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Non-Traditional Learning in STEM: How Students Autonomy and the Impact of Teacher Delivery Develops Deeper Conceptual Understanding at the Middle School Level

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**Non-Traditional Learning in STEM: How Students Autonomy and the
Impact of Teacher Delivery Develops Deeper Conceptual Understanding
at the Middle School Level**

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of Doctor of Education

Sarah Kelly

University of Northern Iowa

December 2023

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Abstract

Keywords- Inquiry Based Education (inquiry-based instruction), Universal Design for Learning, Student Voice and Choice, Teacher Preparation and Professional Development add student autonomy

Non-traditional forms of curriculum development and delivery have shown particular promise in supporting the autonomy of students particularly in relation to science. Programs such as OPENSIED are inquiry based- learning that promotes problem solving skills and cross curricular development supported by the Next Generation Science Standards (NGSS). This mixed method research study sought to illuminate how these types of curricular programs influence student autonomy and learning, especially with the implementation of OpenSciEd within Des Moines Public Schools. The study utilizes student state testing (ISASP) data alongside teacher surveys, interviews and observations to investigate the strengths or potential deficits of inquiry based science education, alongside the curriculum adoption. The purpose of the study is to align current teaching practices using the inquiry-based science curriculum to be reflected in potential growth in student testing data as DMPS fully adopts OpenSciEd. The results will serve as a catalyst within the district to bridge a curricular action that is already occurring at the elementary level and better prepare students for high school, college, and career.

This Study by: Sarah Kelly

Entitled: Non-Traditional Learning in STEM: How Students Autonomy and the Impact of
Teacher Delivery Develops Deeper Conceptual Understanding at the Middle School
Level

has been approved as meeting the dissertation requirements for the
Degree of Doctor of Education

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Chapter 1: Introduction

Access to grade-level, engaging, affirming and meaningful curriculum and instruction is the bedrock of equity-based teaching and learning, and serves as a catalyst for expecting and inspiring brilliance in our young learners. – Matt Smith, Interim Superintendent, Des Moines Public Schools

Choosing and moving into a new curriculum can be a challenging time for any school district. Understanding the nuances and goals of the curriculum often brings about fear or trepidation amongst veteran staff members and new to the profession teachers alike. In the 2021-2022 school year Des Moines Public Schools (DMPS), under new science leadership, decided to push forward with the implementation of the OpenSciEd curriculum to bring a consensus to secondary classrooms. Previously, DMPS adopted the FOSS series for the elementary level, however at the secondary level a curriculum had not been adopted for years and the result was multiple teachers developing their own curriculum and resulting in a vast difference between inquiry-based education and rote text or classic forms of education. At first, schools were given “heavily suggested” use of particular units by our curriculum coordinator teams, while others were in true pilot mode to move forward. The problem of practice I intend to address is the use of inquiry based science education as a base for not only preparing students for college and career but to also address the DMPS board goals in a cross curricular manner. The purpose of this study is to:

- Determine the strengths and weaknesses in the proposed adopted curriculum as evidenced in the student testing data and teacher overview data
- Determine next steps for the adoption of the curriculum

- Develop goals for implementation and data tracking during the adoption process

Des Moines Public Schools (no pseudonym used with district permission) is the largest public school district in the state of Iowa serving approximately 35,000 students. Over the past several years, the district has striven to become “the model of urban education”. With that during the 2018-2019 school year, the sitting school board held sessions to engage the community in developing our board goals and guardrails to help achieve that goal. In Figure 1 below are the board goals as listed by the DMPS school board. These are meant to illustrate the proficiency goals developed by the district as well as provide a starting point for data analysis when determining growth of student achievement or goal needs.

Figure 1

District Board goals provided by DMPS (Board Goals and Guardrails, 2022)

<p>EARLY LITERACY</p> <ul style="list-style-type: none"> • Goal 1: The percent of all third grade students on track in reading will increase from 52% in June 2019 to 72% by June 2024, as measured by FAST. • Goal 2: The percent of black male third grade students on track in reading will increase from 35% in June 2019 to 72% by June 2023, as measured by FAST. <p>ALGEBRA</p> <ul style="list-style-type: none"> • Goal 3: The percent of black male students earning a ‘B’ or higher in Algebra 1 by the end of 9th grade will increase from 17% in August 2019 to 35% by August 2024. <p>GUARDRAILS</p> <ol style="list-style-type: none"> 1. The Superintendent shall not allow the continuation of systemic racism or inequitable treatment of students. 2. The Superintendent shall not allow the social emotional learning needs of marginalized students to be unaddressed. 3. The Superintendent shall not allow the composition of the teaching and learning staff to diverge, regarding demographics and cultural responsiveness, from the student population. 4. The Superintendent shall not allow an environment for both students and staff that is unsafe and unwelcome.
--

DMPS Board Goals and Guardrails

Though the board goals do not list science specifically, the purpose of inquiry-based teaching is to aid in cross curricular connection, ultimately providing strengthening of skills in the listed core subjects such as math and reading. Science education is a key component of the district overall goal as we have not had a prescribed curriculum at the secondary level for several years. Teachers were developing materials and consistency was not a strength of this development. Not only is science education a focus in the largest urban district in Iowa, but it is also a focus across the nation. STEM education

has become a secondary initiative to Language Arts and Conceptual Math in the K-12 system of the United States- “For too long, literacy has been a bully and pushed science and social studies off of the stage,” Pearson said in his final comments. “Literacy should be a buddy, not a bully, for science and social studies.” (ILA, 2019). Because of this, funding is removed from this field and often, students in elementary levels do not receive any minutes of science education (Personal Communication, 2021). This is evidenced in DMPS. For those that focus on a cross curricular education and well-rounded student, teachers are often left ill-equipped to teach in depth concepts outside of the traditional approach of lecture, textbook and predetermined lab structures they learned in their teacher preparation work (Jarvis, 2016). Well-rounded students are often considered those who can matriculate through multiple grades and core courses and have the experiences to learn and move through the levels of learning. Students should have the experiences, but also the content. Inquiry based learning allows for this connection to be more easily formed in the development of the goal student.

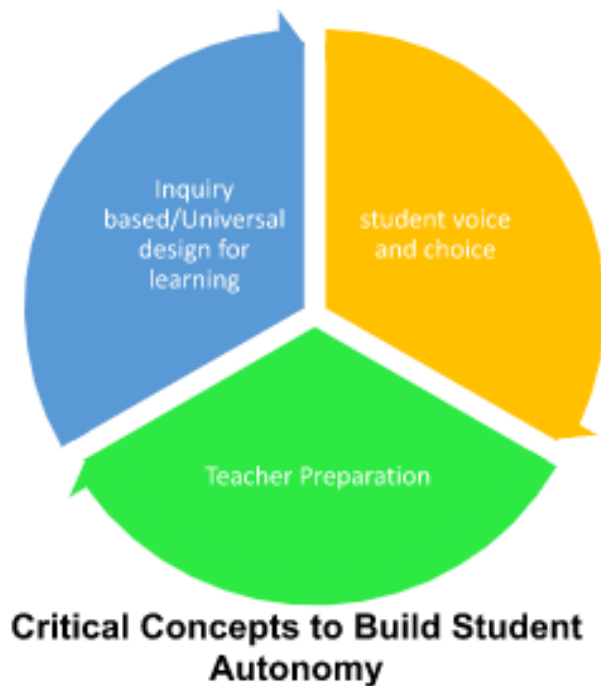
Educators in the K-12 system are often exposed to narrow strategies for teaching science in their teacher preparation program and in teacher professional development. There has been progress in several colleges and universities to move away from this practice, creating another mix of students who are taught using inquiry-based education in their teacher prep program but not allowed to use that practice in the classroom. Conservative, narrow strategies include rote memorization, lecture with notes and traditional assignments such as essays and formatted lab reports. However, students in today’s education system receive more constructivist and transactional education in other core subjects. This leads to two problems: 1) students cannot connect to the material and

only learn it to master a test, and 2) students cannot build on their learning and connect to other core subjects. In core subjects such as Literacy and Social Sciences, students are taught multimodal strategies, but in the general sciences the conservative approach of formal written reports remains in the predominance (Osborne, 2014).

By transferring the constructivist and transactional approach into the science or STEM classroom, and building student autonomy, students will be able to build a stronger conceptual framework (OpenSciEd, 2022). Building this stronger conceptual framework and capacity as a learner not only leads to a deeper understanding of the curriculum, but also addresses the learner in their personal learning style. While doing this, building student autonomy is integral in the concept of building student capacity as learners. Creating this autonomy fortifies the relationship between student and the curriculum as they develop the pathways to a deeper understanding (IBO, 2023). Figure 2 below illustrates the three key components or critical concepts in developing student autonomy.

Figure 2

Critical concepts to build student autonomy



With this current situation in mind, this mixed methods research study is designed to investigate not only the treatment of the inquiry-based curriculum, but also the teacher perceptions, preparation and comfort with teaching this type of curriculum. When approaching this problem, the route to solutions can be found in these research questions:

1. Is there growth in student achievement for teachers who create classrooms focused on inquiry-based universal design for learning compared to the traditional method of instruction?
2. How can a shift in teaching practice from a traditional approach to a focus on inquiry-based universal design for learning impact student autonomy and conceptual learning?

3. How does teacher education and professional development impact teacher practices and the opportunities they create for students to learn science?

Significance of the Research

With this study based in improvement science the goal is to determine overall health of the curriculum adoption as well as next steps or amendments needed for the adoption. Not only will this information and research be shared with the district as a whole, but this will also be a starting point for the science department to determine next steps for teachers and students. The adoption of a high-quality science curriculum is paramount to the work of the district and its equity in education to all students.

Positionality

Personally, this pathway to learning is something that I wish had been prevalent in my early educational setting. Many times, especially in rural Tennessee, the conservative teacher was prevalent. The traditional model was following a workbook or what we now think of as a “cookbook” of teaching. In my practice of teaching, I have discovered so many further in-depth learning moments using the inquiry process. Had I had this option as a student perhaps I would have found even more passion in a certain area of science. I found my early years, in rural Tennessee, to be bound with work books and completely disengaging. I was always in trouble talking to students, because I was bored. I started to hate school about 4th grade, and then I was fortunate enough to be accepted to an arts school where not only the arts were prevalent, but most subjects were inquiry based. I fell in love with school all over again. 8th grade came, and I was lucky enough to have a teacher by the name of Mr. Ellenbogen. Mr. E, as we called him, reengaged the troubled teens and made us love learning again, and never once instructed from a workbook. Even

in his language arts class, we found inquiry. We found a passion for diving into different literature that we had been missing. Moving into high school, I was lucky enough to have many more amazing teachers who followed an inquiry path and brought me full circle from hating school to loving every minute of the day. By developing my student autonomy and helping to build those important cross curricular connections I was able to understand, and problem solve far more than I would have by reading from a textbook. Those teachers gave me a say in the division of my learning.

My personal connection to this work is the driving force behind it. I see the structure of the classrooms that I partner with, and on the opposite spectrum, my classroom. I also see the learning gaps, the student engagement, and the passion for learning from the different classrooms and the difference is staggering. When I first started teaching, I thought of being the teacher that I needed when I was in school and tried to model myself after that passion. Changes have happened, and with programs like Trinect, I have been able to develop a strong IBSE classroom and build stronger relationships with students at the same time. During this time, I have also been provided the opportunity to mentor other teachers and lead district learning communities to help strengthen these skills.

Preview of the Study

This study focused on the ISASP (Iowa State Assessment of Student Progress) scores of the 8th grade students in the year 21-22. This student body was selected as, due to Covid-19, they were the only recent student body to have taken both the 5th grade and 8th grade science portion of the test (at this time, science is only taken in 5th and 8th grade). There were three dynamic intervention groups - 2 or more years of pilot work, 1

year of pilot work, 0 or limited pilot work. Within the groups there were four buildings in the first two groupings and three in the final. These pilot groups were selected based on teacher willingness to pilot the new curriculum and not assigned by the district. The ISASP scores were analyzed to determine growth in science as well as math. Math scores were only reviewed for 5th, 7th and 8th grade, during the 6th grade year ISASP was not completed due to the closing of schools during the start of the Covid-19 pandemic.

In the fall of 2022, the middle school science teachers were provided a survey link to respond openly. From that survey, teachers could volunteer for an interview and classroom observation. Twenty-three of the thirty-nine science teachers responded to the survey and three volunteered for the interview and observation. These responses were analyzed for thematic connections and correlation to the outcomes in the ISASP scores.

Limitations

There are several limitations to the study, notably the small sample size of teachers interviewed and observed as well as the limited number responding to the survey. The limitation of being in one district is also a variable to consider if this were to be a statewide observation, however since the study is based in the singular district and their adoption process the outcome should not be nullified due to this constraint.

Similarly, regarding the student ISASP scores there is a year of data missing due to the Covid-19 pandemic. Students were also potentially hybrid or fully virtual during their 7th grade year. This could present a learning deficit or need to mitigate behaviorally, however for the purpose of this study it was noted however not a cause for exclusion as this was a worldwide issue across schools.

Another potential limitation is the recent turnover of teachers, specifically from middle school. At the end of the 21-22 school year there was an extremely high turnover rate within the district- both from general attrition and retirements. This resulted in the survey potentially going to new to profession teachers and new to content or grade level teachers. This was not exclusionary as these teachers would have provided at least 75% of one semester of teaching the curriculum and be able to include their opinions on the positives and growth areas needed.

Another limitation of the quantitative portion of this study was that statistical methods were used that assume independent observations among participants in the sample. It ignores the fact that students are nested within classrooms, and can lead to an incorrect conclusion in the hypothesis testing process. Unfortunately, the school district was unable to provide generic classroom or teacher level data for this project and so the analyses do not account for the nesting of students within classrooms. However, in supplementary analyses, I examine the differences in achievement and proficiency in other subject areas such as math and ELA among the intervention groups to help provide additional evidence supporting the findings in science.

The root of this study is a single district implementation, however the possibility of the state of Iowa adopting this curriculum as preferred curriculum is also ever present. DMPS, being the state of Iowa's largest public school district, and the adoption process of the curriculum can help inform other districts. In the following chapters I will present and review relevant literature, present the study methodology, discuss the results or findings and offer recommendations based on those findings.

Summary

Though the questions and study design were modeled to determine the next steps in adoption of OpenSciEd, the impact of this study could be far reaching. The state of Iowa will be adopting this curriculum as the recommended curriculum soon, and other districts within the state could benefit from this information. My personal drive for the love of learning in science and equity to access of information is one of the main reasons that drove my personal interest in this work and the process of the adoption. When looking at the limitations of the study, there were several restrictions placed on the research by the Covid-19 pandemic. This limited the grade level selection to one year of 8th graders. Though this does limit the data, it does not negate its importance. In the following chapters there will be a literature review of materials and scholarly works that connect to the purpose and structure of OpenSciEd. Chapter 3 will also present the research methodology and structure. In chapter 4, a full review of the data and outcomes as related to the research questions can be found and the final discussions found in chapter 5.

Chapter 2: Literature Review

Scientific principles and laws do not lie on the surface of nature. They are hidden and must be wrestled from nature by an active and elaborate technique of inquiry. - John Dewey (1956)

Introduction

Inquiry in science learning is at the center of this study. This study examines the impact on student learning when a teacher moves to a constructivist, transactional approach to learning. In this approach, learning happens with transactions or interactions between people and processes (Ulich, 1999). Alongside that, constructivist learning theory presented by Piaget and Vygotsky posits that students build on prior knowledge and develop their skills based on schema and that learning is an active instead of a passive process (Ulich, 1999). Conversely, conservative approaches to teaching are the rote memorization of facts and processing by lecture and book.

The idea shared by Dewey in the opening quote for this chapter, the concept of wrestling from nature as a means of unlocking inquiry, is central to understanding the theoretical foundation for this research study and the purposeful decision making of the school district to align curriculum with a constructivist, transactional approach to learning. Chapter One provided information regarding the decisions and processes within Des Moines Public Schools (DMPS). Those guiding factors also envelop several sections within the literature review. As DMPS aligns their goals to developing a model for urban education, there are systems and processes such as MTSS, inquiry-based learning, social justice in learning, and universal design for learning that are integral to the work within the district. This work led DMPS to pilot OpenSciEd and provide a high quality curriculum for science courses at all levels, after previously adopting Illustrative Math and Education Language (EL) curriculums for other core coursework that are also

inquiry-based in nature. Within the guidance of DMPS, these sections needed to be included, however I found that more connection could be found within the data around our Multilingual students and how inquiry works specifically in a middle school setting. In the following chapter, I will review major themes in the current literature on the need for inquiry-based learning, as well as some classical views from Dewey and his colleagues that inform the theoretical framework for this research study. Additionally, I will provide definitions of key terms while also describing the constructivist approach that brings together a universal design for learning. Constructivist and transnational theory are broader terms creating an umbrella for the Universal Design for Learning (UDL) and Inquiry Based Science Education (IBSE) learning structures that are being studied. The constructivist approach in this study will be referred to as inquiry-based science education or IBSE. The roots of this approach are constructivist and transactional in their origin.

John Dewey

John Dewey is well-known in education as an American philosopher and educational reformer. Dewey believes that education should be student-centered and students should be actively engaged. This theory was foundational in the work leading to our IBSE curricula. One of his leading arguments is that education should not be passive in its form and instead should be actively engaging our students, reviewed in a modern light by Laing and McDermott (Laing, 1933) (McDermott, 1973).

Typically associated with the practice of pragmatism, helping to align with the solving of real-world problems. Dewey was also consistently trying to bridge the gap between theory and practice with his influential works “The Reflex Arc Concept in

Psychology” (1896) and “The School and Society” (1956), which helped lay the foundation for his progressive ideas.

Dewey is also known as being transformative in educational practices. In his book "Democracy and Education" (1916) he laid out his vision of education as a means of social progress (Dewey, 1916/2010). This being the central focus of the current study led to Dewey and his theories being the theoretical foundation of the research.

In "Child and Curriculum," (1902) Dewey moves into the individual relationships with children. This imperative connection also helped to develop social and emotional learning within systems like our MTSS protocol. This work helped connect the education practices and move to student-centered and experiential learning practices within the K-12 system (Dewey, 1956).

One of Dewey’s arguments is that education is not one size fits all, and instead, it should be tailored to meet the needs of the individual student. Through progressive education design, Dewey helped develop a model that would eventually return thoughtful and informed citizens through hands-on learning and individual growth.

Dewey's ideas about learning, and education have been widely discussed and debated in the educational research literature. One of his most influential contributions to the field of education is the emphasis on experience and the role that it plays in the development of students (Dewey, 1930; Feldman, 1934). Dewey believed that a student's experience in the classroom should be intertwined with life at home. Education should be a building block instead of an extra task to complete simply.

Dewey's ideas about learning have been widely adopted in many classrooms and have had a significant impact on the development of progressive education and inquiry-

based learning. Contemporary studies have made strong correlations to the work of Dewey by emphasizing the development of the student as a whole and focusing on their learning (Dewey, 1930; Feldman, 1934). Building upon Dewey's progressive education and inquiry-based learning approach, NGSS or the Next Generation Science Standards began to set the stage for educators to move into this desired state.

Next-Generation Science Standards- NGSS

The adoption of the Next-Generation Science Standards (NGSS) has brought about a drastic change in the format and structure of a traditional science classroom. Within the NGSS, students focus on three-dimensional learning, alongside the performance expectations, which can provide a drastic shift in preparation for teachers and expectations of outcomes for students (Like et al., 2019). NGSS requires a driving question alongside anchoring phenomena and lesson-based phenomena (National Research Council, 2012). This structure is also designed with performance expectations instead of learning targets. Performance expectations are centered around developing scientific skills and knowledge- applying data, designing a model, analyzing results, etc.- This contrasts target item descriptors in previous structures.

The Next Generation Science Standards (2013) noted the following:

Every NGSS standard has three dimensions: disciplinary core ideas (DCIs) (content), science and engineering practices (SEPs), and crosscutting concepts (CCs). Currently, most state and district standards express these dimensions as separate entities, leading to their separation in both instruction and assessment. The integration of rigorous content and application reflects how science and engineering are practiced in the real world.

The Next Generation Science Standards (NGSS) are a comprehensive set of science education standards for K-12 education in the United States, developed by a partnership of states, national science organizations, and experts in science education (National Research Council et al., 2015). The NGSS aims to provide students with a coherent and comprehensive understanding of science, emphasizing scientific and engineering practices, crosscutting concepts, and core ideas in physical sciences, life sciences, earth and space sciences, and engineering, technology, and the applications of science.

Reviews of the NGSS have shown that the standards have been well-received by science educators and adopted by many states across the US. The standards have been praised for their coherence, rigor, and focus on scientific practices and inquiry-based learning (National Research Council et al., 2015).

Research has also shown that the implementation of NGSS in classrooms has the potential to improve students' understanding and engagement in science. Teachers have reported that the standards provide a clear and meaningful framework for planning and teaching science lessons. Focusing on scientific practices and inquiry-based learning has led to more student-centered and hands-on learning experiences (National Research Council et al., 2015).

