Implementation of Inquiry-Based Science Practices

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Master of Education – Educational Leadership

ED 590 Research and Complete Capstone C386

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October 12th, 2024

Dedications: Thank you, Dad, Mom, and Beth, for inspiring a love of learning and education. Thank you to all my grandparents for teaching me the value of hard work. My love for education comes from all of you. I would not be who I am today your influence!

Thank you, Chris, for showing me that anybody can help shape your reality.

Thank you, Dan! We started our educational journey together, and we have both came so far and done so much!

And thank you, Macey, for listening to all the morning mumbles, being a forever proofreader, and being my rock on my hardest days through this and always.

I could not have done it without you guys! I love you all and appreciate all the support more than I can show.

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Abstract

This paper was a synthesis of current research on the implementation of inquiry-based learning (IBL) in high school science classrooms. The research was a combination of quantitative, qualitative, and mixed-method studies done to investigate the barriers to implementation, the importance of proper training and resources, and the effectiveness of IBL practices on student success and interest in science. The research showed several different barriers noted in historical implementation of IBL practices an educational leader should note and prepare for when attempting to implement these strategies. It also showed the positive effect of relevant and meaningful professional development opportunities at many different points in a teacher's educational journey. Finally, it showed the improved academic results for all students and increase in excitement students taught through inquiry experienced. This paper suggests further research on the appropriate level on inquiry used, stacking of inquiry throughout multiple grade levels, and investigating collegiate success of high school students taught through inquiry.

Keywords: barriers, inquiry, inquiry-based learning, professional development

Implementation of Inquiry-Based Science Practices

Chapter 1: Introduction

Today's science classroom can feel completely different for every student. Students must feel they are not only learning facts and information, but they must feel they are actively engaging in the process of science. They must feel they are in a space that allows them to ask questions, search out answers, and actively participate in the world around them. Parsley et. al, stated, "American Science instruction needs to be contextualized for students. Facts are essential, but without a broader framework, and a teacher's ability to facilitate inquiry, they mean nothing" (2004, p. 2). When many students go into their secondary science classes, they envision running complex science experiments in which they create both explosions and personal discovery, described as learning through inquiry; instead, they may experience a classroom environment full of receiving information and regurgitating acquired knowledge on unit assessments. Science education researchers Ozel and Luft researched the enactment of inquiry-based science instructions and stated, "Science teachers do not frequently enact inquiry-based science instruction" (2013, p. 1). In today's world with nearly infinite knowledge at student's fingertips, it is no longer enough to provide students with content information alone. Teachers must enact inquiry-based science instruction. It is now, more pressing than ever, to inspire a lifelong journey of wondering, asking questions, and seeking out answers. Teachers who can facilitate inquiry and connect student's lives to the work they are completing can change a student's entire educational experience.

According to the National Science Teaching Association (NTSA) science teachers must be experts in the teaching of content, nature of science, and inquiry (2021). This means science teachers are not just responsible for relaying information to their students, but they are also responsible for guiding their students through lessons which enables them to partake in the process of being a scientist. Science is constantly changing and gaining knew insights. Because of this, it is extremely important for those involved in science education to be masters of the content and the most research-based instructional practices. To effectively teach, science teachers must also understand how to teach one's students the skills to inquire during their science lessons. The NSTA recommends all teachers commit to inquiry and it becomes a centerpiece in all classrooms. The following literature review will look at how educational leaders can assist in the shift of instructional practices to ensure a shift to IBL practices is done in their schools.

Importance of Topic

When considering secondary science education, there are many conceptions which come to mind. One of the most common thoughts may be a teacher standing up front, talking about scientists of the past who discovered a certain fact or theory, and being asked to retell what their experiments concluded. Another possible concept may be researching scientific facts or information online and then having a quiz or giving a low-level thinking presentation on the subject. Many people have been taught these very lessons in their science education throughout the history of American education; however, according to Purdue University "Science education needs to be more than just memorizing facts or learning the history of discoveries in science, it is about adequately teaching our students how to effectively use the scientific method to solve problems" (2024 p. 1). This emphasis on the teaching of science as a skill introduces the need for an alternative method of teaching science education. A method of teaching where the students are active participants in the process of not just learning the facts and historical discoveries of science but receive instruction in which they learn through inquiry. Educational leaders must be ready to assist in the shift towards inquiry in science classrooms.

One way to for science teachers to teach the ability to inquire is by guiding students through the switch to inquiry-based learning (IBL). With IBL, students can experience science through an active role rather than a passive one in which they are only receiving information. Science educators must have a strong understanding of science content to become a fully qualified teacher. According to the Minnesota Department of Education (MDE) website, “A teacher with a grades 7-12 license (life sciences, physical science, earth and space science) may teach only courses related to their content area and in the grade level of their license” (2019). This means they are qualified to teach their specific science, but with current teacher training programs standards, not every teacher is required to be effective at leading students through inquiry. Training these teachers and implementing IBL strategies could greatly increase the academic experience of all students.

