crime scene to determine the culprit. I had 2 scenarios, one in which there was a gangster convention, and someone was shot in the shoulder. Based upon the entry wound location, the bullets placed in the wall on the other side of the room, and the distance between the location of where the victim was standing to where the bullet entered the wall, they calculated the velocity of the bullet. With that there were 4 guns in the room and only one of them could have been the one used. I had posters of the scenario, meter sticks, tape measures. I used a physics teacher article that had this idea and made up the scenario to fit my classroom. I bought posters from vista print of the crime scene.

In CHS physics we are finding the center of mass in objects. We used general observational techniques of placing our fingers where different two-dimensional objects balance. We used algebra techniques to solve an equation dealing with adding up the position times the mass of objects that are comprised of shapes put together then dividing by the total mass to find the center of mass. We then moved on to geometry techniques of finding an object which is made up of various shapes (different size rectangles, triangles, etc. that are all together to make a shape (like a house). Find the area of different shapes times the center of mass of each shape then divides by the total area. Find the center of mass at a point (x, y) of the shape. I then had a physical cut out of the shape that they verified the location of the center of mass by balancing at the calculated point. Finally, we used calculus techniques of integration to find the center of mass. I again had them verify the answers. I had the technology department use a cnc router to create the physical object that we calculated by area. I used graph paper copied on heavy cardstock to have them cut other shapes.

I used a YouTube video explanation https://www.youtube.com/watch?v=Es8euE8XR1Y and https://www.youtube.com/watch?v=SWDDj0opQcw where I stopped it along the way and had them figure out the calculations then verified.

In AP Calculus we solved related rates problems to apply the chain rule and implicit differentiation. They worked together in groups to do application problems and app problems on the subject. I used worksheets from various internet sources that I cut and pasted into multiple worksheets. Some from previously released app questions, some from our book, some from other worksheets found online. They had to use previous geometry formulas dealing with all sorts of different volume, area, Pythagorean theorem, etc. to set up the equation and known values and then take the derivative of the equation with respect to time to find unknown values.
Appendix D

Artifact

This artifact shared by John (Science teacher) at the rural school during the interview.

Over the last week and a half, we have been discussing homeostasis. We covered cellular transport and how materials move in and out of cells. The students completed a virtual lab using the link below.


This virtual lab helped the students solidify their understanding of cell transport. We then used that to discuss the effects of dehydration on the body. The goal is to take these abstract ideas of cell transport and explain how they affect the student every day.

<table>
<thead>
<tr>
<th>Cell Homeostasis Virtual Lab - Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Homeostasis Virtual Lab What happens to a cell when it is in different environments?</td>
</tr>
<tr>
<td>video.esc4.net</td>
</tr>
</tbody>
</table>
Appendix E

Artifact

This artifact shared by Robert (Mathematics teacher) at the rural school during the interview.

Last week, my Algebra classes focused on solving and graphing inequalities and compound inequalities. We typically work on a warm-up link from a website called “Quizziz.com”. This program allows teachers to create quizzes, tests and practice problems and the students can complete them on their computer. I find it to be a valuable resource because I can change, edit and add as many questions as I want. We also use worksheets a lot in my classroom for practice.

Another resource that we used last week was the “IXL.com” program. It’s another online program where the students can practice various skills and topics in any type of math course. I use Quizziz and IXL frequently, along with a built curriculum guide to help plan for my future lessons.
Appendix F

Artifact

This artifact shared by Ted (Mathematics teacher) at the rural school during the interview.

I often review material from previous years and then apply it to the new situation. For instance, in calculus we last week took the derivative of a logarithm. I first went back to explain that a logarithm is really an exponent. So, the laws of logarithms follow exponent rules in algebra. I also show that the exponent rules in algebra follow the order of operations that they learned earlier in math.

Parentheses
Exponents
Multiply or Divide
Add or Subtract

Below exponents is multiply so when you have exponents, a power to a power you multiply Like $(x^3)^2 = x^6$.

Below multiplication is addition so when you multiply you add the exponents like $(x^4) (x^3) = x^{12}$. Multiplication means repeated addition.

Below division is subtraction so when you divide you subtract the exponents like $(x^6) (x^3) = x^3$ division means repeated subtraction.

Then the laws of logarithms follow the rules of exponents.

$log A + log B = log AB$

$log A - log B = log A/B$

$log A^n = n log A$

I pull resources from the internet of previous learned concepts. I then use AP resources to help with the present calculus problems.

In physics I use several interactives from physics classroom and other sites to either tie the lesson together or establish the pattern that leads to the rules of physics.

https://www.physicsclassroom.com/Physics-Interactives
https://phet.colorado.edu/
https://ophysics.com/
https://interactives.ck12.org/simulations/physics.html