However, implementing NGSS has also posed challenges for some teachers, particularly those who lack prior experience or training in science teaching. The shift to a more inquiry-based approach to science education requires a significant change in instructional practices, and many teachers have reported needing additional support (IE: Paraprofessional assistance, physical items, reading at the student-appropriate level, and

connection to the real world to drive the learning) and professional development to implement NGSS in their classrooms effectively.

The development of the Next Generation Science Standards (NGSS) was a collaborative effort led by a partnership of 26 states, national science organizations, and science education experts. The process was guided by several key principles, including a focus on integrating scientific and engineering practices, crosscutting concepts, and core ideas in science. The following is a summary of the critical steps in the development of the NGSS (National Research Council et al., 2015):

1. Convening of stakeholders: The development of the NGSS began with the convening of a broad group of stakeholders, including educators, scientists, and science education experts, to determine the key principles and goals of the standards.
2. Review of existing standards: The development team conducted a comprehensive review of existing science standards in the United States and around the world to inform the development of the NGSS.
3. Development of draft standards: Based on the review of existing standards and the input from stakeholders, the development team created a draft set of standards for each of the four science domains: physical sciences, life sciences, earth and space sciences, and engineering, technology, and the applications of science.
4. Public review and comment: The draft standards were made available for public review and comment, allowing educators, scientists, and other stakeholders to provide feedback on the content and format of the standards.

5. Revision of standards: Based on the feedback received during the public review process, the development team revised the standards to ensure that they were comprehensive, coherent, and aligned with the goals and principles established at the outset of the development process.

6: Adoption and implementation: The final NGSS was adopted by states and territories across the United States, and efforts have been underway to support the implementation of the standards in classrooms and schools.

The development of the NGSS was a rigorous and transparent process that involved input from a broad range of stakeholders and a comprehensive review of existing science standards. The result is a set of science education standards representing a significant advance in science education in the United States.

Universal Design for Learning - UDL

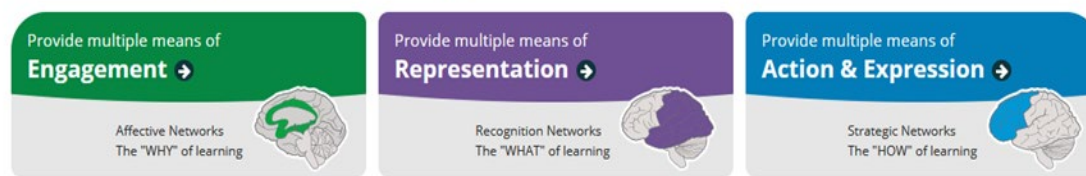
Inquiry-based universal design for learning, providing student voice and choice, and teacher preparation all work simultaneously to foster students' autonomy. By first, and continually, providing quality instruction and teacher preparation, teachers can then in turn create classroom procedures, concepts, and understandings based on inquiry and ultimately result in student voice and choice (Stefanou et al., 2004). Ultimately, if one of these is removed, the autonomy would not be present to fully build the conceptual understanding of the core subject that is needed. A strength of this theory is that it fully supports the inquiry process, which is integral in sciences (Burbules & Berk, 1999). However, most only find the connection to inquiry-based instruction in the sciences, when this could be applied to all core and extended core courses.

“The UDL framework emphasizes the importance of building expert learners in any context. Learning and expertise are not static. They are continuous processes that involve practice, adjustment, and refinement. CAST, formerly known as the Center for Applied Special Technology, defines expert learners as purposeful and motivated, resourceful, knowledgeable, and strategic and goal-directed.” (CAST, 2020b) Defining the expert learner is also integral in building student capacity. Defining student engagement, how they represent their learning and their expression as a learner inevitably will lead to a robust conceptual understanding of their learning (Ciani et al., 2010). Figure 3 illustrates the Universal design for learning in three generalized steps.

Figure 3

Universal Design for Learning Guidelines (CAST)

Universal Design for Learning Guidelines



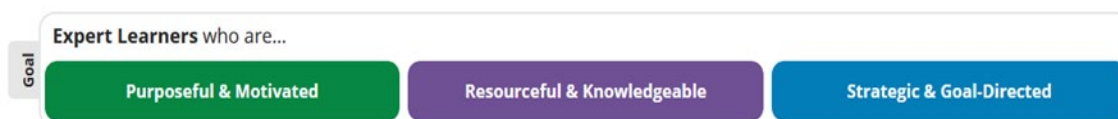
Ultimately, with budget constraints in many states, this must be accomplished with cross-curricular instruction in the early elementary years. Providing scientific knowledge while instructing students in reading and mathematics will be integral in early education (Avramides et al., 2015). However, there are still high levels of inquiry that can be developed in this format. Teachers, administrators, and boards could find ways of providing cross-curricular education to build student knowledge as they progress through to middle and high school. Siloed courses in middle school and high school will also need

to provide cross-curricular instruction, but not to the extreme that elementary teachers will need to provide. It will still be essential to connect and plan across curriculum teams, including extended core classes, to align learning and find pathways of connections for students (McNew-Birren et al., 2018).

Within the UDL (Universal Design for Learning), students can learn at their capacity and be taught in their modality (CAST, 2020 b). CAST promotes a UDL that promotes engagement, self-reflection, and analysis (CAST, 2020 a). Though CAST was initially pushed as a support to Special Education, it is now fully supported by general education programs and multiple states are adopting their model to align their classrooms to a true UDL. Within the UDL, CAST has a three-step goal to match the three-step process as shown in Figure 4:

Figure 4

Goal of Expert Learners from CAST:UDL



Providing this connection to expert learners who connect to their learning and are goal-directed is imperative to facilitating the UDL in general education settings.

Another program of learning that follows a UDL is the International Baccalaureate (IB). Within the IB, students investigate themselves as learners and build their capacity through inquiry-based learning. IB is relevant to the study as half of the DMPS middle schools were following the IB programming during the initial pilot of this

program. At the conclusion of the study, two remain IB schools due to funding constraints. IB also provides further inquiry connection to the already IBSE curriculum.

From the IB informational guide:(International Baccalureate,2020)

The IB's programs are different from other curricula because they:

- encourage students of all ages to think critically and challenge assumptions
- develop independently of government and national systems, incorporating quality practice from research and our global community of schools
- encourage students of all ages to consider local and global contexts
- and develop multilingual students.

Within the IB program, students learn at their level and build their capacity as a learner (Henderson, 1973). Students are also provided opportunities to engage in community connections through a community project, they are required to participate in language courses and design courses and reflect on their learning using the IB Criterion of learning (IBO, 2023). The IB program is one that has been successful in creating a non-traditional UDL, and worldwide the result of that learning is evident in the student performance. Because the IB is an international program, other countries utilize their learning profile as a general curriculum. Still, in the US, fewer schools align and apply with the IB to create a program (International Baccalaureate, 2023). Schools must apply, certify, and re-certify tri-annually to maintain their capacity as an IB school. There are also larger financial requirements for IB schools, which can be cost-prohibitive for some areas. But when we look at the performance of these schools, should this be a priority? Allowing the students to have a say in the decisions in the classroom ultimately leads to

skill-building in leadership, problem-solving, and ultimately stronger decision-making (Ladson-Billings, 2014).

According to Ciani, et al. (2010), goal creation leads to further development of student autonomy and a solid conceptual understanding. The structure of goal creation in the classroom not only develops the classroom culture but also develops the student's capacity as a learner. From the IB program, students follow a learner profile system (see Figure 5).

Figure 5

Learner Profile Characteristics (IBO, 2023)

The infographic is titled "As IB learners we strive to be:" and lists ten characteristics in two columns. Each characteristic has a title in all caps and a descriptive paragraph below it.

As IB learners we strive to be:	
<p>INQUIRERS We nurture our curiosity, developing skills for inquiry and research. We know how to learn independently and with others. We learn with enthusiasm and sustain our love of learning throughout life.</p>	<p>OPEN-MINDED We critically appreciate our own cultures and personal histories, as well as the values and traditions of others. We seek and evaluate a range of points of view, and we are willing to grow from the experience.</p>
<p>KNOWLEDGEABLE We develop and use conceptual understanding, exploring knowledge across a range of disciplines. We engage with issues and ideas that have local and global significance.</p>	<p>CARING We show empathy, compassion and respect. We have a commitment to service, and we act to make a positive difference in the lives of others and in the world around us.</p>
<p>THINKERS We use critical and creative thinking skills to analyse and take responsible action on complex problems. We exercise initiative in making reasoned, ethical decisions.</p>	<p>RISK-TAKERS We approach uncertainty with forethought and determination; we work independently and cooperatively to explore new ideas and innovative strategies. We are resourceful and resilient in the face of challenges and change.</p>
<p>COMMUNICATORS We express ourselves confidently and creatively in more than one language and in many ways. We collaborate effectively, listening carefully to the perspectives of other individuals and groups.</p>	<p>BALANCED We understand the importance of balancing different aspects of our lives—intellectual, physical, and emotional—to achieve well-being for ourselves and others. We recognize our interdependence with other people and with the world in which we live.</p>
<p>PRINCIPLED We act with integrity and honesty, with a strong sense of fairness and justice, and with respect for the dignity and rights of people everywhere. We take responsibility for our actions and their consequences.</p>	<p>REFLECTIVE We thoughtfully consider the world and our own ideas and experience. We work to understand our strengths and weaknesses in order to support our learning and personal development.</p>

Students begin the school year identifying themselves as one of the 10 learner profile traits. Still, as the school year progresses, they work to develop skills in the other profile traits (IBO, 2023). This process allows students to develop themselves and

discover how they best learn. Also, by going through this process students can identify how they best reflect their learning. Each learner trait provides connections to different learning modalities.

Multi-Tiered Systems of Support (MTSS)

Multi-Tiered Systems of Support (MTSS) is a comprehensive and integrated framework for addressing the academic and behavioral needs of all students in a school. MTSS involves a three-tiered system of support, with each tier providing increasingly intensive and individualized interventions for students who need additional help to succeed (Jimerson et al., 2016).

Studies by Malone et al. (2022), Eagle et al. (2015), Averill et al. (2011), and Benner et al. (2013), used as foundational work by the Iowa Department of Education, have shown that MTSS is effective in improving student outcomes and reducing disparities in academic achievement. MTSS has been shown to improve academic outcomes for students, particularly those who are struggling in school, by providing them with evidence-based interventions and support that are tailored to their individual needs. Additionally, MTSS has been shown to reduce the number of students who are referred to special education, thereby reducing disparities in academic outcomes for students with disabilities (Freeman et al., 2017).

The implementation of MTSS requires significant changes in the way schools and teachers approach student support, including the development of a data-driven and evidence-based culture, the integration of assessment and intervention systems, and the provision of ongoing professional development for teachers and school leaders (Freeman et al., 2017). Implementing MTSS has been shown to be more effective when schools

have strong leadership, a collaborative culture, and a clear understanding of the principles and practices of MTSS (Malone et al., 2022).

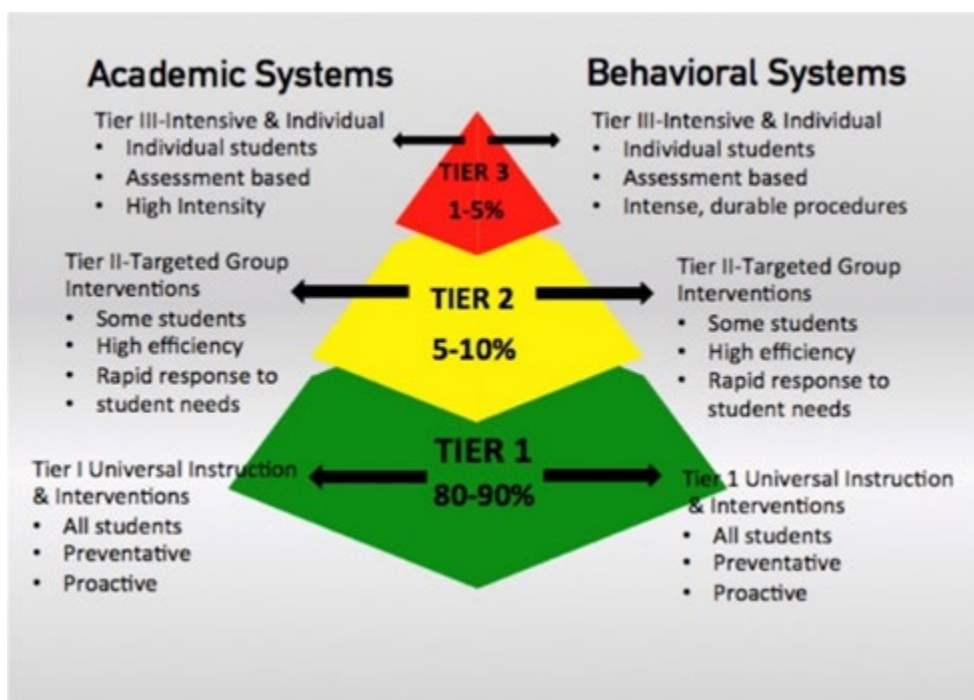
However, the implementation of MTSS can also be challenging, particularly for schools that lack the resources and capacity to fully implement the framework. Schools may struggle to establish a comprehensive system of support, to provide adequate professional development and training for teachers, or to sustain the implementation of MTSS over time.

A potential setback is the pushback and reluctance to let students explore and stumble on the answers. Discovery learning can be a concern for many educators, fearing that students either will not discover or will discover incorrectly (McNew-Birren et al., 2018). Traditional learning models can be hard to break, oftentimes I have noticed in my 10 years of experience working in the K-12 system the hardest shift is found with veteran teachers. This could be a stumbling block for any district attempting to implement this kind of change. From the time of Democritus, and his Atom theory of breaking things into small pieces and putting them back together, educators have been differentiating and scaffolding their instruction for students. However, over the past few years, there has been a genuine push to ensure that is happening (Ladson-Billings, 2014). There can be stark differences in veteran classrooms where teaching is more didactic and a new to profession teacher where inquiry starts to find a home. Often based on my experience and conversations in leadership roles, veteran teachers follow the provided basal text and what is thought of as “cookbook” instruction, feeling that the vast majority of students would fall into the 80/20 split, that does not break from the script of the basal text. When looking at an 80/20 percent, the thought is, that if 80% of your students are showing

proficiency, the 20% are outliers and instruction can continue (MTSS). But are we doing a disservice to students when we leave that 20% behind? This connection refers to the MTSS (Multi-Tiered System of Support) structure which reflects that 80% of the students should fall into the general instruction pattern and Tiers 2 and 3 will include the remaining 20% of students. (Figure 6)

Figure 6

Multitiered System of Support. (Iowa Department of Education)



Programming Structures Outside the General Education Classroom

Cross-curricular connections are an essential component of inquiry-based science education. By connecting science content and skills to other subjects, such as mathematics, language arts, and social studies, students can engage in more meaningful and relevant learning experiences (Gibson & Chase, 2002). With the emphasis on asking

questions and seeking answers, the IBSE curricula are well-suited to cross-curricular connections as they help to support the work of science within other disciplines.

A study by the National Research Council has shown that cross-curricular connections can enhance students' understanding of science content and skills, as well as improve their overall academic achievement. For example, by connecting science lessons to mathematics, students can use mathematical concepts and skills, such as graphing and data analysis, to better understand scientific phenomena. By connecting science lessons to language arts, students can develop their critical thinking, reading, and writing skills as they explore scientific concepts and communicate their ideas and findings (National Research Council et al., 2015).

However, creating effective cross-curricular connections in science education can also be challenging. Teachers must be knowledgeable about both science content and the content and skills of the other subject area and must be able to effectively integrate the two in a meaningful way. Furthermore, teachers must have the necessary resources and support to plan and implement cross-curricular lessons, including access to high-quality science and other instructional materials, ongoing professional development, and the support of school and district leaders (Freeman et al., 2017).

This structure can also exist and thrive in programs that are shorter in length, like summer programs. Gibson and Chase (2002) conducted their research during a two-week summer program at Hampshire College in Amherst, MA. In this study, middle school students were enrolled in a summer program for science education that was application-based. The results of the study were that students who completed the program, which was also considered fully inquiry-based, had a more positive attitude towards science than

those students who were not enrolled in the summer program. Though it could also be viewed in this case that the students were applying for a science program and would likely have a better view of science education, the results showed a more positive attitude towards the structure versus the same group of students who applied but were not enrolled.

Another similarly resulting study looked at the InStep program, which is a short 1–2-week summer program for girls to engage in science with higher rigor (Kim, 2016). This program also sought to bring science to more females, but also to increase the engagement with students of minority cultures, and strengthen the diversity of the science career applicants. The study, much like that of Gibson and Chase (2002), found an increase in engagement and desire to pursue science careers. Kim (2016) also found that the achievement gap between those enrolled in the program and those not enrolled was higher than the other students. When Bacharach et al. (2003) studied achievement gaps across gender groups, differences were shown to exist between male and female students tracing back to the eighth grade.

Social Justice and IBSE

An interesting thought of sociocultural teacher preparation also brings strong connections to an IBI classroom. McNew-Birren et al. (2018) state, “While both social mobility and democratic equality approaches prioritize expanded educational opportunity, the democratic equality emphasis on equitable educational distribution is also a priority for sociocultural science education scholars.” The process of Social Democracy and scientific discourse can be wholly applied to other core and extended core subjects.

In her historical review of urban science education research, McLaughlin (2014) identified “conflicting discourses” between teachers and their students as the most prominent challenge to effective science education in urban settings. Characterizing scientific proficiency as the ability to discursively support claims with appropriate evidence based on observation, the research McLaughlin synthesized agreed that a central priority for urban science teachers is to invite students to participate in scientific discourses that incorporate and sustain their own cultural and linguistic backgrounds. It is notable that the focus of engaging in contextually embedded scientific discourse does not commodify the educative value of classroom interactions, but rather concentrates on use values in terms of what students are able to do and how they can apply scientific knowledge in their communities. (McNew-Birren et al., 2018)

The consideration of social justice in terms of teacher preparation is not something that is often seen in school or teacher practices, but it is an important component of student learning today. But if teachers are not instructed in culturally responsive pedagogy, culturally responsive thinking, and culturally proficient practices, they are less likely to be successful in implementing these processes and thoughts in their classrooms (Burbules & Berk, 1999). When trying to apply discourse and inquiry in the classroom, you must also address the background knowledge of the students. The structure and planning for buildings in the same district could look very different based on the cultural structure of their community and the student body. A perfect example of this is a math curriculum that kept referring to a “pitcher of lemonade”, many of the students in my class didn't know that a pitcher was what they called a jug or container (Open Up Resources, 2022). They only knew the word pitcher as it connected to baseball

or misunderstood what was being said and heard the word picture instead of pitcher. This misinformation created problems in understanding the problem being presented in the curriculum. Students were very confused about why they would be measuring a picture of lemonade. The general curriculum did not allow for differentiation in the cultural makeup of the classroom.

Teacher Preparation

Another aspect of teacher preparation is the continuing education that teachers receive in the form of professional development. Professional development is typically chosen at the district or building level, and depending on the level of involvement and level of instruction, it could either be an amazing insight and opportunity or what most would consider a waste of time (McNew-Birren et al., 2018). To drive the practice of IBSE into the existing classrooms, teachers would need a strong base in professional development to learn how to manage, instruct, and guide an IBSE, which for many districts and buildings could be cost-prohibitive. Professional development is, however, an integral part of the process of creating the inquiry-based classrooms that the students truly need and deserve (Avramides et al., 2015).

Overall, without a strong teacher preparation program and teacher professional development, creating and maintaining inquiry-based classrooms the goal of structured IBSE or IBI cannot move forward. Teachers cannot create or maintain an inquiry-based classroom without the knowledge of how to do so. To avoid the free-for-all thought and students having full reign over everything in the classroom, teachers need to know how to set up the structures and expectations in the classroom. The only way to accomplish this

paradigm shift is to root the changes at the post-secondary level, and then push to the professional development of current educators (Rosenholtz & Wilson, 1980).

The National Research Council Developed Goals for teachers learning to implement the IBSE. These goals help to guide teachers in their planning and development in the implementation. These goals are written verbatim as they are integral to the goal and design of the study.

Goals for teachers learning to implement IBSE:

1. Developing a deep understanding of inquiry-based science education: Teachers should have a comprehensive understanding of the principles and practices of inquiry-based science education, including its focus on student-centered learning, hands-on exploration, and the development of critical thinking and problem-solving skills (National Research Council et al., 2015)
2. Building subject matter knowledge: Teachers should have a strong foundation in science content, including the concepts and principles that are essential for inquiry-based learning, and should be able to effectively integrate this knowledge into their instruction (National Research Council et al., 2015).
3. Designing effective inquiry-based lessons: Teachers should be able to design and implement inquiry-based lessons that engage students in hands-on exploration and encourage them to ask questions, make observations, and seek answers (National Research Council et al., 2015).
4. Using technology and other resources: Teachers should be proficient in using technology and other resources, such as online simulations and virtual labs, to

enhance students' understanding of science concepts and skills (National Research Council et al., 2015).