Scope of Research

There is a large repository of research that has been done on the importance of implementing IBL strategies. The following paper focused on fifteen studies in secondary education which support the importance of correctly training and implementing IBL practices into science classrooms. It is a combination of qualitative, quantitative, and mixed-method studies which try to determine three main strands, the major barriers and solutions seen historically when implementing IBL, the effectiveness of these strategies on student performance, and the training available to ensure that teachers are effectively implementing the designed curriculum.

The research looks first at historic barriers seen in the implementation of inquiry-based practices at both small and large scales. Research suggested training and professional development increase perception about the importance of these practices, frequency of these practices observed in teachers, and level of preparedness teachers feel to implement these practices. The research analysis then shifted to studies about the classroom success of these methods, with a look into how underrepresented groups of students in traditional science, technology, engineering, and mathematics (STEM) settings are affected by IBL. It then looks at the change in confidence and interest in S.T.E.M. opportunities of students instructed through inquiry. The research articles in Chapter Two can be found in the article tracking matrix in Appendix A and show a picture of implementation at several different levels and scopes.

The research did not look at primary education. There is a large amount of research done on the importance of these strategies in primary schools, but the high school science classroom was the main route of study for this paper. It also does not look at implementing IBL practices into other types of secondary classrooms. It does mention the importance of students being familiar with the words of inquiry, but not how to implement those strategies in other classes. Higher education is not looked at besides how it affects pre-service teachers in their ability to teach IBL strategies.

Research Question

Teacher's beliefs and their ability to implement IBL practices effectively are vital to a smooth transition into research-based IBL practices, and this shift must be grounded in research showing the benefit to student's science education. With the Minnesota Department of Education's new science standards stating "Scientifically literate classroom communities make observations of the world around them, design investigations to answer questions, make connections between ideas across the science disciplines, and solve problems using technologies for an ever-changing world" (*Science - Academic Standards (K-12)*, 2019), educational leaders must strive to ensure all students are receiving an education allowing them to truly use the skills and thought processes of a scientist through inquiry.

The research will connect how these viewpoints are looked at as we try to answer the research question, in light of what is known about pedagogy in the contemporary educational setting, how can educational leaders assure each student receives an equitable, high-level science education by training teachers in inquiry-based learning and effectively implementing inquiry into the classroom setting? This paper will also connect and guide educational leaders in how to use inquiry in science classrooms using the program research question in light of what is known about pedagogy in the contemporary educational setting, how shall educators lead equitably and inclusively in order to positively impact student development and learning?

Definition of Terms

Barriers are challenges found during the process of educational shifts (Johnson & Tawfik, 2022).

Inquiry is the act of a student learning use the curriculum to ask questions and find answers (Koksal & Berberoglu 2013).

Inquiry-based instruction practices are a combination of hands-on activities, and lessons where students build upon or adapt previous knowledge, use science skills, and practice inquiry while being guided by a teacher to think beyond the scope of the individual classroom (Kim, 2011).

Professional development are opportunities to build knowledge and practices pertaining to educational settings, often including explicit instructions for implementation (Ozel & Luft 2013).

Summary

Science classrooms can be a place where all students learn and succeed. With science being a required course for students to graduate from high school and very specific requirements of inquiry in NSTA suggested learnings from courses, it is as important as ever that educators are not just giving students information, but that they are training those students to become ethical contributors to their communities. Teachers must ensure they are instructing through research-backed methods and constantly adapting to the needs of their classrooms. To achieve this goal, trainings must be provided and prioritized for in-service and pre=service science teachers to be adequately and equitably implement inquiry-based learning methods in their classrooms. Educational leaders must ensure that the shift to IBL practices is effective and smooth for all teachers and students. They must find historic barriers and potential solutions that have been encountered when implementing IBL on all scales and settings.

This paper will connect how these viewpoints and will look at these questions and how they answer research question, “In light of what is known about pedagogy in the contemporary educational setting, how can educational leaders ensure each student receives and equitable, high-level science education by training teachers in inquiry-based learning and effectively implementing inquiry into the classroom setting?”

Chapter 2

Literature Review

Throughout this paper the barriers for the implementation of inquiry-based learning practices and potential solutions posed by researchers and those who have experienced the implementation process have discovered and noted will be discussed. One of the most common barriers found in the literature are proper training and teacher opinions and reluctance shifting to new type of instruction. Research on the effectiveness of proper training both on pre-service and current teachers abilities and willingness to adapt will be addressed. There are several deeply held beliefs by teachers on the effectiveness and practicality of implementing new ideas in science and how these beliefs can change depending on the amount of training in implementing new instructional strategies a teacher receives. There will be studies look at how an inquiry-based approach can change students' science content knowledge, processing skills, and attitudes towards science. When considering public education, one of the most important issues is ensuring all students get a free, equitable, and fair education which supports their individual needs. This paper will also look at studies which observed how increased inquiry in science education reaches each student, including students who are traditionally underrepresented in STEM fields.