5. Assessing student learning: Teachers should have a deep understanding of formative and summative assessment practices and should be able to use assessment data to guide their instruction and monitor student progress (National Research Council et al., 2015).
6. Supporting all learners: Teachers should have a strong understanding of the needs of all students, including those with diverse learning styles and backgrounds, and should be able to modify their instruction to meet the needs of all learners (National Research Council et al., 2015).
7. Collaborating with colleagues: Teachers should be able to work effectively with colleagues to plan and implement inquiry-based lessons and should be able to seek and provide support and feedback to one another (National Research Council et al., 2015).
8. Maintaining professional growth: Teachers should have opportunities for ongoing professional development, including opportunities to participate in workshops, attend conferences, and engage in ongoing learning and reflection (National Research Council et al., 2015).
9. Building strong partnerships with families and communities: Teachers should be able to build strong partnerships with families and communities to support students' learning and development and to involve families and communities in their students' education (National Research Council et al., 2015).

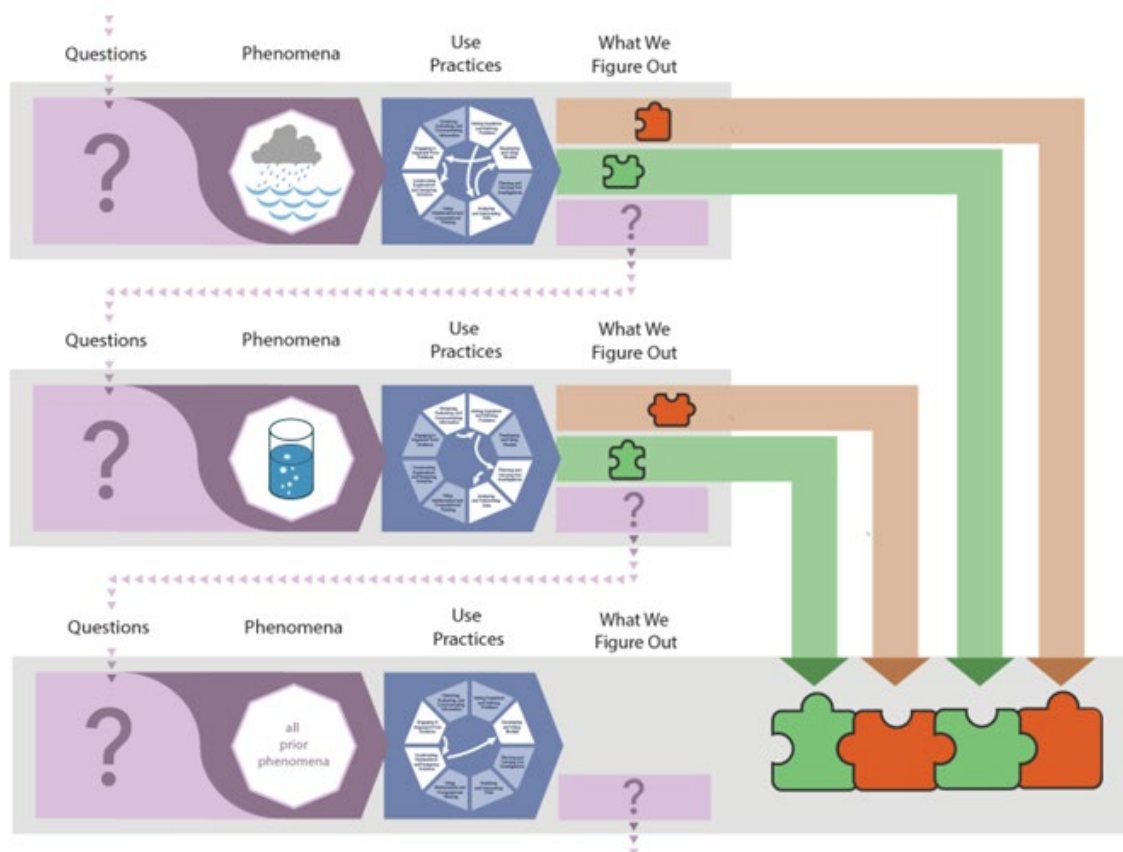
Namdar (2018) sought to use inquiry-based learning strategies to teach pre-service teachers about Global Climate Change. This study provides a structure for teaching preservice teachers how to use inquiry. The results showed that there was significant growth in the pre and post-test scores for the GCC content and in the resulting questionnaire, preservice teachers felt more prepared to teach Global Climate Change in the future versus the preservice teachers who followed a traditional learning approach. Though this specifically is focused on Global Climate Change, Monroe also found that the teachers noted in their questionnaire their preference to learn in this manner to understand better and connect to the instructional material.

This investigation provides a guiding structure for creating an inquiry-based classroom that centers on constructivist and transactional learning through inquiry-based universal design for learning (CAST, 2020 b). By working with these theories of education, students can create a stronger conceptual framework for science instead of simply reflecting knowledge utilization on a final exam. Building and stretching student capacity as a learner, risk taker and communicator will only help to build their personal conceptual framework and provide connections between core competencies (International Baccalaureate).

Classroom Routines for IBSE

When looking at the needs of students and the development of an inquiry-based classroom or curriculum, it is important to make sure that both teacher and student needs are being realized and addressed and students find that they can solve the problems (Reiser, Brody et al., 2017). Students need to learn how to “do science” versus just “do school,” and creating storylines to follow is an integral part of that process (Jiménez-

Alexandre et al., 2000). This process is known as, creating a problematizing routine, and is the next step in the NGSS, Next Generation Science Standards. A key feature of coherence or connections in NGSS is that scientific ideas must be built piece by piece. Each new investigation brings another piece of the puzzle and raises more questions. At key points, students need to be prompted and guided to put the pieces together they have figured out so far. Sometimes this can be accomplished by “earning specific vocabulary” or reviewing with graphics like a “gotta-have-it” checklist (OpenSciEd, 2022). In this type of work, students take the pieces of ideas they have developed across multiple lessons and figure out how they can be connected to account for the phenomenon they have been working on. The goal is that students pull together the key moments or big ideas across lessons, and attempt to collaboratively develop a product (model, explanation, design) that works for the range of phenomena they have encountered so far. An illustration of this routine is shown below in Figure 7.

Figure 7*Problematizing Routine (OpenSciEd, 2022)*

A key assertion or assumption with this is that students can be partners in their learning. They can work through the ideas in productive steps along the way. This brings along three major connections or issues that are evident when these practices are being developed: the nature of science practices, epistemic agency, and the nature of knowledge building in science.

The nature of science as a practice is centered around not just “learning” science but “doing” science. In a classroom focused on IBSE, there should be more time in the doing section, just like Dewey believed (Dewey, 1916 /2010). The idea of practices, versus skills or goals is frequently mentioned by Reiser et al. (2017). Reiser also brought

in the work of Osborne (2014) which helped align the thought of the “cookbook” style of learning, what some would refer to as traditional or classic forms of learning, versus the hands-on. Reiser also brings in Ford & Forman, 2006 who illuminate the need for structure around phenomena, discussions, and setting expectations with common goals. It can seem elementary to some, but solid structures where students know and practice the routines needed to be confident in their doing are an imperative part of setting up the classroom. Following the cookbook does not mean that students are learning, they are the academic lemmings in this equation. Jiménez-Aleixandre, et al., 2000 and Lehrer & Schauble, 2006 are others that Reiser et al. cite to solidify the need for structure and routine. Simply manipulating materials and following a prescribed lab report does not lead to learning in the end. With the addition of multi-step model making and consensus discussions, students can begin to move into the learning realm (Reiser et al., 2017).

Stroupe (2014) brings forth the concept of Epistemic agency, which is then reviewed in a more contemporary or urban setting by Reiser et al. Creating a classroom culture that embraces learning and mistakes is imperative to truly move into the realm of inquiry. Damşa et al. (2010, also brings to light the need for teachers to share the epistemic agency and create a department that can solidly support a culture of learning and not just doing. Damşa reflects on Reiser and Stroupe’s previous work in his study on epistemic agency and emergent construct. All of these further studies circle back to Stroupe’s original work of building science knowledge in a classroom and how classroom culture is imperative in the development of an inquiry-based program. Passmore et al. (2014) is also brought to light in Reiser et al. where the idea of exploratory knowledge is built. Reiser et al. mentions that to truly build this you must build in explanatory

knowledge building where things are tested and built upon to have a solid foundation.

The need to create a cyclical learning and do things where you are explaining and understanding the core versus a process are at the root of building classroom routines and procedures to support a classroom in the world of IBSE.

Process Quality

Process Quality is a concurrent component of Inquiry Based Science Education. Process Quality, the degree to which a process is being followed to produce accurate results, is often thought to be directly related to the teacher's preparation, questioning, and general content knowledge (Soysal, 2022). Teachers are needed to guide the inquiry but not dictate the directory. For example, for students who are following the process but analyzing either the wrong data or incorrect data, it is up to the teacher to redirect the process and ensure the inquiry process is a positive one. Students who endlessly engage in work that is incorrect work or simply find out that the process was incorrect, resulting in a lower assessed grade, can have negative effects on the student's autonomy and capacity building as a learner (Soysal, 2022). Ensuring that teachers are following the inquiry process and are knowledgeable of potential outcomes can also affect, often in a positive way, the social-emotional learning state of the students (Schwartz et al.,2017) The quality of the processes used in science education can have a significant impact on student learning outcomes. Process quality refers to the characteristics of instructional practices and the learning environment that facilitate student engagement, critical thinking, and problem-solving skills. Science education that is high in process quality is characterized by student-centered instruction, hands-on exploration, and opportunities for students to ask questions and seek answers.

Research has shown that process quality in science education is positively related to student learning outcomes, including increased motivation and engagement, improved critical thinking and problem-solving skills, and a deeper understanding of science concepts and skills (Soysal, 2022). Inquiry-based science education, which emphasizes process quality, has been found to be particularly effective in enhancing student learning outcomes (Freeman et al., 2017).

However, achieving high process quality in science education can also be challenging, and requires strong teacher preparation, ongoing professional development, and support from school and district leaders. Teachers must be knowledgeable about inquiry-based science education and be able to integrate its principles and practices into their instruction effectively. They must also have access to high-quality science and instructional materials and be able to use technology and other resources to enhance students' learning experiences (Soysal,2022).

Inquiry-Based Practices in Middle School

Fogleman et al. (2011) have an interesting view of middle school specifically regarding inquiry-based learning. Their research focused on science-based curriculum and how teachers were adapting or needing to adapt, teacher self-efficacy, and the teacher experience of enacting the unit. Overall, this study showed similar correlations to previously reviewed research. This article presents valuable insights into the complex relationship between teacher modifications and student outcomes in science education.

The study conducted by Fogleman et al(2011). delves into the effects of teachers' adaptations to a middle school science curriculum unit focused on inquiry-based learning. The authors investigate whether and how teachers' adjustments to the curriculum affect

students' understanding of scientific concepts and their engagement in the learning process.

The research methodology employed in this study is commendable. The authors employed a mixed-methods approach, combining quantitative data analysis and qualitative assessment to gain a comprehensive understanding of the subject matter. They collected data through classroom observations, student assessments, and teacher interviews to evaluate the effectiveness of teacher adaptations on student learning outcomes. Their findings that teacher adaptation matters and student engagement is integral, especially in middle school, are the foundation for the work the current study is reviewing.

The review article, "Focus on Middle School: Using Inquiry-Based Learning to Keep Students Engaged and Learning in All Content Areas," by Savitz, published in *Childhood Education* in 2016, offers an evaluation of the column in *Focus on Middle School* edited by Mary Hudson (Hudson, 2015). Savitz takes the original thoughts of Hudson on scaffolding choice and moves them into the realm of inquiry-based design. The column under review explores the application of inquiry-based learning in middle school education, aiming to keep students actively engaged and promote learning across various content areas. This review aims to assess the content, strengths, and contributions of the book to the field of education. One of the book's notable strengths is its emphasis on practical guidance for educators. It offers concrete strategies to move through the chaos of middle school. It uses forms of scaffolding choice instead of guided instruction, lesson plans, and classroom examples that empower teachers to incorporate inquiry-based learning into their middle school curriculum effectively. This aspect makes it a valuable

resource for novice and experienced teachers (Savitz, 2016). The central theme of engaging middle school students is effectively conveyed throughout the book. It provides educators with a repertoire of tools and activities designed to captivate students' interest, stimulate curiosity, and enhance their overall learning experiences.

Middle school is an ideal stage for the implementation of inquiry-based learning, as it provides a critical transition point in a student's education (Savitz, 2016). During this period, adolescents are naturally curious and eager to explore the world around them. By integrating inquiry-based learning into middle school curricula, educators can harness students' innate curiosity and foster critical thinking skills, problem-solving abilities, and a genuine love for learning. This approach empowers students to take an active role in their education, making the middle school years a pivotal time for cultivating lifelong learners (Savitz, 2016).

IBSE and English Language Learner Students

The article titled "Sweet Science for ALL! Supporting Inquiry-Based Learning Through M&Ms Investigation for English Language Learners," authored by Song, Higgins, T., and Harding-DeKam and published in the journal *Science Activities* in 2014, presents an engaging and innovative approach to science education, specifically targeting English Language Learners (ELLs). This review aims to provide an evaluation of the article's content, methodology, and contributions to the field of science education. This article provided an interesting parallel to the research in the current study also researching the importance or effect of inquiry-based learning and how it can positively affect a multilingual student. This was a discovery in the current study that was a secondary outcome. Though not originally a part of a research question this became

quickly evident as an added benefit for non-traditional learners. Song et.al showed results that inquiry-based learning was one of the better connections to students that are English Language Learners or new to the country. This connection would allow the student to not only learn but display their learning in a manner that does not require the use of written English.

Song, Higgins, and Harding-DeKam's article offers a valuable contribution to the field of science education by introducing an innovative and inclusive teaching approach for ELLs. The use of M&Ms as a teaching tool to facilitate inquiry-based learning is both creative and effective. This article is a resource for educators seeking to engage ELL students in science education while promoting critical thinking and inquiry skills.

Although further research and exploration of potential challenges are warranted, "Sweet Science for ALL!" is a noteworthy example of how thoughtful pedagogical adaptations can enhance science education for a diverse range of learners.

Though traditional students benefit from this learning structure, English Language Learners (ELLs) can greatly benefit from inquiry-based learning approaches. ELL or MLL (English Language Learners or Multi-Lingual Learners) can learn with hands-on discovery even without knowing the language. There is some current go-between in many educational settings regarding the difference between an ELL student versus an MLL student, to align with cultural proficiency standards it is becoming more and more acceptable to use MLL. This review will maintain the use of the original author, but they are interchangeable. By engaging in hands-on investigations and problem-solving activities, ELL students not only develop their language proficiency but also gain a deeper understanding of academic content. This interactive and student-centered

approach not only fosters language acquisition, not only in the science classroom but in other academic vocabulary as well, but also promotes critical thinking, curiosity, and a genuine passion for learning among ELLs, making it an effective method for their overall educational growth and success (Song et al., 2014).

The primary focus of Early and Kendrick's article is to explore how inquiry-based pedagogies, which emphasize student-driven exploration and problem-solving, can be harnessed effectively to support English Language Learners (ELLs). The authors investigate the potential of multimodal learning, which incorporates various modes of communication, and the role of students' multilingualism in facilitating their success within these pedagogical frameworks (Early & Kendrick, 2020). They found that these multimodal approaches allowed the students to develop an academic vocabulary base which gained them access to content knowledge at their grade level. They also noted within the findings that educators' resistance to change posed barriers to access for these students (Early & Kendrick, 2020). One of the biggest challenges found was an underestimation of required resources. The most prominent of the challenges is the human capital and being able to locate, plan, and develop these tools for students to use (Early & Kendrick, 2020).

The article presents a compelling argument for integrating inquiry-based pedagogies in language education, emphasizing the benefits of active student engagement and critical thinking. The authors assert that such approaches can empower ELLs to take ownership of their language learning. The discussion on multimodal learning is particularly noteworthy. The authors highlight the significance of incorporating multiple modes of communication, such as visuals, gestures, and technology, to cater to the

diverse needs and preferences of ELLs. This approach recognizes the importance of accommodating various learning styles and abilities (Early & Kendrick, 2020). The article underscores the value of leveraging students' multilingualism as an asset in language learning. It promotes a positive view of linguistic diversity and suggests strategies for capitalizing on students' existing language skills to facilitate English language acquisition. The authors acknowledge the challenges associated with implementing inquiry-based pedagogies and multimodal learning for ELLs, such as the need for teacher training, access to resources, and assessment considerations (Early & Kendrick, 2020).

Summary

In middle school education, we are setting the stage for lifelong learners. This integral developmental age is where we can most root ourselves in processes like IBSE which can then move into their secondary and postsecondary education. This is the age where it is imperative to engage the students with their need to develop as a student learner and build their capital as a learner.

Though there is ample literature in regard to inquiry-based education, many do not have a solid connection to the work of Des Moines Public Schools and its students. In this review, Dewey's concept of wrestling with nature as a means of inquiry is central to the study because of a desired alignment of inquiry-based learning, social justice and equitable educational outcomes using the Universal Design for Learning. The desire to become the model of urban education and provide a culturally proficient and equitable education to all students, which also pushes them to build their capacity as a student learner is evident in this work. It discusses the alignment of Des Moines Public Schools

(DMPS) with inquiry-based learning, social justice, and universal design for learning. The adoption of OpenSciEd and NGSS in science education is highlighted. Dewey's influence on progressive education and inquiry-based learning is emphasized, with research showing the benefits of student-centered, hands-on learning. The Next Generation Science Standards (NGSS) are a comprehensive shift in science education towards inquiry-based learning, focusing on scientific practices, crosscutting concepts, and core ideas. The development process of NGSS is outlined, emphasizing stakeholder involvement and public feedback.

Universal Design for Learning (UDL) is a framework used by DMPS and other inquiry-based districts that promote student autonomy and engagement through inquiry-based learning, student voice and choice, and adequate teacher preparation. It emphasizes the importance of building on the students learning capital and allowing them to be motivated, resourceful, and strategic in their learning. This approach to learning is one that aligns well with programs like the International Baccalaureate and many others. UDL is a process that is also continuous, promoting the lifelong learning mentality that students will be able to carry into college and career.

UDL involves three generalized steps, as illustrated in Figure 3:

- Providing scientific knowledge while instructing students in reading and mathematics, especially in early education.
- Implementing cross-curricular instruction in middle and high school to connect learning across subjects.
- Planning and aligning curriculum teams, including extended core classes, to facilitate connections for students.

UDL allows students to learn how they learn, to drive their education, and to promote their needs as individual students.

Multi-tiered systems of Support (MTSS) is an integrated system or framework that addresses not only the academic but behavioral needs of students. MTSS is considered the pyramid of instructional or behavioral needs. Tier 1 should be supportive for 80% of students, tier 2 should be for 15% and only 5% should require Tier 3 support. Systems like the SAMI or Self-Assessment of MTSS implementation were designed for the state of Iowa to allow buildings that are falling below preferred ratings to align their building processes and goals to reach their tier support for students better. Some of the biggest hurdles in setting goals within this system are financial. This often causes reluctance from many individuals, including teachers and staff, to move into the desired state.

Teacher preparation is one of the most vital roles in the implementation of IBSE. Teachers will need to have all of the structure learning and classroom management needs to be able to implement with fidelity. Traditional classroom management typically does not combine well with IBSE. However, implementing inquiry-based strategies often allows teachers to have stronger roots in their classroom management and it is often the case that teachers who fully implement with fidelity have fewer behaviors as the student engagement is considerably higher.

With the implementation of the NGSS, the science standards have now been designed and aligned to grade levels and age-appropriate levels to better support the implementation of the IBSE. Within the NGSS there are constant reflective notations of cross-cutting concepts that allowing for cross-curricular connections. These cross-

curricular connections allow students to see that science isn't just one classroom, but it is truly rooted in all of their core subject work.

IBSE is also highly effective for students who fall into our MLL or ELL populations.

Even without full language proficiency, students can access grade-level content and develop skills that allow them further access to academic vocabulary. Though financial constraints often lead to teacher reluctance, it is clear that this particular population is in the highest need of structures such as these.

Chapter 3: Research Methodology

“We are a work in progress, the goal is to have students like inquiring better and like problem solving better because I think we've created a culture they've been spoon fed for so long that they don't know quite yet how to problem solve or they don't necessarily want to. They are so used to just instant gratification. So if we can teach them not to be instantly gratified, inquiry really will start to take off.”- Janice, 8th grade science teacher

The “why” of Importance

This research is considered improvement science as a need to verify the effectiveness of the treatment or implementation of the new curriculum and future needs for teacher preparation and student achievement (Personal communication about district goals, 2022). To review the pilot of the curriculum in the DMPS school district, I am investigating not only student growth based on state testing but teacher preparedness and perception using a mixed methods approach. This was chosen so that not only the needs, practices and concerns of the teachers can be brought to light, but also the improvement of student data as aligned to district board goals. On the quantitative side, I will investigate the growth of student scores from 5-8th grade in math and science making comparisons in pilot schools and non-pilot schools. Qualitative research will be in surveys, interviews, and observations of the curriculum in use in the classroom.

Research Questions

Based on the district board goals, the analysis of the science team and teacher perception conversations, the following questions were developed to better understand the implementation of the curriculum.

1. Is there growth in student achievement for teachers who create classrooms focused on inquiry-based universal design for learning compared to the traditional method of instruction?

2. How can a shift in teaching practice from a traditional approach to a focus on inquiry-based universal design for learning impact student autonomy and conceptual learning?
3. How does teacher education and professional development impact teacher practices and the opportunities they create for students to learn science?

Setting and Participants

Des Moines Public Schools is the largest public school district in the state of Iowa, serving approximately 32,000 students. Within this urban district 76% of students are on the free and reduced lunch program and 23% of students are multilingual learners. Students in DMPS were born in 109 countries and speak 83 languages, also serving over 50 students every year who are newcomers to the United States. As of the 21-22 school year 15% of the students in DMPS had an individualized education plan for special education services and 8% were classified in the Alternative Learning Program (formally known as Gift & Talented). The average daily attendance for students is 90% and a graduation rate of 83%. 52% of those graduating enters into post-secondary education. There are approximately 2400 certified instructional staff working in the district. (Des Moines Public Schools, 2022)

Table 1*Interview and Observation Participant List*

Participant Pseudonym	Participant Building Pseudonym	Years of Service	Specialty/Subjects/Grade Level Taught
Janice	Bradley Middle School	13 years	8th grade science
Darla	Maxwell Middle School	25+ years	7th & 8th grade science
Hannah	Channel Middle School	20+ years	Behavior disorders special education / seclusion classroom

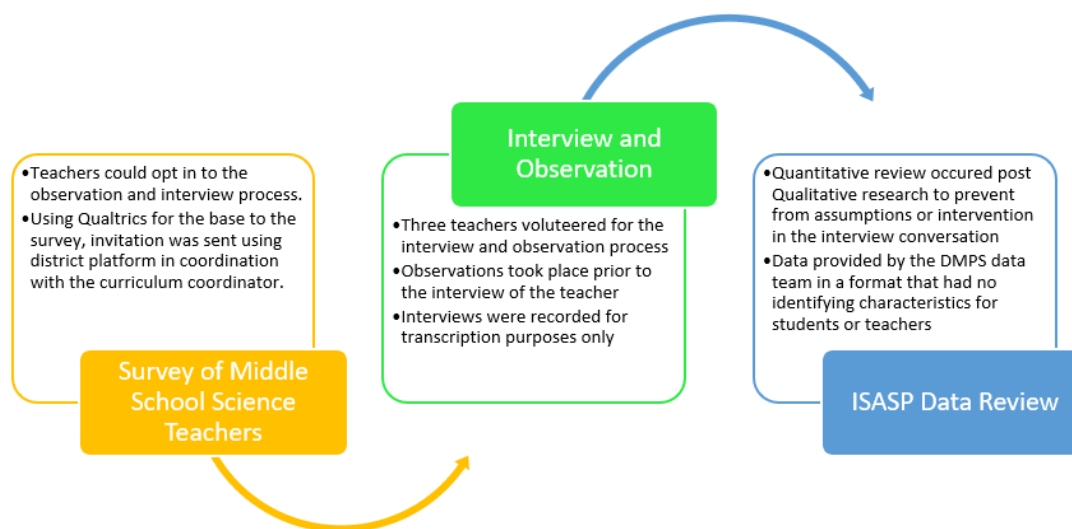
Research Design

This is a mixed method, quasi-experimental study. Qualitative and quantitative data collection and analysis were conducted to explore the outcomes of students using ISASP scores and teacher interviews/observations for the classrooms that have adopted the inquiry-based science curriculum.

Students' scores from the ISASP (Iowa Statewide Assessment of Student Progress) for school year 2021-2022 8th graders for math and science were used to measure student achievement and proficiency. The district not only provided ISASP test scores from grade 8 (testing completed during spring 2022) on the study cohort but it also provided their ISASP scores from when the students were in grade 5 (spring 2019) and grade 7 (spring 2021) to be utilized as prior achievement measures. This district did not provide ISASP scores from when the students were in grade 6 due to lack of testing/school closure because of COVID-19. As a requirement of DMPS data sharing policies, each principal was required to give permission to research in the building post IRB approval. This approval was received by all administrators on November 19, 2022.

There was a total of 2,134 students included in the data file provided by the district. However, ISASP test scores were not available for all students. Given the focus of this study on science and math, students who did not have science and math scores from grade 8 were not included in the study analysis data file. This exclusion criteria resulted in 2,045 students being included in the study analysis data file.

Teacher observations and interviews will be conducted based on selection criteria to analyze standing themes and occurrences. Surveys were sent to all 6-8th grade science teachers within the DMPS district. At this time, there are 11 middle schools in the proposed district, which include an alternative center and virtual campus. Surveys were sent to all science teachers on November 19th, 2022, excluding the alternative center and virtual campus as they do not use the OpenSciEd curriculum. Each standard campus has 4 science classroom teachers at a minimum and at most 7. Each class traditionally has approximately 35 students per class period.

Figure 8*Model of Research Planning*

As part of the survey, teachers could opt into an observation and interview, of those 20 who responded only 3 opted in to the second portion (Table 1). Observations and interviews were conducted with the three teachers, who were each from a different building. One teacher who volunteered is also a behavioral disorders special education teacher who does not solely teach science. Based on a priori power calculations using a two-tailed test shown in Figure 9, 1,936 to 2,587 students would be able to detect a small effect size at 0.3 at 80% to 90% power.

Figure 9

Data Estimates for Effect Sizes as Provided by ISASP (ISASP, n.d)

Table 1: Estimated required number of students to detect small to large effect sizes by power
Calculations based on 38% IB vs. 62% traditional/non-IB split, a two-tailed test, and a significance level of .05

Effect size	Power	Total required sample size from t test (ignoring clustering/multilevel modeling)	Total required sample size accounting for clustering (the design effect)
0.8 (large)	80%	64	282
0.8 (large)	90%	86	378
0.8 (large)	95%	104	458
0.5 (moderate)	80%	160	704
0.5 (moderate)	90%	214	942
0.5 (moderate)	95%	264	1,162
0.3 (small)	80%	440	1,936
0.3 (small)	90%	588	2,587
0.3 (small)	95%	726	3,194

* Based on assuming an intraclass correlation coefficient (ICC) of 0.10 (the proportion of the variance in ISASP scores that can be explained by between cluster differences).

Under this scenario, the design effect was estimated to be 4.4 - that is, the numbers in the last column of the table above were obtained by taking the numbers in the 3rd column (obtained using GPower based on two-sample independent t test) times the design effect of 4.4 based on ICC of 0.10.

Classroom observations were not recorded for student privacy, however, notes and classroom sketches will be used to develop qualitative themes (See Observation Protocol in Appendix B). Interviews were recorded (audio or audio/video) and took place on TEAMS to aid in transcription of the interview. The recordings will be securely held for 6 months post defense and graduation and destroyed as part of the approval with the IRB. (See Interview Protocol in Appendix C). Surveys were developed using the district software on Qualtrics, using both LIKERT formatting as well as open ended answers (See Survey Contents in Appendix D). Though LIKERT responses are more quantitative in nature, they will aid the analysis of the qualitative based survey questions, interview,

and observations. All instruments and questions were approved by the DMPS data team post IRB approval.

Data Analysis Procedures

ISASP scores, as provided by Des Moines Public Schools, were analyzed using SPSS and general coding. Descriptive statistics were processed to verify the statistical balance of the demographics such as gender, race, SPED status, 504 status and Free/Reduced lunch (marker of socio-economic level) status across the three intervention groups, which included the following grouping of schools -

1. Schools with 2 or more years of pilot instruction
2. Schools with 1 year of pilot instruction
3. Schools with limited or no pilot instruction

Because students were not randomly assigned to the intervention groups, I tested to see if there were significant differences in prior achievement levels and demographic characteristics among the three intervention groups. These tests were examined prior to conducting the analyses to determine if other student characteristics needed to be controlled for in the analyses to answer the first research question. The chi-squared test was used to determine if there were significant differences in the categorical demographic characteristics among the inquiry-based intervention groups. One-way analysis of variance (ANOVA) was used to determine if there were significant differences in prior achievement scores among the inquiry-based intervention groups. The post-hoc pairwise comparison method following the ANOVA results was the least significant differences (LSD) method.

Multiple linear regression was used to answer the first research question to determine whether there were differences in grade 8 ISASP science and math scores among the three intervention groups, while statistically controlling for prior achievement levels and demographic characteristics. Multiple logistic regression was used to answer the first research question to determine whether there were differences in grade 8 science and math proficiency levels among the three intervention groups, while statistically controlling for prior achievement levels and demographic characteristics. Because classroom level indicators were not provided by the district, I was unable to use the multilevel modeling due to lack of classroom clustering information. Instead, multiple linear and logistic regression models – which assume independent observations – were used to analyze the relationships between the intervention groups and the outcome variables.

In the fall of 2022, all middle school science teachers were sent a survey link. Of the 39 possible teachers, 23 completed the survey. Within the survey there was an option to participate in the interview and observation process, three teachers volunteered for this process. Observations were performed in the teacher's classroom for one hour (or length of one class period) and interviews were conducted after the observation and on the platform TEAMS. Using this platform allowed for recording and transcription of the recording, however the recordings were destroyed for privacy when the transcription was completed. Survey responses, interviews and observations were coded using an In vivo thematic style. Themes were grouped using the platform Quirkos. Within the coding process, themes were grouped, analyzed and sub-grouped further. The initial coding process was identificatory in nature, meaning the goal was to see what lived in the

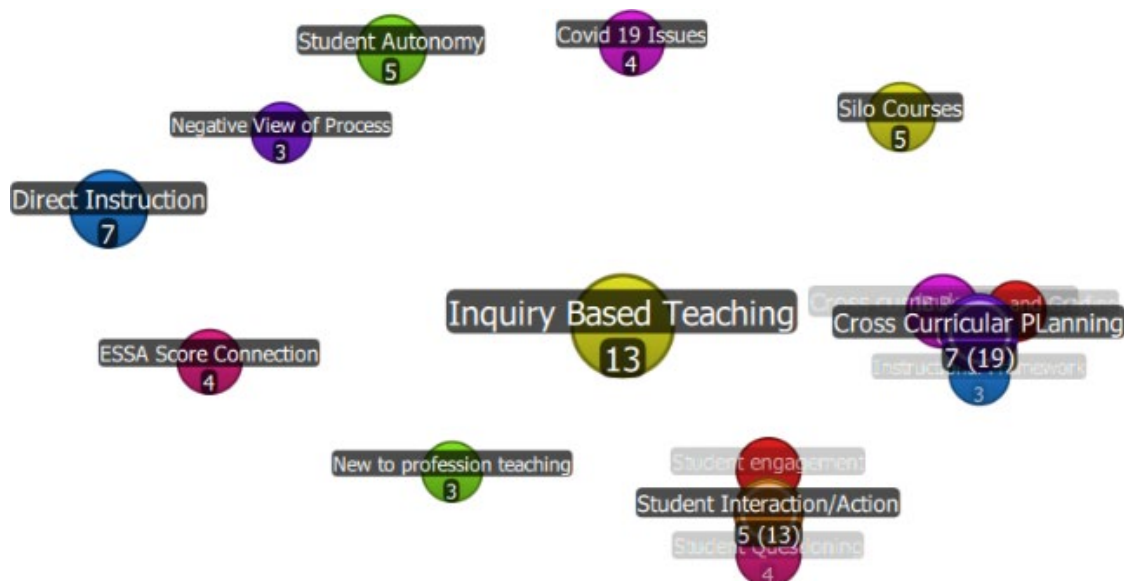
results. While being analyzed, word clouds were first used to see what common words were more prevalent in the response. This helped to name the Quirks or groupings. Within the Quirks, further steps to find common terms and phrases were also taken. This created multi-level Quirks for further analysis.

Data will be analyzed separately for qualitative and quantitative needs.

Qualitative data will be reviewed for emerging themes using the system Quirkos. A sample of this coding technique is displayed in Figure 10. Each grouping is known as a Quirk in this system.

Figure 10

Coding Example Using Quirkos



This tool uses InVivo style coding to group information visually, which helps pool themes into like areas and digitally connect the quotes/answers/input for access when analyzing the data.

Prior evidence exists on the reliability of ISASP scores as well as the validity evidence for using ISASP scores to measure student achievement. Internal structure validity evidence shows the degree to which items and test components conform to the construct on which the proposed test score interpretations are based (ISASP, 2022). According to Figure 3.4, the goodness-of-fit report from ISASP shows internal structure of the items from each subject test measuring a single construct, namely achievement in the subject area.

Figure 11

Goodness of fit report from ISASP (ISASP, 2022)

Table 7.1 Goodness-of-Fit of Bifactor Internal Structure Models for ISASP Domain Scores Based on the Iowa Core Standards

ISASP Test	Model Fit	3	4	5	6	7	8	9	10	11
Reading	CFI	.997	.987	.998	.999	.998	.998	.998	.995	.997
	SRMS	.009	.016	.006	.005	.006	.006	.007	.010	.008
	RMSEA									
Language/ Writing	CFI	.888	.931	.924	.904	.873	.915	.922	.927	.907
	SRMS	.078	.061	.069	.065	.085	.080	.063	.062	.079
	RMSEA									
Mathematics	CFI	.992	.932	.990	.990	.992	.983	.987	.992	.988
	SRMS	.012	.035	.013	.014	.012	.016	.015	.012	.016
	RMSEA									
Science	CFI	-	-	.980	-	-	.987	-	.988	-
	SRMS	-	-	.016	-	-	.014	-	.014	-
	RMSEA	-	-	-	-	-	-	-	-	-

There are several ways of estimating reliability, including test-retest, alternate forms, and internal consistency methods. The primary type of reliability reported in this technical manual is an internal consistency measure, coefficient alpha, which is derived from analysis of individuals' consistency of performance across items within a test. Coefficient alpha was chosen as it is the most common measure of internal consistency and requires only one administration of the test. (ISASP, 2022)

As shown in Figure 12, the reliability estimates were 0.80 or higher in science and math across the grade levels. The reliability estimates were also high for English Language Arts (ELA) scores.

Figure 12

Reliability as provided by ISASP, 2022.

Table 8.1. Estimates of Reliability and Standard Errors of Measurement for 2019 ISASP

Grade	Reliability Index	Reading	Language/ Writing	English Language Arts	Mathematics	Science
3	Reliability	0.88	0.84	0.92	0.88	.
	SEM	10.4	11.3	7.6	9.9	.
4	Reliability	0.86	0.83	0.91	0.88	.
	SEM	12.9	14.1	9.6	11.9	.
5	Reliability	0.87	0.83	0.91	0.89	0.80
	SEM	14.9	16.9	11.4	13.7	18.3
6	Reliability	0.88	0.84	0.92	0.87	.
	SEM	15.9	18.1	12	16.4	.
7	Reliability	0.88	0.87	0.93	0.88	.
	SEM	18.2	18	12.7	17.3	.
8	Reliability	0.87	0.87	0.93	0.90	0.80
	SEM	20	19.8	13.7	17.4	24.5
9	Reliability	0.85	0.86	0.92	0.86	.

Summary

Within this chapter, the methodology for this mixed-method research was presented. The specific structure of using Mixed Methods allowed for a quantitative analysis of student test scores alongside the qualitative analysis of teacher perception and

input. Both of these tools will help inform the district with next steps. The district provided data on 2,045 students using their 8th grade ISASP scores. This quantitative data was analyzed using SPSS and multiple linear regressions (for test scores) along with multiple logistic regressions (for proficiency status). A limitation of these analyses was that I was unable to account for students being clustered within classrooms.

The survey was sent to all middle school science teachers, approximately 40, who teach within 11 buildings. This qualitative data was analyzed using Quirkos and In Vivo coding with minimal quantitative/Likert style interactions from some survey questions. Initially, I wanted to review the qualitative data first, before analyzing the quantitative data so that my thoughts in coding and analysis were not skewed with the possible results. Once the first few levels of coding were complete, I felt confident in moving through the quantitative analysis. In chapter 4 I will present the data that answers the research questions.

Chapter 4

“As soon as teachers started doing this in the classroom with students, that’s where the magic happened. The stories that were coming back far exceeded expectations- it blew our minds.”- OpenSciEd

Introduction

In the following section a short review of the research questions and design will be presented. Following the introduction an analysis of the data by research question will be presented. Implications and additional data responses will be presented in chapter 5. In previous chapters the need for this research was presented. Based on the needs of the district to provide equity of access to high quality curriculum that aligns to our board goals, the goals of the implementation of the OpenSciEd curriculum are imperative to meeting this goal. The quantitative review of the ISASP testing data, as it corresponds to the research questions, helps illuminate positive implications that using OpenSciEd curriculum can have on student achievement and proficiency in science.

Overview of the Study Results

The following questions were developed to aid the district with the implementation of the OpenSciEd curriculum, both from the student perspective and the teacher perspective. The questions are listed again to reflect alignment together as well as reiterate the research goals from this study.

1. Is there growth in student achievement for teachers who create classrooms focused on inquiry-based universal design for learning compared to the traditional method of instruction?

2. How can a shift in teaching practice from a traditional approach to a focus on inquiry-based universal design for learning impact student autonomy and conceptual learning?
3. How does teacher education and professional development impact teacher practices and the opportunities they create for students to learn science?

To better understand the final data, the research design is again presented below, with some specifics to the final research outcomes. Knowing the timing, structure and completion rate of the teacher perception questions can help inform the final data analysis.

In the fall of 2022, all middle school science teachers within Des Moines Public Schools were sent an electronic survey. Of the 39 teachers surveyed, 23 responded to the survey. Within the survey was an option to participate in an interview and observation process, three teachers volunteered to participate.

Student ISASP (Iowa Statewide Assessment of Student Progress) scores for students who were 8th graders in school year 2021-2022 were used to measure student achievement and proficiency status in science and math. The scores and proficiency rates were compared among the intervention groups. The groups included: students who were exposed to more than one year of inquiry-based pilot work (labeled as Group 1), those who were exposed to one year of pilot work during their eighth grade (labeled as Group 2), and those who had no or limited exposure to the inquiry-based curriculum (labeled as Group 3). Student testing data from 5th and 7th grade for the 2021-2022 cohort of eighth graders was also reviewed to compare prior achievement levels among the three groups of students. No 6th grade data for these students was analyzed due to lack of

testing/school closure due to COVID-19. As a requirement of DMPS data policies, each principal was required to give permission to research in the building post IRB approval. This approval was received by all administrators on November 19, 2022. In the following sections, first, descriptive statistics will illuminate the structure and demographics of the data set from the ISASP data by intervention group. This provides a statistical picture of how the three groups compare on prior achievement and demographic characteristics prior to further analysis. Following the descriptive statistics, each research question will be explored through the relevant data and statistics.

Data Analysis

Descriptive Statistics

For the purposes of this study, the intervention groups were assigned as more than one year of intervention, one year of intervention and limited or no intervention based on the school attended by the students. These groups were determined by the pilot start year for OpenSciEd. Only one school had three years of intervention and three others had two years; these two groups were combined to create the more than one year intervention grouping. Because students were assigned to the intervention groups based on middle schools piloting the inquiry-based program and not randomly assigned, I wanted to check for differences in prior achievement levels and demographic characteristics among the groups. Table 2 provides descriptive statistics comparing students' demographic characteristics and prior achievement levels in science and math among the three intervention groups. Analyses for each student characteristic was based on students with the available data.

First, there was a significant difference in prior achievement in math and science among the three intervention groups, where group coding referred to in this study are as follows:

Group 1- More than one year of intervention

Group 2- One year of intervention

Group 3- Limited or no intervention.

Table 2

Descriptive Statistics Table

Descriptive Statistics

Student characteristics	No intervention		One year intervention		More than one year intervention		Comparison of the three groups	
	N	%	N	%	N	%	Test statistic	p value
Gender	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 0.747$	0.688
Female	231	52.26%	392	50.98%	415	49.76%		
Male	211	47.74%	377	49.02%	419	50.24%		
Race/ethnicity	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 64.352$	<.001***
Asian	42	9.50%	51	6.63%	69	8.27%		
Black/African American	66	14.93%	190	24.71%	172	20.62%		
Hispanic/Latino	145	32.81%	289	37.58%	215	25.78%		
Other or More than one race	31	7.01%	65	8.45%	70	8.39%		
White	158	35.75%	174	22.63%	308	36.93%		
FRL	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 45.831$	<.001***
Free	299	67.65%	546	71.00%	482	57.79%		
None	106	23.98%	135	17.56%	263	31.53%		
Reduced	37	8.37%	88	11.44%	89	10.67%		
ELL Status in Grade 8	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 38.528$	<.001***
ELL	87	19.68%	183	23.80%	110	13.19%		
Exited ELL	78	17.65%	144	18.73%	131	15.71%		
Non-ELL	277	62.67%	442	57.48%	593	71.10%		
Special education status	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 6.480$	0.039*
No	352	79.64%	617	80.23%	704	84.41%		
Yes	90	20.36%	152	19.77%	130	15.59%		
Status 504	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 3.345$	0.188
No	425	96.15%	748	97.27%	797	95.56%		
Yes	17	3.85%	21	2.73%	37	4.44%		
Grade 8 Math proficiency	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 20.494$	<.001***
Not proficient	291	65.84%	513	66.71%	473	56.71%		
Proficient & Advanced	150	34.16%	254	33.29%	361	43.29%		
Grade 8 Science proficiency	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 36.473$	<.001***
Not proficient	286	64.71%	456	59.30%	405	48.56%		
Proficient & Advanced	155	35.07%	311	40.44%	429	51.44%		
Grade 8 ELA proficiency	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 43.726$	<.001***
Not proficient	218	49.32%	414	53.84%	314	37.65%		
Proficient & Advanced	219	49.55%	352	45.77%	513	61.51%		
Grade 7 Math proficiency	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 38.088$	<.001***
Not proficient	261	59.05%	411	53.45%	364	43.65%		
Proficient & Advanced	140	31.67%	232	30.17%	368	44.12%		
Grade 5 Math proficiency	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 14.889$	<.001***
Not proficient	209	47.29%	357	46.42%	328	39.33%		
Proficient & Advanced	183	41.40%	289	37.58%	396	47.48%		
Grade 5 Science proficiency	442	100.00%	769	100.00%	834	100.00%	$\chi^2 = 18.010$	<.001***
Not proficient	278	62.90%	492	63.98%	476	57.07%		
Proficient & Advance	113	25.57%	153	19.90%	247	29.62%		
ISASP Scores	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)		
Grade 8 Math scores	442	485.1 (41.3)	769	483.2 (38.0)	834	494.8 (46.1)	F=16.873	<.001***
Grade 8 Science scores	442	493.8 (48.1)	769	498.4 (45.7)	834	510.7 (51.6)	F=21.460	<.001***
Grade 8 ELA scores	438	497.7 (48.2)	768	492.0 (46.5)	827	509.8 (52.0)	F=27.083	<.001***
Grade 7 Math scores	401	462.8 (43.0)	644	461.5 (38.2)	732	477.3 (44.2)	F=29.107	<.001***
Grade 5 Math scores	392	432.2 (32.6)	646	430.1 (31.5)	724	438.8 (35.6)	F=12.319	<.001***
Grade 5 Science scores	391	433.1 (34.2)	645	429.6 (31.6)	723	438.0 (38.9)	F=9.606	<.001***

* $p < .05$; ** $p < .01$; *** $p < .001$

Note: Percentages may not sum to 100% due to missing data where the full sample was used as the denominator.

More specifically, ISASP grade 7 math scores significantly differed on average among the three groups ($F(2,1774)=29.107$, $p < .001$). Based on post-hoc pairwise

comparisons, intervention group 1 scores were significantly higher than group 2 ($p < .001$) and group 3 ($p < .001$) scores, but there was not a significant difference in ISASP grade 7 math scores between groups 2 and 3 ($p = 0.625$). Similarly, ISASP grade 5 math scores significantly differed on average among the three groups ($F(2,1759)=12.319$, $p < .001$). Based on post-hoc pairwise comparisons, intervention group 1 scores were significantly higher than group 2 ($p < .001$) and group 3 ($p = .002$) scores, but there was not a significant difference in ISASP grade 5 math scores between groups 2 and 3 ($p = 0.331$). ISASP grade 5 science scores also significantly differed on average among the three groups ($F(2,1756)=9.606$, $p < .001$). Based on post-hoc pairwise comparisons, intervention group 1 (more than one year of intervention) scores were significantly higher than group 2 (one year of intervention) ($p < .001$) and group 3 (limited or no intervention) ($p = .029$) scores, but there was not a significant difference in ISASP grade 5 science scores between groups 2 and 3 ($p = 0.122$).

Further analysis also includes the Chi Square analysis model which uses the formula below in figure 13. Based on the chi-squared test (Table 2), the percentage of students scoring at the proficient or advanced level combined also significantly differed among the intervention groups. For example, the percentage of students that were proficient or advanced in science at grade 5 significantly differed among the intervention groups ($\chi^2 = 18.010$, $df=2$, $p < .001$) with 29.62% of students in group 1 being proficient or advanced compared to 25.57% of students in group 3 and 19.90% of students in group 2.

Figure 13*Chi-Square Equation*

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

χ^2 = chi squared

O_i = observed value

E_i = expected value

There were also significant differences among the three intervention groups for many of the demographic characteristics. First, there was a significant difference in race/ethnicity among the three groups ($\chi^2 = 64.352$, $df=8$, $p < .001$) with group 2 being comprised of a smaller percentage of White students than the other two groups (22.63% vs. 35.75%-36.93%, respectively) as well as being comprised of a larger percentage of Black/African American students (24.71% vs. 14.93% or 20.62%). There was a significant difference in free or reduced lunch status among the three groups ($\chi^2 = 45.831$, $df=4$, $p < .001$) with group 2 having a greater percentage of students on free lunch than the other two groups (71.00% vs. 57.79%-67.65%, respectively). There was a significant difference in ELL status among the three groups ($\chi^2 = 38.528$, $df=4$, $p < .001$) with group 2 having a greater percentage of ELL students than the other two groups (23.80% vs. 13.19%-19.68%, respectively). There was a significant difference in special education status among the three groups ($\chi^2 = 6.480$, $df=2$, $p = 0.039$) with group 1 having a lower percentage of special education students than the other two groups (15.59% vs. 19.77%-20.36%, respectively). Each group included a smaller percentage (between 2.73% to 4.44%) of students on status 504 than were not on status 504 ($\chi^2 =$

3.345, $df=2$, $p = 0.188$). Each group was roughly composed of an even split between male and female students ($\chi^2 = 0.747$, $df=2$, $p = 0.688$).

Because there are existing differences in prior achievement levels and demographic characteristics among the intervention groups that can influence grade 8 achievement and proficiency levels, these other factors need to be considered when comparing grade 8 achievement scores and proficiency levels among the three intervention groups. These potential limitations will be discussed in chapter 5.

In the following sections, I will present the findings of the research by focusing on each of the research questions independently. Chapter 5 will feature further discussion outside of findings in relation to the research questions.

Research Question 1

Is there growth in student achievement for teachers who create classrooms focused on inquiry-based universal design for learning compared to the traditional method of instruction?

Table 3 provides the correlations among the ISASP test scores for the district. All correlations were positive and statistically significant ($p < .001$). The correlations ranged between .638 (for grade 5 ELA score and grade 8 math score) to .832 (for grade 7 ELA score and grade 8 ELA score). In particular, the correlation between grade 5 science score and grade 8 science score was 0.659 ($p < .001$). The correlation between grade 7 math score and grade 8 math score was .800 ($p < .001$).

Table 3*Bivariate Correlation Analysis*

<i>Correlations</i>		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ISASP score	Statistic								
Grade 8 Science Scale (1)	Pearson Correlation	--							
	N	2045							
Grade 8 Math Scale (2)	Pearson Correlation	.757**	--						
	N	2045	2045						
Grade 8 ELA Scale (3)	Pearson Correlation	.790**	.711**	--					
	N	2033	2033	2033					
Grade 7 Math Scale (4)	Pearson Correlation	.708**	.800**	.670**	--				
	N	1777	1777	1768	1777				
Grade 7 ELA Scale (5)	Pearson Correlation	.746**	.704**	.837**	.740**	--			
	N	1753	1753	1743	1740	1753			
Grade 5 Math Scale (6)	Pearson Correlation	.658**	.728**	.658**	.727**	.675**	--		
	N	1762	1762	1753	1630	1608	1762		
Grade 5 ELA Scale (7)	Pearson Correlation	.666**	.638**	.728**	.653**	.705**	.725**	--	
	N	1762	1762	1753	1630	1608	1762	1762	
Grade 5 Science Scale (8)	Pearson Correlation	.650**	.653**	.675**	.647**	.706**	.727**	.758**	--
	N	1759	1759	1750	1628	1606	1759	1759	1759

***. Correlation is significant at the 0.01 level (2-tailed). p-values for all tests < .001*

Multiple Linear Regression Results for Grade 8 Math and Science Scores

Table 3 provides the results from the multiple linear regression results for grade 8 ISASP math and science scores in relation to the intervention group while statistically controlling for prior achievement and student demographic characteristics. Figure 14 below breaks down the multiple linear regression formula.

Figure 14*Multiple Linear Regression Formula*

$$y = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \epsilon$$

- y = the predicted value of the dependent variable
- B_0 = the y-intercept (value of y when all other parameters are set to 0)
- $B_1 X_1$ = the regression coefficient (B_1) of the first independent variable (X_1) (a.k.a. the effect that increasing the value of the independent variable has on the predicted y value)
- ... = do the same for however many independent variables you are testing
- $B_n X_n$ = the regression coefficient of the last independent variable
- ϵ = model error (a.k.a. how much variation there is in our estimate of y)

Table 4*Multiple Linear Regression- Science (N = 1,628)*

Coefficients

Model	Unstandardized Coefficient				Collinearity Statistic
	<i>B</i>	<i>Standard Error</i>	<i>t</i>	<i>p</i> -value	Variance Inflation Factor (VIF)
Constant	79.634	13.155	6.054	<.001	
Grade 5 Science Scale	0.444	0.030	14.925	<.001	1.862
Grade 7 Math Scale	0.492	0.026	19.159	<.001	1.951
Intervention			<i>F</i> =7.698	<.001	
More than one year intervention vs. Limited/none	6.223	2.061	3.019	0.003	1.701
One year intervention vs. Limited/none	8.109	2.115	3.835	<.001	1.691
Gender - Female vs. Male	2.506	1.584	1.582	0.114	1.033
Race/ethnicity			<i>F</i> =4.337	0.002	
Asian	9.724	3.546	2.742	0.006	1.587
Black/African American	-4.455	2.570	-1.734	0.083	1.650
Hispanic	-1.050	2.608	-0.403	0.687	2.457
Multiracial or other race	-1.465	3.121	-0.469	0.639	1.180
Free and reduced lunch (FRL) status			<i>F</i> =5.765	0.003	
Free lunch vs. No FRL	-7.163	2.135	-3.355	<.001	1.767
Reduced lunch vs. No FRL	-4.096	2.984	-1.372	0.170	1.465
ELL status			<i>F</i> = 9.811	<.001	
ELL vs. non-ELL	-3.175	2.688	-1.182	0.238	1.647
Exit ELL vs. non-ELL	8.649	2.594	3.334	<.001	1.752
Special education status - Yes vs. No	-10.168	2.215	-4.591	<.001	1.219
Status 504 - Yes vs. No	4.161	4.155	1.001	0.317	1.043

a Dependent Variable: Grade 8 Science Scale

R-squared for the model = 0.598.

Science Test Score Results

The model shown in Table 4.3 for science achievement accounts for 59.8% of the variation in grade 8 ISASP science scores. The grade 7 math score was included because it improved the model fit by 13.3 percentage points. If a more proximal science score was available (from grade 7), it would have been included instead of the grade 7 math score, however students only take the science portion of the exam in grades 5, 8 and 10. This was also part of the grade level selection criteria to only include the students in 8th grade in the 21-22 school year. Prior year 8th graders would have missed the testing due to

Covid-19 closures. The model was based on 1,628 students who had all prior science and math achievement scores and demographic characteristics available.

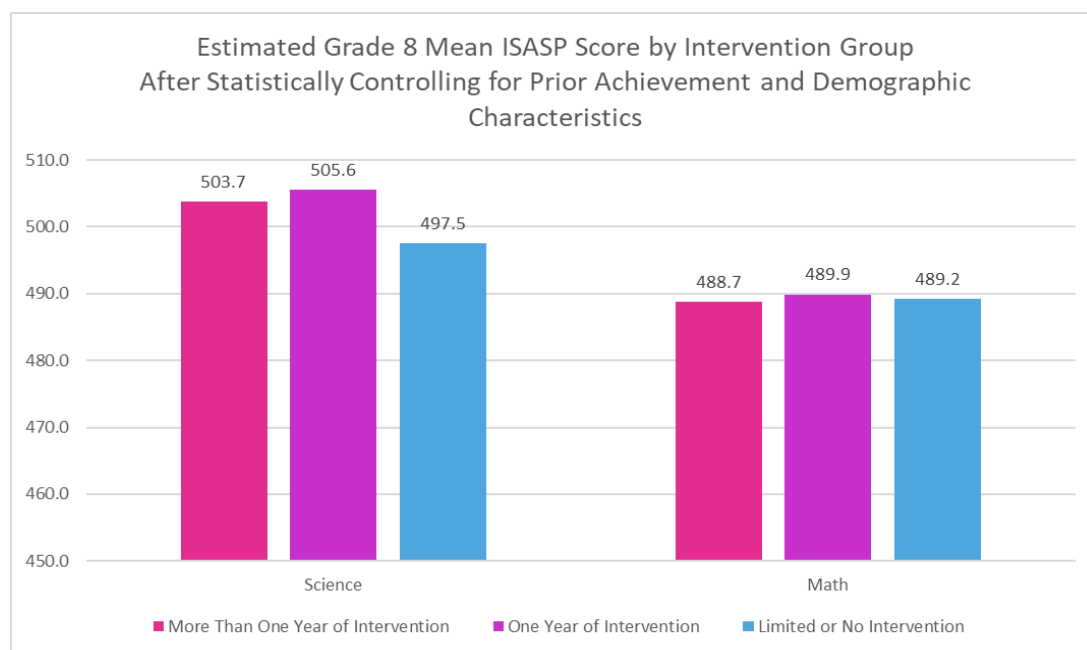
The following prior achievement scores and demographic characteristics were significantly related to grade 8 ISASP science scores for the district: grade 5 science scores ($t(1612) = 14.925, p < .001$), grade 7 math scores ($t(1612) = 19.159, p < .001$), race/ethnicity ($F(4,1612) = 4.337, p = .002$), free or reduced lunch status ($F(2,1612) = 5.765, p = .003$), ELL status ($F(2,1612) = 9.811, p < .001$), and special education status ($t(1612) = -4.591, p < .001$). For an example of how to interpret the parameter estimates for some of the significant demographic characteristics from the model shown in Table 4.3 such as race/ethnicity: Grade 8 science scores were significantly higher on average for Asian students than for White students (by 9.7 score scale units, $p = 0.006$), holding all other variables in the model constant. Grade 8 science scores for the other race/ethnic groups (e.g., Black/African American, Hispanic, and multiracial or other race) did not significantly differ from those of White students, on average (p ranged from .083 for Black/African American students to 0.687 for Hispanic students).

After statistically controlling for students' prior achievement levels and demographic groups, there was a statistically significant difference in ISASP grade 8 science scores among the three intervention groups ($F(2,1612) = 7.698, p < .001$). More specifically, grade 8 ISASP science scores for those with more than one year of intervention or those with one year of intervention were 6.2 score scale units higher on average ($t(1612) = 3.019, p = .003$) or 8.1 score scale units higher on average ($t(1612) = 3.835, p < .001$) than those with no or limited intervention, respectively, holding all other variables in the multiple linear regression model constant.

Figure 15 shows the estimated grade 8 mean ISASP score by intervention group after holding the other variables in the multiple linear regression model constant at their sample mean values. As shown in the figure, the estimated mean grade 8 science score was estimated to be 503.7 for the more than one year of intervention group, 505.6 for the one year of intervention group, and 497.5 for the limited or no intervention group. If the difference between grade 5 and grade 8 ISASP science scores had been used as the outcome instead of the grade 8 ISASP science scores, the same typical differences among the intervention groups would have resulted. Note: the difference in scores across grade levels is possible to calculate because the score scale of the ISASP is a vertical scale that spans the full performance continuum on each test from grades 3 to 11.

Figure 15

Estimated Grade 8 Mean ISASP Score by Intervention Group



Based on multiple linear regression results for this alternative outcome of student growth, the estimated mean ISASP three-year science score change was estimated to be 69.8 for the more than one year of intervention group, 71.7 for the one year of intervention group, and 63.6 for the limited or no intervention group, after holding all other variables in the model constant at their sample mean values. The assumptions for applying linear regression – namely, normality of the residuals and homoscedasticity – were satisfied. Additionally, although there were moderate to large size correlations among the grade 7 math and grade 5 science scores (Table 2) the variance inflation factors (VIF) did not suggest that collinearity was an issue among the independent variables in the regression model (all VIF < 2.5). The assumption of independence among student records is likely not satisfied given that students are clustered within classrooms. However, the classroom level data was not available to evaluate and account for the nesting of students within classrooms. Therefore, it is important to keep this limitation in mind for this study.

Given the district had interest in examining growth for ELL students, I conducted supplemental analyses to examine whether ELL status moderated the relationship between the intervention groups and ISASP grade 8 science scores. In these supplemental analyses, the interaction between ELL status and the three groups on grade 8 science scores was evaluated. The overall interaction effect between ELL status and the three groups on grade 8 science scores was not statistically significant ($F(4,1608)=0.536, p = .709$), after statistically controlling for all the other variables shown in Table 4.3 This finding suggests that the impact of the intervention on science achievement as measured by ISASP grade 8 science scores did not differ across the ELL status groups.

Math Test Score Results

The model shown in Table 4.4 for math achievement accounts for 68.9% of the variation in grade 8 ISASP math scores. The following prior achievement scores and demographic characteristics were significantly related to grade 8 ISASP math scores for the district: grade 7 math scores ($t(1614) = 26.362, p < .001$), grade 5 math scores ($t(1614) = 14.644, p < .001$), free or reduced lunch status ($F(2,1614) = 8.692, p < .001$), ELL status ($F(2,1614) = 4.367, p = .013$), and status 504 ($t(1614) = 2.702, p = .007$). For an example of how to interpret the parameter estimates for some of the significant demographic characteristics from the model shown in Table 4 such as for free or reduced lunch status: Grade 8 math scores were significantly lower on average for students on free lunch (by 6.3 score scale units, $p < 0.001$) and for students on reduced lunch (by 7.9 score scale units, $p < 0.001$) than for students not on free or reduced lunch, holding all other variables in the model constant.

Table 5*Multiple Linear Regression- Math (N=1,630)**Coefficients*

Model	Unstandardized Coefficients				Collinearity Statistics
	B	Std. Error	t	p-value	Variance Inflation Factor (VIF)
Constant	59.743	10.227	5.842	<.001	
Grade 7 Math Scale	0.561	0.021	26.362	<.001	2.298
Grade 5 Math Scale	0.390	0.027	14.644	<.001	2.306
Intervention			F=0.345	0.708	
More than one year intervention vs. Limited/none	-0.459	1.573	-0.292	0.771	1.697
One year intervention vs. Limited/none	0.699	1.615	0.433	0.665	1.689
Gender - Female vs. Male	1.315	1.208	1.089	0.276	1.029
Race/ethnicity			F=0.691	0.598	
Asian	0.175	2.707	0.065	0.948	1.582
Black/African American	1.274	1.949	0.654	0.514	1.627
Hispanic	-1.592	1.986	-0.802	0.423	2.440
Multiracial or other race	-1.212	2.377	-0.510	0.610	1.179
Free and reduced lunch (FRL) status			F=8.692	<.001	
Free lunch vs. No FRL	-6.266	1.634	-3.836	<.001	1.772
Reduced lunch vs. No FRL	-7.853	2.279	-3.447	<.001	1.461
ELL status			F=4.367	0.013	
ELL vs. non-ELL	1.852	2.057	0.900	0.368	1.651
Exit ELL vs. non-ELL	5.802	1.982	2.927	0.003	1.751
Special education status - Yes vs. No	1.333	1.711	0.780	0.436	1.244
Status 504 - Yes vs. No	8.528	3.157	2.702	0.007	1.046

a Dependent Variable: Grade 8 Math Scale

R-squared for the model = 0.689.

After statistically controlling for students' prior achievement levels and demographic groups, there was not a statistically significant difference in ISASP grade 8 math scores among the three intervention groups ($F(2,1614) = 0.345, p = .708$). Figure 15 shows the estimated grade 8 mean ISASP math score by intervention group after holding the other variables in the multiple linear regression model constant at their sample mean values. As shown in the figure, the estimated mean grade 8 math score was estimated to be 488.7 for the more than one year of intervention group, 489.9 for the one year of intervention group, and 489.2 for the limited or no intervention group. If the difference between grade 7 and grade 8 ISASP math scores had been used as the outcome

instead of the grade 8 ISASP math scores, the same typical differences among the intervention groups would have resulted. Note: the difference in scores across grade levels is possible to calculate because the score scale of the ISASP is a vertical scale that spans the full performance continuum on each test from grades 3 to 11.

More specifically, the estimated mean ISASP math score one-year change was estimated to be 20.4 for the more than one year of intervention group, 21.6 for the one year of intervention group, and 20.9 for the limited or no intervention group, after holding all other variables in the model constant at their sample mean values. The assumptions for applying linear regression – namely, normality of the residuals and homoscedasticity – were satisfied. Additionally, although there were moderate to large size correlations among the grade 7 math and grade 5 math scores (Table 2), the variance inflation factors (VIF) did not suggest that collinearity was an issue among the independent variables in the regression model (all VIF < 2.5). The assumption of independence among student records is likely not satisfied given that students are clustered within classrooms. However, the classroom level data was not available to evaluate and account for the nesting of students within classrooms. Therefore, it is important to keep this limitation in mind for this study.

Supplementary ELA Test Score Results

Given that the intervention group was confounded with school building (i.e., the inquiry-based curriculum was implemented schoolwide at the middle school) and students were not randomly assigned to groups, I conducted supplementary analyses to determine whether grade 8 ELA ISASP scores significantly differed among the intervention groups to provide additional evidence supporting the science finding in this

study. It was hypothesized that given that the intervention is related to science discovery and inquiry that there would be no differences. Table 6 provides the results from the multiple linear regression results for grade 8 ISASP ELA scores in relation to the intervention group while statistically controlling for prior achievement and student demographic characteristics. The model was based on 1,599 students who had all prior ELA achievement scores and demographic characteristics available.

After statistically controlling for students' prior achievement levels and demographic groups, there was a statistically significant difference in ISASP grade 8 ELA scores among the three intervention groups ($F(2,1583) = 4.274, p = .014$). However, ISASP grade 8 ELA scores were found to be significantly lower for the one-year intervention group ($t(1583)=-2.106, p = 0.035$) than the limited or no intervention group by 3.6 scale score units; a finding in the opposite direction of that for grade 8 science scores. There was not a statistically significant difference in mean grade 8 ELA scores between the more than one year intervention group and the limited or no intervention group ($t(1583)=0.293, p = 0.770$).

Table 6*Multiple Linear Regression Table - ELA (N=1,599)*

Model	Unstandardized Coefficients				Collinearity Statistics
	B	Std. Error	t	p-value	Variance Inflation Factor (VIF)
Constant	57.623	11.151	5.168	<.001	
Grade 7 ELA Scale	0.603	0.024	24.828	<.001	2.930
Grade 5 ELA Scale	0.386	0.031	12.416	<.001	3.230
Intervention			<i>F</i> =4.274	0.014	
More than one year intervention vs. Limited/none	0.488	1.666	0.293	0.770	1.693
One year intervention vs. Limited/none	-3.625	1.721	-2.106	0.035	1.697
Gender - Female vs. Male	4.990	1.282	3.894	<.001	1.029
Race/ethnicity			<i>F</i> =2.326	0.054	
Asian	0.524	2.884	0.182	0.856	1.580
Black/African American	-4.170	2.077	-2.007	0.045	1.646
Hispanic	-4.844	2.104	-2.303	0.021	2.424
Multiracial or other race	-2.021	2.518	-0.803	0.422	1.180
Free and reduced lunch (FRL) status			<i>F</i> =6.738	<.001	
Free lunch vs. No FRL	-5.403	1.736	-3.113	0.002	1.780
Reduced lunch vs. No FRL	-7.988	2.412	-3.311	<.001	1.451
ELL status			<i>F</i> =3.030	0.049	
ELL vs. non-ELL	4.508	2.254	2.000	0.046	1.741
Exit ELL vs. non-ELL	4.500	2.102	2.141	0.032	1.758
Special education status - Yes vs. No	-7.813	1.914	-4.083	<.001	1.375
Status 504 - Yes vs. No	-0.748	3.322	-0.225	0.822	1.048

a Dependent Variable: Grade 8 ELA Scale

R-squared for the model = 0.740.

After holding the other variables in the multiple linear regression model constant at their sample mean values, the estimated mean grade 8 ELA score was estimated to be 504.1 for the more than one year of intervention group, 500.0 for the one year of intervention group, and 503.6 for the limited or no intervention group. If the difference between grade 7 and grade 8 ISASP ELA scores had been used as the outcome instead of the grade 8 ISASP ELA scores, the same typical differences among the intervention groups would have resulted. Based on multiple linear regression results for this alternative outcome of student growth, the estimated mean ISASP ELA score one-year change was estimated to be 36.1 for the more than one year of intervention group, 32.0

for the one year of intervention group, and 35.6 for the limited or no intervention group, after holding all other variables in the model constant at their sample mean values.

The model estimated for ELA achievement accounts for 74.0% of the variation in grade 8 ISASP ELA scores. The following prior achievement scores and demographic characteristics were significantly related to grade 8 ISASP ELA scores for the district: grade 7 ELA scores ($t(1583) = 24.828, p < .001$), grade 5 ELA scores ($t(1583) = 12.416, p < .001$), gender ($t(1583) = 3.894, p < .001$), free or reduced lunch status ($F(2,1583) = 6.738, p < .001$), ELL status ($F(2,1583) = 3.030, p = .049$), and special education status ($t(1583) = -4.083, p < .001$). The assumptions for applying linear regression – namely, normality of the residuals and homoscedasticity – were satisfied. Additionally, although there were moderate to large size correlations among the grade 7 ELA and grade 5 ELA scores (Table 4.2) the variance inflation factors (VIF) did not suggest that collinearity was an issue among the independent variables in the regression model (all VIF < 3.3). The assumption of independence among student records is likely not satisfied given that students are clustered within classrooms. However, the classroom level data was not available to evaluate and account for the nesting of students within classrooms. Therefore, it is important to keep this limitation in mind for this study.

Multiple Logistic Regression Results for Grade 8 Math and Science Proficiency Levels

The district not only reviews students' ISASP subject scores, but also examines students' proficiency levels. Therefore, in addition to analyzing ISASP subject scores, I also examined the differences in science and math proficiency rates among the intervention groups.

Science Proficiency Results

Table 7 provides the results from the multiple logistic regression results for grade 8 science proficiency rates in relation to intervention group while statistically controlling for prior achievement and student demographic characteristics. In terms of model fit for the model shown in Table 7 for science proficiency, the classification accuracy was 82.1% representing a 27.3 percentage point increase over the baseline accuracy rate of 54.8%. Additionally, the Nagelkerke R-square value was 0.567. The grade 7 math score was included in the grade 8 proficiency model to be consistent with it being included in the model for grade 8 science scores. If a more proximal science score was available (from grade 7), it would have been included instead of the grade 7 math score. The following prior achievement scores and demographic characteristics were significantly related to grade 8 science proficiency for the district: grade 5 science scores (Wald χ^2 test statistic(1) = 75.062, $p < .001$), grade 7 math scores (Wald χ^2 test statistic(1) = 113.714, $p < .001$), race/ethnicity (Wald χ^2 test statistic(4) = 15.637, $p = .004$), ELL status (Wald χ^2 test statistic(2) = 22.784, $p < .001$), and special education status (Wald χ^2 test statistic(1) = 19.001, $p < .001$).

Table 7*Multiple Logistic Regression Model for Grade 8 Science Proficiency or Higher*Table 4.6: Multiple Logistic Regression Model for Grade 8 Science Proficiency
(Analyses based on 1,628 students)

Variable	B	SE	Wald Chi-square	df	p	OR
Intercept	-24.396	1.584	237.063	1	<.001	
Grade 5 science score	0.025	0.003	75.062	1	<.001	1.025
Grade 7 math score	0.029	0.003	113.714	1	<.001	1.029
Intervention group			8.593	2	0.014	
More than 1 year vs. Limited/none	0.436	0.183	5.685	1	0.017	1.546
One year vs. Limited/none	0.532	0.188	8.022	1	0.005	1.702
Gender - Female vs. Male	0.254	0.139	3.342	1	0.068	1.289
Race/ethnicity			15.637	4	0.004	
Asian vs. White	0.472	0.301	2.455	1	0.117	1.603
Black/African American vs. White	-0.407	0.222	3.372	1	0.066	0.666
Hispanic vs. White	-0.398	0.222	3.203	1	0.074	0.672
Multiracial or other race vs. White	-0.458	0.266	2.973	1	0.085	0.632
Free or reduced lunch status			5.157	2	0.076	
Free lunch vs. No FRL	-0.395	0.18	4.814	1	0.028	0.674
Reduced lunch vs. No FRL	-0.181	0.25	0.523	1	0.469	0.834
ELL status			22.784	2	<.001	
ELL vs. non-ELL	-0.308	0.26	1.401	1	0.237	0.735
Exit ELL vs. non-ELL	0.757	0.206	13.464	1	<.001	2.132
Special education status - Yes vs. No	-1.050	0.241	19.001	1	<.001	0.350
Status 504 - Yes vs. No	0.271	0.355	0.585	1	0.444	1.312

Note. B = unstandardized parameter estimate; SE = standard error; df = degrees of freedom; OR = odds ratio
The classification accuracy of the model was 82.1% and Nagelkerke R-square = 0.567.

As an example for interpreting the adjusted odds ratios for the demographic characteristics included in the model such as free or reduced lunch status: the odds of achieving grade 8 science proficiency was estimated to be 0.674 times lower for students on free lunch than for students not on free or reduced lunch (Wald χ^2 test statistic(1) = 4.814, $p = 0.028$), holding all other variables in the model constant. Grade 8 proficiency rates did not significantly differ between students on reduced lunch and those not on free or reduced lunch (Wald χ^2 test statistic(1) = 0.523, $p = 0.469$).

After statistically controlling for students' prior achievement levels and demographic groups, there was a statistically significant difference in grade 8 science

proficiency rates among the three intervention groups (Wald χ^2 test statistic(2) = 8.593, $p = .014$). More specifically, the odds of achieving grade 8 science proficiency was estimated to be 1.546 times greater for students from the more than one year intervention group (Wald χ^2 test statistic(1) = 5.685, $p = .017$) and 1.702 times greater for students from the one year intervention group (Wald χ^2 test statistic(1) = 8.022, $p = .005$) than those with no or limited intervention, respectively, holding all other variables in the multiple logistic regression model constant.

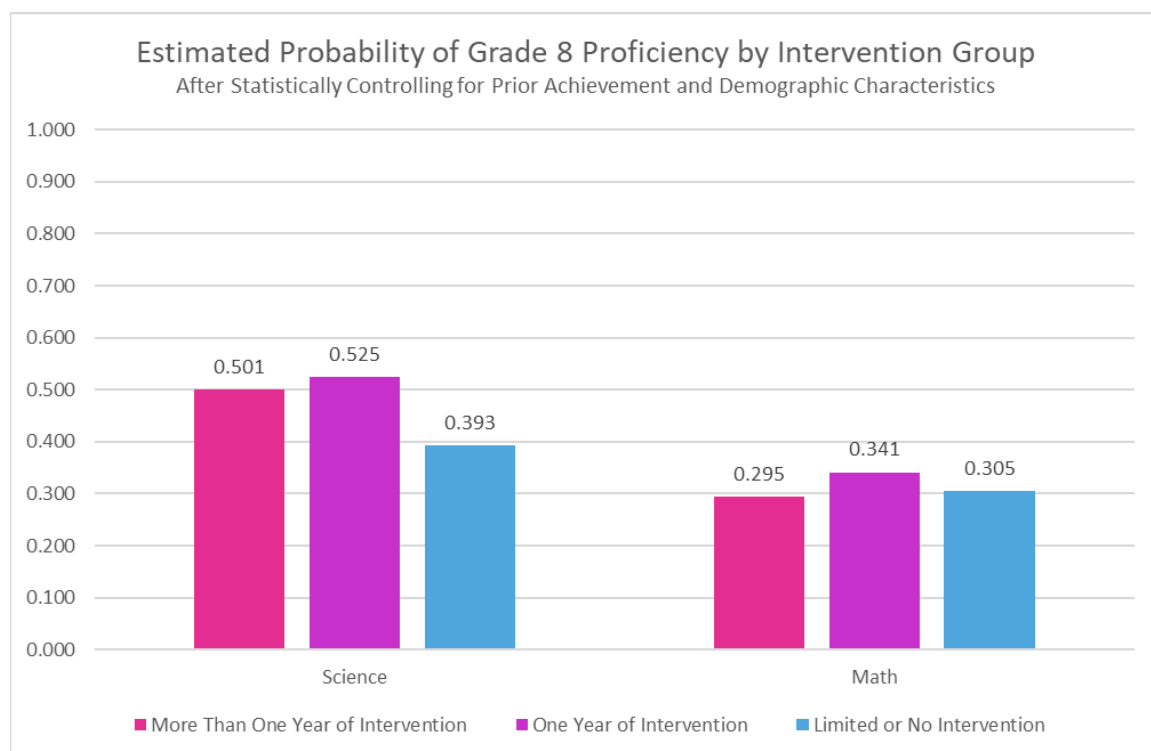
Figure 16 shows the estimated probability of grade 8 science proficiency or higher by intervention group after holding the other variables in the multiple logistic regression model constant at their sample mean values. As shown in the figure, the estimated probability of being proficient or above proficient in science at grade 8 was estimated to be 0.501 for the more than one year of intervention group, 0.525 for the one year of intervention group, and 0.393 for the limited or no intervention group. The assumption of independence among student records is likely not satisfied given that students are clustered within classrooms. However, the classroom level data was not available to evaluate and account for the nesting of students within classrooms. Therefore, it is important to keep this limitation in mind for this study.

Additionally, similar to that for science scores, I conducted supplemental analyses, to examine the interaction between ELL status and the three groups on grade 8 science proficiency was evaluated. The overall interaction effect between ELL status and the three groups on grade 8 science proficiency was not statistically significant (Wald χ^2 test statistic(4) = 0.878, $p = .928$), after statistically controlling for all the other variables

shown in Table 7. This finding suggests that the impact of the intervention on science proficiency did not differ across the ELL status groups.

Figure 16

Estimated Probability of Grade 8 Proficiency by Intervention Group



Math Proficiency Results

Table 8 provides the results from the multiple logistic regression results for grade 8 math proficiency rates in relation to intervention group while statistically controlling for prior achievement and student demographic characteristics. In terms of model fit for the model shown in Table 8 for math proficiency, the classification accuracy was 83.1% representing a 23 percentage point increase over the baseline accuracy rate of 60.1%.

Additionally, the Nagelkerke R-square value was 0.633. The following prior achievement

scores and demographic characteristics were significantly related to grade 8 math proficiency for the district: grade 7 math scores (Wald χ^2 test statistic(1) = 142.707, $p < .001$), grade 5 math scores (Wald χ^2 test statistic(1) = 85.935, $p < .001$), free or reduced lunch status (Wald χ^2 test statistic(2) = 9.398, $p = .009$), ELL status (Wald χ^2 test statistic(2) = 14.674, $p < .001$), and special education status (Wald χ^2 test statistic(1) = 4.695, $p = .03$). For an example interpretation for the adjusted odds ratios for one of the demographic characteristics such as free or reduced lunch status: the odds of achieving grade 8 math proficiency was estimated to be 0.666 times lower for students on free lunch (Wald χ^2 test statistic(1) = 4.505, $p = 0.034$) and 0.434 times lower for students on reduced lunch (Wald χ^2 test statistic(1) = 9.028, $p = 0.003$) than for students not on free or reduced lunch, holding all other variables in the model constant.

Table 8*Multiple Logistic Regression Model for Grade 8 Math Proficiency*Table 4.7: Multiple Logistic Regression Model for Grade 8 Math Proficiency
(Analyses based on 1,630 students)

Variable	B	SE	Wald Chi-square	df	p	OR
Intercept	-32.473	1.906	290.155	1	<.001	
Grade 7 math score	0.038	0.003	142.707	1	<.001	1.039
Grade 5 math score	0.033	0.004	85.935	1	<.001	1.034
Intervention group			1.601	2	0.449	
More than 1 year vs. Limited/none	-0.048	0.197	0.06	1	0.806	0.953
One year vs. Limited/none	0.165	0.202	0.662	1	0.416	1.179
Gender - Female vs. Male	-0.003	0.15	0	1	0.984	0.997
Race/ethnicity			1.919	4	0.751	
Asian vs. White	0.122	0.314	0.15	1	0.698	1.130
Black/African American vs. White	-0.129	0.24	0.288	1	0.591	0.879
Hispanic vs. White	-0.198	0.239	0.686	1	0.408	0.820
Multiracial or other race vs. White	-0.175	0.287	0.37	1	0.543	0.840
Free or reduced lunch status			9.398	2	0.009	
Free lunch vs. No FRL	-0.407	0.192	4.505	1	0.034	0.666
Reduced lunch vs. No FRL	-0.834	0.278	9.028	1	0.003	0.434
ELL status			14.674	2	<0.001	
ELL vs. non-ELL	-0.259	0.303	0.731	1	0.393	0.772
Exit ELL vs. non-ELL	0.68	0.222	9.393	1	0.002	1.973
Special education status - Yes vs. No	-0.607	0.28	4.695	1	0.03	0.545
Status 504 - Yes vs. No	0.407	0.375	1.18	1	0.277	1.503

Note. B = unstandardized parameter estimate; SE = standard error; df = degrees of freedom; OR = odds ratio
The classification accuracy of the model was 83.1% and Nagelkerke R-square = 0.633.

After statistically controlling for students' prior achievement levels and demographic groups, there was not a statistically significant difference in grade 8 math proficiency rates among the three intervention groups (Wald χ^2 test statistic(2) = 1.601, $p = .449$). Figure 16 shows the estimated probability of grade 8 math proficiency by intervention group after holding the other variables in the multiple logistic regression model constant at their sample mean values. As shown in the figure, the estimated probability of being proficient or above proficient in math at grade 8 was estimated to be 0.295 for the more than one year of intervention group, 0.341 for the one year of intervention group, and 0.305 for the limited or no intervention group. The assumption of independence among student records is likely not satisfied given that students are clustered within classrooms. However, the classroom level data was not available to

evaluate and account for the nesting of students within classrooms. Therefore, it is important to keep this limitation in mind for this study.

Supplemental ELA Proficiency Results

Given that the intervention group was confounded with school building (i.e., the inquiry-based curriculum that was implemented schoolwide at the middle school) and students were not randomly assigned to groups, I conducted supplementary analyses similar to those for ISASP ELA test scores to determine whether grade 8 ELA proficiency rates significantly differed among the intervention groups to provide additional evidence supporting the science finding in this study. It was hypothesized that given that the intervention is related to science discovery and inquiry so that there would be no differences. Table 9 provides the results from the multiple logistic regression results for grade 8 ISASP ELA proficiency rates in relation to the intervention group while statistically controlling for prior achievement and student demographic characteristics.

In terms of model fit for the multiple logistic regression model for ELA proficiency, the classification accuracy was 85.7% representing a 29.6 percentage point increase over the baseline accuracy rate of 56.1%. Additionally, the Nagelkerke R-square value as 0.685. The following prior achievement scores and demographic characteristics were significantly related to grade 8 math proficiency for the district: grade 7 ELA scores (Wald χ^2 test statistic(1) = 163.11, $p < .001$), grade 5 ELA scores (Wald χ^2 test statistic(1) = 39.063, $p < .001$), gender (Wald χ^2 test statistic(1) = 7.757, $p = .005$), ELL status (Wald χ^2 test statistic(2) = 10.372, $p = .006$), and special education status (Wald χ^2 test statistic(1) = 7.036, $p = .008$). An example of an interpretation for the adjusted odds ratios for one of

the demographic characteristics such as gender: the odds of achieving grade 8 ELA proficiency or higher was estimated to be 1.553 times greater for female students than male students (Wald χ^2 test statistic = 7.757, $p = .005$), holding all other variables in the model constant. After statistically controlling for students' prior achievement levels and demographic groups, there was not a statistically significant difference in grade 8 ELA proficiency rates among the three intervention groups (Wald χ^2 test statistic(2) = 5.890, $p = .053$).

Table 9

Multiple Logistic Regression Model for Grade 8 ELA Proficiency

Table 4.8: Multiple Logistic Regression Model for Grade 8 ELA Proficiency
(Analyses based on 1,599 students)

Variable	B	SE	Wald Chi-square	df	<i>p</i> -value	OR
Intercept	-30.306	1.984	233.44	1	<.001	
Grade 7 ELA score	0.044	0.003	163.11	1	<.001	1.045
Grade 5 ELA score	0.024	0.004	39.063	1	<.001	1.025
Intervention group			5.89	2	0.053	
More than 1 year vs. Limited/none	0.169	0.208	0.659	1	0.417	1.184
One year vs. Limited/none	-0.268	0.214	1.565	1	0.211	0.765
Gender - Female vs. Male	0.44	0.158	7.757	1	0.005	1.553
Race/ethnicity			6.947	4	0.139	
Asian vs.White	-0.004	0.366	0	1	0.991	0.996
Black/African American vs. White	-0.344	0.244	1.988	1	0.158	0.709
Hispanic vs. White	-0.566	0.258	4.816	1	0.028	0.568
Multiracial or other race vs. White	-0.156	0.311	0.251	1	0.616	0.855
Free or reduced lunch status			4.208	2	0.122	
Free lunch vs. No FRL	-0.445	0.219	4.145	1	0.042	0.641
Reduced lunch vs. No FRL	-0.416	0.297	1.958	1	0.162	0.660
ELL status			10.372	2	0.006	
ELL vs. non-ELL	0.04	0.288	0.02	1	0.889	1.041
Exit ELL vs. non-ELL	0.708	0.242	8.567	1	0.003	2.030
Special education status - Yes vs. No	-0.671	0.253	7.036	1	0.008	0.511
Status 504 - Yes vs. No	-0.508	0.435	1.367	1	0.242	0.602

Note. B = unstandardized parameter estimate; SE = standard error; df = degrees of freedom; OR = odds ratio
The classification accuracy of the model was 85.7% and Nagelkerke R-square = 0.685.

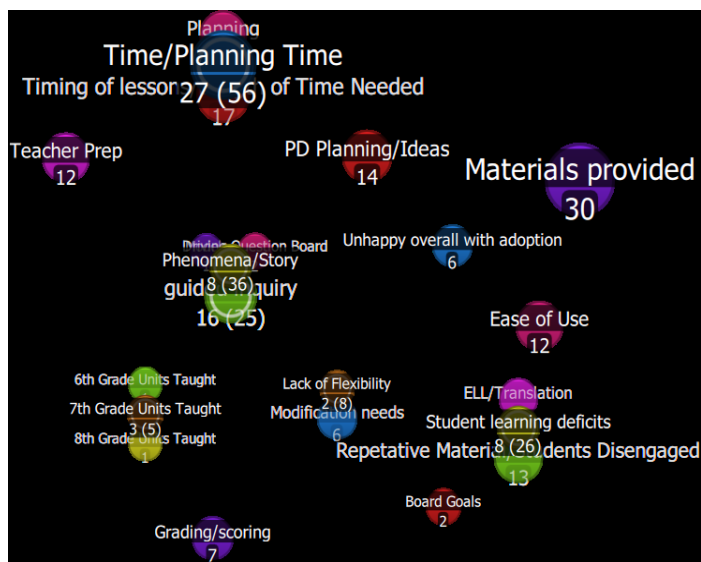
The estimated probability of grade 8 ELA proficiency by intervention group after holding the other variables in the multiple logistic regression model constant at their sample mean values. The estimated probability of being proficient or above proficient in ELA at grade 8 was estimated to be 0.626 for the more than one year of intervention

group, 0.519 for the one year of intervention group, and 0.586 for the limited or no intervention group. The assumption of independence among student records is likely not satisfied given that students are clustered within classrooms. However, the classroom level data was not available to evaluate and account for the nesting of students within classrooms. Therefore, it is important to keep this limitation in mind for this study.

Research Question 2

How can a shift in teaching practice from a traditional approach to a focus on inquiry-based universal design for learning impact student autonomy and conceptual learning?

When the survey results were analyzed, it was made clear in the themes presented and interviews of participants that the desired outcome was to be in the state of inquiry, however based on teacher perceptions we are not at that teaching point yet. It was also clear within the thematic coding that time and preparation was a key factor in the shift to this paradigm. Below is an example of the Quirks (thematic groupings) found and the quantity of each notation of theme.

Figure 17*Quirks or Coding Groups from Survey and Interview Analysis*

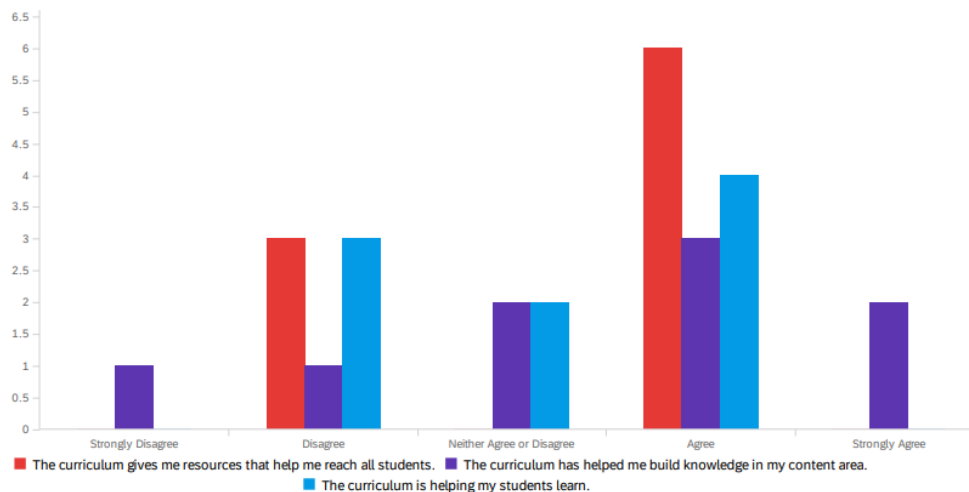
When coding into further subgroups under time, it was evident that teachers were overwhelmed with the quantity of supplies and documents provided, but thankful at the same time. Many felt overwhelmed by the amount of time needed to learn and present the materials effectively. One survey respondent stated “the preparation time for some lessons is unreasonable. Some lessons take up to 8 hours to plan.” This also led to further groupings under lack of flexibility and ease of use. Even at opposite ends of the spectrum, both were found to be open dynamics of teacher perception. Though teachers were appreciative of the ease of locating materials and guide information, the sheer amount was hard to digest in the limited planning time frames currently being faced within the district. When asked What about planning around this curriculum seems to be the most difficult, a survey respondent stated “Trying to fit it in the time allotted, trying to do labs with full classes (30+), the curriculum is dense and a LOT of teacher reading (although it is good that it is complete)”. Another response states “Reading the teacher

guide. There was no training on how to do so from DMPS. It is also hard to find alternatives for lessons when supplies aren't at our buildings.” Though many had constructive or negative comments based on the timing and planning, there were several survey responses that were positive in regards to planning for the new curriculum, one such comment was “I do appreciate having resources at my fingertips. It is wonderful to have suggestions for discussions with students! That really helps. Having materials translated to Spanish is also helpful.” To aid in this planning time, the district did approve up to 20 hours of paid time outside of contract time for teachers to be able to engage in curriculum development and planning.

A non-conventional review of the prevalent terms can be found in a word cloud as seen below. When developing thematic codes, being able to process consistent terms was helpful in further coding process. Figure 18 below shows a word cloud developed from all survey responses, interviews, and observation notes.

Figure 19*Survey Responses to Question 1*

Q1 - The following statements are centered around teacher satisfaction with the inquiry based learning curriculum.



Equity of access to high quality curriculum and instruction is a deeply embedded goal within DMPS and evident in this response that we have the materials within this curriculum to achieve this step within the perception of the teacher's responses. During the interview with Janice at Bradley Middle School, she responded to the connection to the DMPS board goals with, "...because inquiry is so much about problem solving and being able to read well, follow directions well and thinking to algebra you can also tie it to reading because even if we give them instructions you still have to be able to process the instructions and get your thoughts down on paper which all the tie into reading and problem solving. So yeah, it could. It really could." Chapter 5 will present recommendations for this need within the district.

Research Question 3

How does teacher education and professional development impact teacher practices and the opportunities they create for students to learn science?

Within the interview, participants were asked about their professional development and preparation to develop a classroom based in IBSE. This was also a question on the survey. In the survey one response was, “Not much, really. But I was in college in the 80's. The most beneficial aspect was practicum and student teaching. We have to actually DO it to learn HOW to do it.” Within the interview, all three participants were eager to participate in any professional development available to them. Hannah at Channel Middle School offered this response to the need for professional development, “I like, I like professional development that is useful. I like professional development that applies to me. I like professional development that is not repetitive.” Janice at Bradley also included, “helpful PD where you get to actually collaborate with other teachers and like bounce ideas. And here's what I did. Here's what I did, and we kind of concluded together that this is what's best practice. Those ones are always great.” Each participant also mentioned that they would like to have time to observe urban classrooms using this curriculum to gauge the structure of the procedures and classroom needs in an urban setting. Also, during the interview portion, the three participants were not originally taught in teacher preparation programs how to use or instruct with IBSE. They were either outside the time of instruction of IBSE or moving from other content areas and not originally in the science instruction program.

Within the survey, teachers were asked if further collegiate preparation was needed for this change, several teachers responded with a positive response signifying

that we do need further instruction, but not classroom instruction, instead needing physical introduction into the classrooms and placements into classrooms who are successfully using OpenSciEd to better learn how to use the curriculum. One survey response reflected just that, “Prep programs need to help support teaching the unmotivated student. Prep programs need to support teachers in assessing using authentic investigations and how to analyze the results from student lab work in context of skills/content.” Another emphatic response to the same question was, “I have gained so much guided inquiry knowledge throughout my career, but my student teacher and newer teachers are struggling with how to question students to get them to the correct thought/idea. The inquiry-based process depends on teachers who are prepared to listen to students and guide them how they are thinking.”

When asked in the survey about future professional development needs, several participants mentioned the need for time to read and analyze the materials as well as having all materials present to be able to engage fully in the curriculum. A survey response brought several needs to light for the district, “I attended a summer PD that was very useful. I also enrolled in an AEA course that made a big difference for me because we interacted with the curriculum. We were students and teachers interchangeably. In both of those instances I worked with people who are problem solvers and very growth minded. That's the key.” Another emphatic response was, “Teachers need to figure out how to quickly utilize the tools/guides. Teachers need lab materials organized for them by unit/investigation. Until these operational things are achieved, teachers can't really get into the PD work around what/how to engage and enhance science skills/knowledge!!!!”

Summary of Findings

In the quantitative research there was evidence of slightly greater growth not only in science achievement but also on science proficiency rates for the groups who received the intervention or pilot programming of inquiry-based curriculum. Within that, it was also clear that the differences in achievement and proficiency was primarily in science, and not in math or ELA. The latter is important to know as both ELA and Math were adopting or piloting their own curriculum programs at the same time. Key findings from the research include:

- Greater growth was seen in science achievement as measured by grade 8 ISASP science scores for the intervention groups compared to those of students in the traditional teaching methods classrooms.
- A greater percentage of 8th grade students were classified as being proficient or advanced in science (based on ISASP science test scores) in the intervention groups, compared to that for students in the traditional teaching methods classrooms.
- In supplemental analyses, there were no differences by ELL status in the growth in science achievement and proficiency levels associated with the inquiry-based curriculum over the traditional method of instruction.

Within the qualitative responses, teachers were hesitant to accept the benefits of the program and often stated the negative sides or correlations they see in their classrooms. This was also evidenced in the survey responses that were Likert in style. Key findings in the qualitative data include:

- Teachers were overall receptive to the structure of the program, however, they felt overwhelmed by the time requirements and supply chain issues that the district faced.
- Teachers were also unhappy with the restraint of the program that some felt, however that is not being dictated by the district during the adoption.

Further discussion and recommendations will be provided in Chapter 5.

Chapter 5: Interpretation of Results, Discussion and Implications

We're all instructors to realize that the quality of the mental process, not the product of correct answers. The path of least resistance and least trouble is a mental rut already made. It requires troublesome work to undertake the alteration of old beliefs."- John

Dewey

Interpretation of Results

This study investigated the relationship between the pilot or introduction of the OpenSciEd curriculum within the Des Moines Public Schools and student achievement and proficiency levels. This curriculum was introduced or piloted by the middle schools and gradually added school each year into the pilot program. Though there was some fluctuation in the fidelity of the pilot or intervention due to supplies, COVID-19 and student dynamics such as movement between schools and behavior within the specific school, there appeared to be greater growth in student achievement and proficiency levels for the schools that piloted the program compared to those who did not. The schools were classified into three groups based on length of time of using the inquiry-based curriculum - more than one year of intervention, one year of intervention and limited/no intervention.

Based on multiple linear regression which statistically controlled for students' prior achievement (as measured by grades 5 and 7 ISASP scores) and demographic characteristics, there was a statistically significant difference in grade 8 science scores among the three intervention groupings ($p < .001$). with the growth being 6.2 to 8.1 points higher for students receiving the inquiry-based curriculum intervention than the traditional instruction. Moreover, students receiving the inquiry-based curriculum were also more likely to be classified as proficient or advanced in science than students in the limited/no intervention schools (50.1% to 52.5% vs. 39.3%, respectively; $p = .014$). In comparison to the science findings, there were no significant differences among the three intervention groups in math achievement and math and ELA proficiency. For ELA achievement, although there was a significant difference among the three intervention groups, it was in the opposite direction of the science findings, where for instance students in the one year intervention group tended to have significantly lower grade 8 ELA scores than those in the limited or no intervention group. The math and ELA results help provide further evidence that the use of the inquiry-based curriculum in the district may be having a positive effect on students' achievement and proficiency in science.

Though not part of the original research questions, the association of the intervention with student achievement and proficiency in science was not moderated by ELL status, suggesting that all students regardless of ELL status seemed to benefit from the inquiry-based curriculum. When reviewing the qualitative data, it is evident that teachers see the benefit of this classroom structure but are hindered by constraints such as time (planning, time to complete units), supply chain delays in the shipment of materials and frustration in the full roll out of the curriculum in the 22-23 school year because of

the issues with supplies and printing. This chapter will focus on the results, potential implications and future research that has been brought forward because of this study.

Research Questions

In the paragraphs following, the research questions will be discussed based on the data collected throughout the study. The three research questions are as follows:

1. Is there growth in student achievement for teachers who create classrooms focused on inquiry-based universal design for learning compared to the traditional method of instruction?
2. How can a shift in teaching practice from a traditional approach to a focus on inquiry-based universal design for learning impact student autonomy and conceptual learning?
3. How does teacher education and professional development impact teacher practices and the opportunities they create for students to learn science?

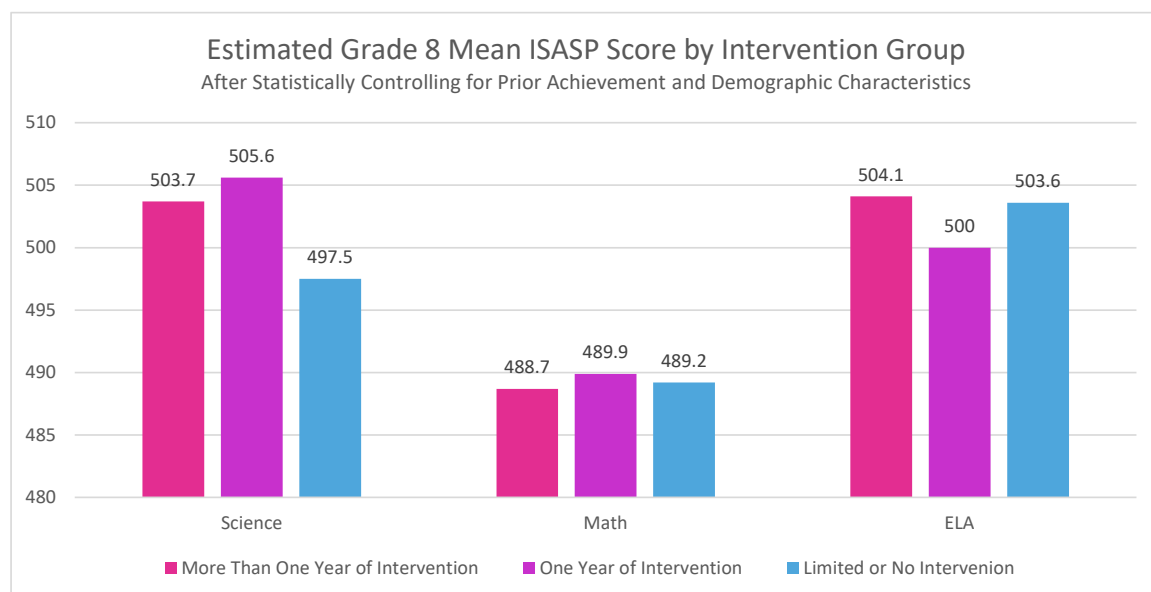
Research Question 1 & 2

Based on the ISASP scores analyzed, there were statistically significant results reflecting that there is a strong relationship between the implementation or pilot of the OpenSciEd curriculum and grade 8 student achievement in science. Grade 8 ISASP scores were estimated to be between 6.2 to 8.1 points higher on average for students in the OpenSciEd curriculum intervention groups compared to those in the traditional instruction group, after holding the other variables in the multiple linear regression model constant at their sample mean values. In comparison, there was not a significant difference in grade 8 math scores among the three groups ($p = .708$). Moreover, for ELA achievement, although there was a statistically significant finding, it was in the opposite

direction of the science finding. More specifically, grade 8 ISASP ELA scores tended to be 3.6 units lower for the one year of intervention group compared to the limited or no intervention group.

Figure 20

Estimated Grade 8 Mean ISASP Score by Intervention Group



Chapter 2 offered multiple liturgical connections between the use of inquiry-based science and growth of students. Based on these test scores, it is reflective of similar results within DMPS. Though growing pains were evident, continuation of the adoption will likely yield positive results in the student ISASP scores.

Question 2 focused on the connection between the development of student autonomy and student capacity. The ISASP scores were reflective of student growth, but not necessarily of student autonomy. During the observation of three teachers, I did witness behavioral deficits which impeded the proper structure for an inquiry-based

science classroom. Because students are learning how this process works at the same time and returning from hybrid/virtual learning due to the COVID-19 pandemic, the behaviors presented by students are a strategic struggle in setting up expectations and procedures for a fully proposed inquiry based science classroom.

Research Question 3

Question 3 focused on teacher preparation and perception of the new curriculum. Though many spoke highly of the gains and ease of use, there was a high level of frustration with the adoption because of supply chain issues, time constraints in terms of planning and preparation etc. Teachers also reported that overall, they do feel supported in the change and understand that many of the issues that were prevalent in the roll out were not in the control of the district.

When asked about teacher preparation at the collegiate level, staff members also responded that they did not receive training in IBSE (due to age/length of service) or learned about the structure but had never been able to practice the structure. It was also noted that teachers in student teaching placements should be exposed to these classrooms to allow for the “do” in learning instead of simply learning in a class. Truly experiencing the IBSE in its practice.

Summary of Research Findings

In summary, the data indicated three critical findings:

1. There is evidence of student growth in science achievement and proficiency based on grade 8 ISASP scores in the intervention groupings, with growth being evident

in both more than one year of intervention and one year of intervention, compared to traditional instruction.

2. Teacher perception of this curriculum is mixed, but many of the stated issues were with logistical problems that were encountered (supply timing, planning time etc) instead of the curriculum itself.
3. To fully implement this high-quality curriculum, teachers will need support in the areas of planning, time for PLC work and opportunities to engage in professional development with OpenSciEd.

In the following sections, I will discuss the limitations of this study and implications for future research and practice.

Limitations of the Study

This study, though timely with the adoption of the curriculum, presented a potentially significant limitation with the COVID-19 pandemic and the effect of testing/test score data and learning during the middle school years for the 8th graders in the school year 2021-2022 due to constraints on the learning environment (hybrid and virtual) during their middle school years between grades 5 to 8. Although this was a potentially significant issue, the results support the use of the OpenSciEd curriculum for improving science achievement and proficiency. To limit the influence of this real dynamic in the review, questions for interviews were limited to exclude discussion of the hybrid/virtual environment or potential COVID-19 learning deficits.

Even though the improvements in science achievement and proficiency were quite impressive, it is important to keep in mind that students were not randomly assigned to the intervention groups. The pilot schools were assigned by interest and willingness to

participate in the pilot at the middle school building level. This restricted the randomization of student assignments. While I tried to control and account for differences among the groups in prior achievement levels and demographic characteristics, there could have been differences in other student characteristics such as student motivation, interest in science, and other intrinsic motivators, as well as differences among the groups based on teacher and school characteristics that could be explaining the results. Unfortunately, data on these additional attributes were not provided by the district.

Additionally, because the district was unable to provide data regarding teacher and classroom clustering, I was not able to apply multilevel modeling that takes students being nested within classrooms into account for the quantitative portion of this study. Instead I used multiple linear or logistic regression methods that assume independence among students in the sample, and ignores that students were nested within classrooms. This can lead to incorrect conclusions in the hypothesis testing process. However, supplementary analyses were conducted to compare ELA achievement and proficiency among the three intervention groups, where it was anticipated that there would be no differences among the three groups. The ELA results help provide further evidence that the use of the OpenSciEd curriculum in the district may be having a positive effect on students' achievement and proficiency in science.

Another limitation of this study is the dynamic of being held within a single district. Though the implications of this study will help guide and inform the further adoption of the OpenSciEd curriculum within Des Moines Public Schools, having information from a single district within the time constraints of the study presents

unresolved questions and suggests further research is needed. We can look at the top layer of the information, but further research will be needed for definitive evidence.

Additionally, I was also not privy to the information for attendance in elementary school. There are several elementary buildings that limit or restrict science and social studies time, creating a void in science education overall. This push has been due to declining math and ELA scores and the push for further intervention time with the two subjects.

Recommendations

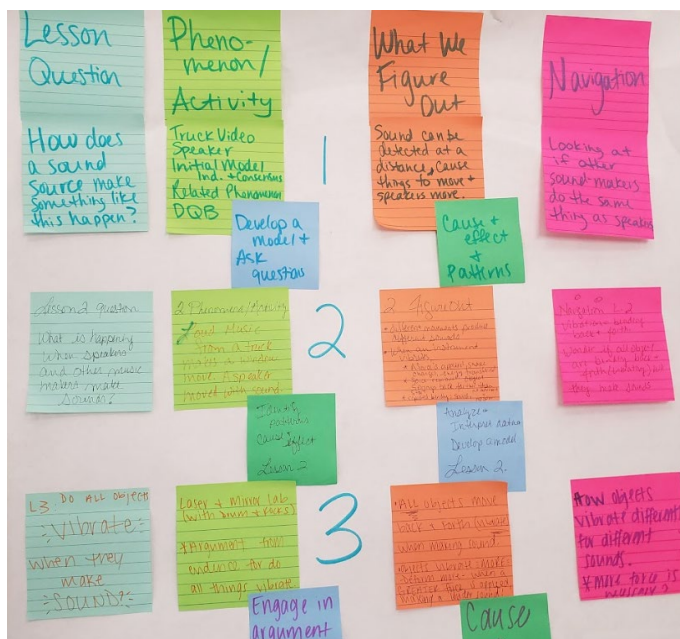
Based upon the analysis of interviews and ISASP test scores, it is recommended that DMPS proceed with the full implementation of the middle school curriculum using OpenSciEd. Teachers implementing with fidelity should yield growth in science and potentially Math and ELA scores based on the analysis of two years of data. Within this adoption, it is imperative that teachers feel supported with professional development, supplies and time dedicated to professional planning and preparation for an equitable classroom experience.

Professional development for teachers should include PLC (professional learning community) time as an entire science staff, not just by grade level, to map out the units as they present themselves. This professional development time should also include the in-person or web based professional development offered by OpenSciEd. Within this should be an opportunity for teachers to unpack each unit using the question, phenomenon/activity, what we figure out, navigation protocol as seen below in Figure 21.

As an opportunity to visualize the desired state in planning, I have included the process followed by OpenSciEd to map each unit in Figure 21. This allows teachers the time to truly unpack each unit and understand the why behind each portion of the lessons.

Figure 21

Image of a planning map from unit 8.3 in OpenSciEd



Chapter 2 discussed the need for UDL within the IBSE and how NGSS aligned UDL in the structures like phenomena introduction and problematizing. Within the OpenSciEd PD, there are multiple days and units of learning for the structure of UDL and NGSS built within the design of the curriculum. It will be imperative that teachers are given ample learning opportunities and time to develop new skills within this curriculum. If it is half way realized from the professional development side, it will be halfway realized from the implementation side. Being able to fully realize the desired instructional model will be imperative to the success of the implementation. Below is an example of

the OpenSciEd instructional model in question below in Figure 22. This is also key to understand this is not a direct line for learning, teachers must ebb and flow through the guided inquiry and require the time and support to do so.

Figure 22

Instructional model (OpenSciEd, 2022)



Future Research

There are several potential research opportunities that present themselves with the conclusion of this research. First opportunity would be to analyze further with classroom clustering to determine validity within the intervention groups. This would need to be done within DMPS for the privacy of student information. This information could be

used to identify potential outliers for lead or mentor teachers within the middle schools as a support system for DMPS.

Another potential option is extending the research over the next year to validate with the full implementation of the curriculum happening in the 2022-2023 school year. This would potentially validate the research in the initial study further by analyzing growth of student ISASP scores for the current 8th grade class. The analysis would need to be adjusted as the current 8th graders would not have taken the 5th grade ISASP due to the COVID-19 pandemic.

Finally, since the state of Iowa is adopting OpenSciEd as a statewide preferred curriculum, it would be beneficial to review the future classes of 8th graders within other districts and analyze the growth with the demographic inclusion of districts in mind. This has the added benefit of empowering the entire state of Iowa science educators to bring life to the student learning of science. Potentially, bringing a passion back to the subject and a drive to learn more.

Back to Dewey

The theoretical framework for this study centered around Dewey and his practices in conceptual learning. Based on the outcomes, Dewey and his thinking weren't just a novel idea at the turn of the century. Truly revealing best practice, especially in a science classroom, it is evident that pragmatism and experiential learning are an integral part of learning for students (Dewey, 1973). Maintaining classroom engagement and teacher support to develop and adopt this curriculum fully will be imperative in supporting this inquiry-based science curriculum. Dewey's social reform promotion is also evident in the needs of the classroom now, knowing that social justice is prevalent in day-to-day life

and learning for all students (Feldman, 1934). Dewey says it best, “Education is not an affair of “telling” or being told, but an active and constructive process” (Dewey, 1973).

Afterword

As an afterword, this work is so closely aligned to my current reality that the outcomes have brought cheers, tears and so many wonders of how we can do better. As a former middle school science teacher within the district I was lucky enough to begin the pilot of this curriculum. I feared my bias and love of the inquiry developed within OpenSciEd would make any potential negative data outcomes hard to swallow. However, with the outcomes showing the power of an inquiry-based approach and the power, even within a pandemic and multiple learning modalities, the data showed the hard work we have all put in. I look forward to promoting this adoption within my new role as an instructional coach and all the future passion we can bring back to middle school science. We, as a society, need scientists from every angle and my passion for science started in middle school, hopefully we can ignite the fire of future scientists within DMPS.

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Appendix A: Positionality Statement & Curriculum Vitae

I found myself in education abruptly, and with the notion of- “why didn’t I listen to my mother when I was 18”. In undergrad, I was an opera performance major, but decided I wanted a family and then changed majors 3 times in two semesters because I was going to make my million working as a CPA in corporate finance. I spent 10 years in finance, even earning my MBA and achieving the level of assistant CFO in a major corporation- but I wasn't happy, I constantly thought back to what my mother had said when I was 18 and choosing Opera Performance as a major- why not music education. I am married now, and any kind of change in career would need to involve my husband, and a major pay change and adjustment to our lifestyle. Luckily, he was supportive of the idea. I went back to school, again, and earned my MAT while still in Nashville. I student-taught in Iowa, since my husband and I wanted to relocate here eventually and have been here since.

Now in my seventh year of teaching (5 years in 4th grade, 2 years in 7th grade), I have noticed that the draw for me was to create a classroom that was what I needed while in school. I thought I wanted elementary school, but I have found a home with middle school. With this home, I also see a deficit in the needs of the students. Middle school students are thrown from a general education classroom with one teacher to all rotations with no shift in adjustment of age or learning. I found that my students were being spoon fed from the curriculum, and not being led to build themselves as learners. This is an area where I struggled in school. I often wanted to know the why and how, and I was told because.

I want my students to be able to explore, to learn, to find problems, to make mistakes, to be able to realize the cross curricular connections and be able to have the tools to find the how and why. The current model used for middle school is not something that allows for that. Middle schools are sectioned into siloed courses (similar to high school and college) and provide no transition time for students to adapt from general education classrooms with all course subjects to sectional. We remove the option (and time) to be able to create the cross curriculum connections and the inquiry drive, and sadly, that removes the problem solving and sense and drive for learning. In a basic statement, I want for my students (and future middle school students) to be able to have the experience of building student capacity and developing as a learner that I was never provided- and in the best way for them socially and emotionally.

Sarah-Elizabeth Kelly
 1803 94th Place
 Knoxville, IA 50138
 (615) 418-3156
 SarahKellyTN@Gmail.com

Objective

To obtain a responsible and challenging position that will utilize my education and background, expand my knowledge, and offer opportunities for personal and professional growth.

Education

University of Northern Iowa	2020-Present
EdD (In Progress, Expected in 2023)	
GPA-4.0	

University of Northern Iowa	2018-2020
Administration Certification	
GPA-4.0	

Trevecca Nazarene University	2012-2014
Master of Arts in Teaching—K-6	
GPA-3.91	

Trevecca Nazarene University	2006-2009
Masters of Business Administration	
GPA-3.78	

Middle Tennessee State University	2002-2006
BS Liberal Studies	
Minors in Music, History, and Political Science	

Hillwood High School	1998-2002
Honors Diploma obtained	
Whitley Scholar (4 years Math/Science)	
Employment History	

Des Moines Public Schools

2014-Current

- Instructional Coach- Focus on Math and Science
- 4th Grade Teacher (2014-2019) / 7th Grade Math and Science Teacher (2019-2023)
- Multiple grants earned, including Governors STEM Council
- Building leadership and Tier 1 behavior teams
- Building technology and science lead
- PTO and community involvement
- Drama Club Sponsor
- District PLC Leader

Southeast Polk Community School District

2014

- Student Teacher - Mitchellville Elementary
- 2nd Grade
- Lesson planning, curriculum instruction and assessment
- Differentiated instruction
- IEP Accommodations and Modifications

Metro Nashville Public Schools
2013

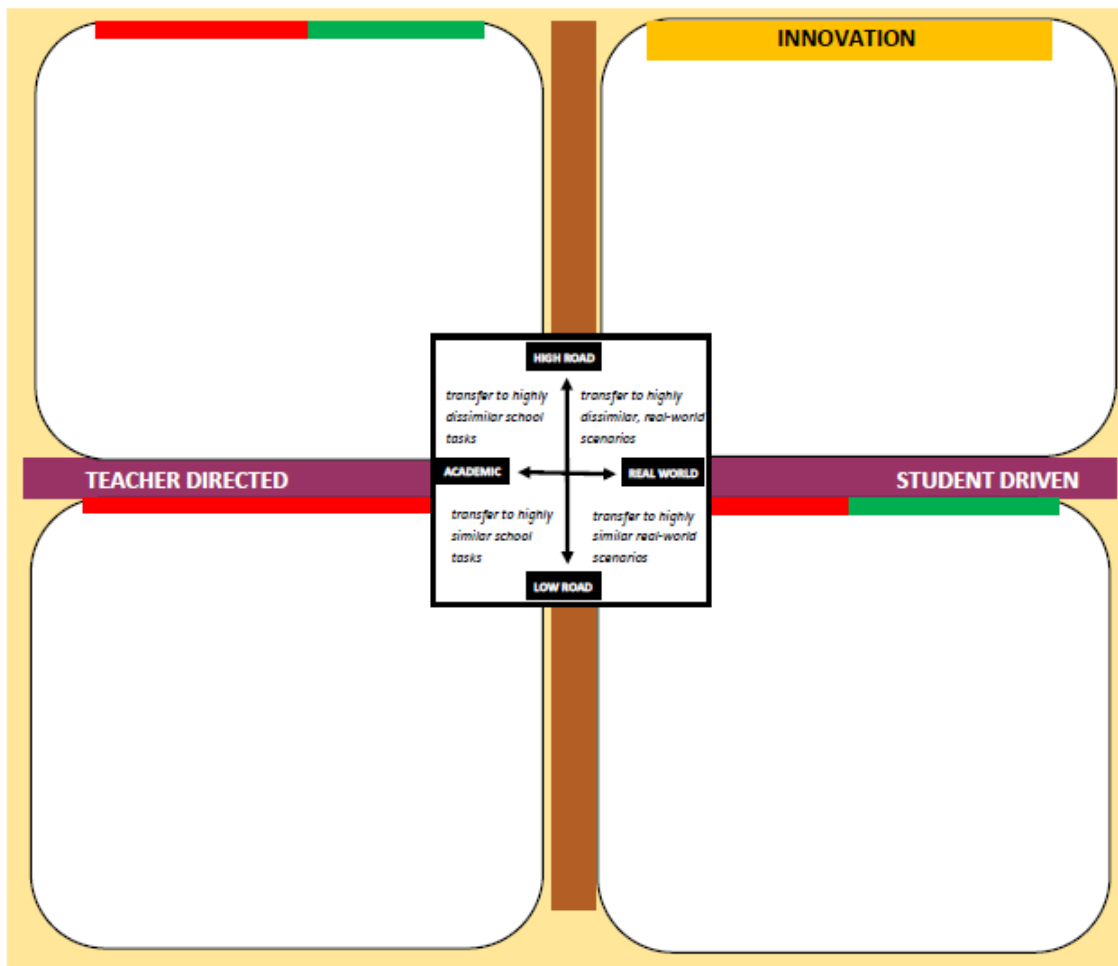
- Substitute teacher
- Lesson plan writing
- Long-term positions held

Comdata Corp
2008-2013

- Merchant Relations Representative
- Audit review and preparation for SOX yearly audit
- Managed workflow and resolution assistance for 8 associates
- Analysis reporting for merchant fulfillment group
- Winner of several quarterly performance awards since its inception
- Maintained a monthly performance standard above the rest of the department
- Created and maintained training documentation

Appendix B: Observation Protocol

In the study, I will be considered a nonparticipant or observer as a participant. I will be using an adapted version of our IB walkthrough criteria (shown below) to reflect on inquiry being actualized in the classroom.



INQUIRY: _____

APPROACH (AtL): _____

EXPLORATION: _____

INQUIRY is EVIDENT in STUDENT WORK

- ___ SOI
- ___ Factual Qs
- ___ Conceptual Qs
- ___ Debatable Qs

Appendix C: Interview Protocol

I interviewed and observed 3 teachers, after observing the teachers providing direct and small group instruction for one hour using the inquiry-based curriculum.

Topic Domain: Inquiry Based Teaching Approach

Lead question: Please share with me your journey to becoming a teacher, and specifically a science teacher.

{Covert Categories: teacher preparation, non- Science/Math teaching, instructional framework from support staff, student learners, cross planning in curriculum, preferred instructional method}

Possible Follow up Questions:

1. What structure did your teacher prep program follow for science instruction?
2. How has professional development contributed to your practice? What type of professional development has been least impactful to your teaching practice?
3. What, if anything, drew you to the sciences?

Lead question: What relationship do you see between an inquiry-based approach and the growth of student autonomy or capacity as a student learner?

{Covert Categories: new to profession teacher, non- Science/Math teaching, instructional framework from support staff, student learners, cross planning in curriculum, non-siloed model of middle school}

Possible Follow up Questions:

1. What strategies do you implement to process inquiry in your classroom?
2. What is your perception of the implementation of this model of teaching?
3. Tell me about a time you witnessed the inquiry-based approach working/ or not working in your classroom.

4. What tools or processes do you use to monitor the growth of student capacity as a learner, or student autonomy?
5. Do you feel this process (non-siloed, inquiry based) would benefit district wide to better achieve the Board goals?

Topic Domain: Student Autonomy/Student Capacity as a Learner

Lead off Question: How would you describe this model as working or not working at Brody?

{*covert categories:* ESSA model connection, equity of instructional time}

Possible follow-up questions:

1. Prior to knowing the ESSA scores had increased overall (as shared in the staff meeting), did you have the same perception of the inquiry-based model?
2. What other tools could be utilized besides the ESSA scores to reflect a relationship between this model and standard conservative approach to teaching?
3. In your opinion, how much of this model is evident versus the use of the IB program at Brody in the growth of the ESSA scores?

Appendix D: Survey Questions/Information

Notes on Survey Construction

Multiple choice questions that allow teachers to rate their response, such as a Likert scale, are helpful for understanding high-level trends. These questions can be rated on a scale of 1-5 where 1=disagree, 2=somewhat disagree, 3=neutral, 4=somewhat agree, and 5=agree. While it takes time to read open-ended responses, they provide important details about teachers' experiences and additional context for interpreting the responses teachers give to the multiple-choice questions.

In addition to hearing about stakeholders' experiences with the curriculum, surveys can be helpful in gathering notes and ideas about specific lessons and units. Teachers and coaches can use surveys to answer questions like "What was challenging?" or "What would we modify?" This would also move into the need for professional development and guide the tools needed for true implementation and guided assistance.

**UNIVERSITY OF NORTHERN IOWA
HUMAN PARTICIPANTS REVIEW
INFORMED CONSENT**

Project Title: Non-Traditional learning in STEM: How student autonomy and the impact of teacher delivery develops deeper conceptual understanding at the middle school level

Name of Investigator(s): Sarah Kelly

Invitation to Participate: You are invited to participate in a research project conducted through the University of Northern Iowa. The following information is provided to help you make an informed decision about whether or not to participate.

Nature and Purpose: The purpose of this study is to determine the extent to which students have shown growth using inquiry based science along with the teacher delivery of science education at the middle school level. The results of the study will be provided to the school district prior to the end of the 2022-2023 school year.

Explanation of Procedures: You are invited to participate in an online survey where responses are voluntary, and all will be kept confidential. At the end of the survey, you will also have an option to identify your name and express your interest in participating in second part of this study which involves a classroom observation and a follow up interview. The observations include you as a participant/teacher conducting a general education middle school science course for one hour. After the school day or during a time as agreed upon between the investigator and participant, you will be interviewed over the Teams platform and a recording will take place of the interview. The recordings will only be used for transcription purposes and will be destroyed after transcribed.

Privacy and Confidentiality: Information obtained during this study which could identify you will be kept confidential. The summarized findings with no identifying information may be published in an academic journal or presented at a scholarly conference. No guarantees can be made regarding the interception of data transmitted electronically.

Discomforts, Risks, and Costs: Risks to participation are minimal. Risks to participation are similar to those experienced in day-to-day life.

Benefits and Compensation: No direct benefits to participants are expected, but this research may generate important information about the adoption of the OpenSciEd curriculum at Des Moines Public Schools.

Right to Refuse or Withdraw:: Your participation is completely voluntary. You are free to withdraw from participation at any time or to choose not to participate at all, and by doing so, you will not be penalized or lose benefits to which you are otherwise entitled. Your decision to allow use of your data is voluntary.

Questions: If you have questions regarding your participation in this study or about the study generally, please contact (investigator) at 615-418-3156 or (if appropriate) the project investigator's faculty advisor Dr. Lori Norton-Meier at the Department of Education- Jacobson Center, University of Northern Iowa 319-273-2053. For answers to questions about the rights of research participants and the research review process at UNI, you may contact the office of the IRB Administrator at 319-273-6148.

Agreement:

I am fully aware of the nature and extent of my participation in this project as stated above and the possible risks arising from it. I hereby agree to participate in this project. I acknowledge that I have received a copy of this consent statement. I am 18 years of age or older.

The following statements are centered around teacher satisfaction with the inquiry based learning curriculum.

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
The curriculum gives me resources that help me reach all students.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The curriculum has helped me build knowledge in my content area.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The curriculum is helping my students learn.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What do you like about the curriculum? Why?

What don't you like about the curriculum? Why?

The following statements are centered around Teacher knowledge and confidence with the curriculum.

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
I understand how to use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The curriculum is easy to use.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I understand where to find information in the curriculum when I need it	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am confident in my ability to teach a full lesson with the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I understand the learning goals of the unit I'm currently teaching.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What about planning and using the curriculum is most challenging? Why?

What part of planning and teaching with the new curriculum do you feel best about? Why?

The following questions are centered around Teacher preparation with the curriculum.

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
I have a system for preparing to teach lessons that works for me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have the time I need to prepare to teach lessons.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have the resources I need to prepare to teach lessons.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

How do you prepare to teach lessons?

What is most helpful in preparing to teach with the curriculum?

What additional resources or supports would help you in your lesson preparation?

What has to happen in PD to help support teachers?

The following statements are centered around Teacher satisfaction with curriculum supports.

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Trainings on the curriculum help me understand and use the materials.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Common planning supports help me understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Observations and feedback from my coach help me understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Meetings with my coach help me understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Observations and feedback from my principal help me understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Module walkthroughs help me understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have the support I need to understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have resources that help me understand and use the curriculum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What kinds of curriculum supports have been most helpful? Why?

What additional supports do you wish you had

The following questions are centered around adjustments to the curriculum on your most recent unit.

Which unit did you teach?

If you made any modifications, what were they? Did they work?

What should we modify the next time we teach this unit?

What was challenging?

What worked really well?

The following questions are centered around teacher preparation at the collegiate level.

What do you feel your teacher preparation program prepared you for in the classroom?

Do you feel that more training in the preparation programs at the collegiate level is needed to support this change?

If you are interested in participating in an interview (held on Teams) and observation of the OpenSciEd Curriculum in your class room, please provide your email address.