The first theme which emerged during research on inquiry-based learning was one all educational leaders should note: The historical and current barriers others have seen prevent successful implementation of IBL in school curriculums. In both small- and large-scale studies and analyses, researchers found a consistent need for better training and buy-in from educators, and several other needs present in implementation depending upon the level they were observed in. Chahine et al. (2020) stated at small levels, proper training is needed and requested and there are specific needs such as a designed curriculum with administrative help on classroom and school culture. Then, Johnson and Tawfik (2022) looked at fifteen high school teachers in low-income Arkansas to determine specific barriers to inquiry access affected by socio-economic status. While Fitzgerald et al., (2017) found a similar need for training, they emphasized a need for strategic implementation and increased curriculum reflection time.

With the need to overcome teacher caution with the concepts and teachers perceived inability to teach inquiry outlined in the previous studies, the next step is to ensure proper learning opportunities for all science teachers. First year teachers' opinions were looked at and their ability to implement these strategies in Ozel and Luft (2013). In contrast, Herrington et al., (2016) looked at many experienced teachers and their opinion shift and improved implementation ability after specified training for introducing inquiry into their science curriculum and lessons. The following two studies by Riordan et al. (2019) and Kang et al. (2017) show the importance of modeling inquiry during both pre-service and in-service trainings to teacher candidate and teachers to ensure maximum implementation.

The third and perhaps most important theme in making the decision to switch to IBL practices, was the actual effectiveness of inquiry-based learning. Tornee et al. (2019) and Koksal and Berberoglu (2014) compared a more traditional approach to teaching science and a more inquiry-based approach and viewed the results and differences between the styles of teaching. Chen and Wang (2020) found that IBL practices can be used in the increasingly digital world of education. A sub-theme emerged through the research noticed the equitable outcomes for traditionally underrepresented people in STEM fields found by Kim (2011), Seeker (2022), and Rende Mendoza and Johnson (2023). This ties to the program's essential learning goal, as it ensures educational leaders are putting equitable outcomes as a priority. And finally, a sub-theme related to an increase in interest for science careers when inquiry is used in the classroom is viewed. Buedeker (2021) and Rubino-Hareet al., (2021) saw a direct correlation with inquiry lessons usage and interest in science and scientific careers.

Barriers and Solutions to Implementation

The shift into an inquiry-based science approach either at a personal or national level can cause possible barriers to implementation which must be addressed if a wide shift towards IBL practices is to occur. The following articles will introduce how implementation has been challenging for different schools and organizations on both small- and large-scale projects and solutions to implementing inquiry-based learning practices into their classrooms.

In all STEM fields, there are times inquiry can be used. To see possible barriers, research was done on the implementation of a unit Georgia math and science educators implemented on robotics and engineering design, Chahine et al. (2020) noted a successful implementation of content still had significant and consistent barriers. Their case study looked at two middle school systems with relatively low numbers of highly qualified math and science teachers and focused on training and implementation of an inquiry-based unit school-wide. This study was a mixed-method study done on twenty middle school math and science teachers during a one-year experimental inquiry-based curriculum. It looked at their abilities to implement inquiry pre and post intensive training and looked at themes that emerged as barriers for implementation. The barriers which were found will be discussed, as well as the potential solutions to these barriers.

In the qualitative analysis of the study, the researchers performed structured interviews both before and after training and implementation. The teachers involved in the introduction process named several themes which hindered the implantation of the inquiry-based science unit. Chahine et al. (2020) described the five themes emerged: Creating collaborative spaces, being open to alternative perspective and teaching strategies, building meaningful connection, support from systems and modeling of techniques, and designed curriculum and funding. These were the results of compiled interview data and show a picture of certain needs described by the teachers involved in teaching students. “Proper time, training, curriculum, and supports put into place into the school, can really help ease a lot of the barriers seen in this study” (Chahine et al., 2020, p.). The importance for proper curriculum was a continued theme in the structured interviews, which can be extremely helpful when looking at implementation. This showed that well-structured, pre-designed curriculums can help sculpt an environment where teachers and students have clear learning targets and goals.

There are often changes needed to be made on a different sized scales and each situation can look different. Johnson and Tawfik (2020), performed a qualitative study on fifteen high school teachers in low-income Arkansas, to see first, second, and third order barriers to incorporation of IBL units. These teachers were recruited from the entire state to ensure there were multiple different cultural perspectives, both rural and more urban were heard and their barriers were considered. Each teacher did both open questionnaires and interviews. All of which were designed to discover the barriers schools with higher levels of poverty might face in implementation. Many of the challenges were unique to schools with lower levels of funding (Johnson & Tawfik, 2020). This gave a new view into the challenges of adapting inquiry in schools with less resources.

Order one barriers were the most immediate and well-known barriers to the teachers. Level two barriers were often less obvious to teachers but came through in the analysis of the interview process. Level three barriers were barriers the teachers did not self-identify, but the researchers gleaned with consensus using the interview and observational data. When looking at level one barriers, or the barriers most pressing to the teachers, the barriers all seemed to be related to relative lack of resources, including a lack of training, a lack of resources and technology tools, and a lack of administrative support in shifting curriculum. This showed a clear connection to the relative lack of funding these schools in higher poverty areas can experience (Johnson & Tawfik, 2020). This could pose an issue for lower income schools, and their comfortability of shifting to new curriculums or pedological structures such as IBL strategies. Educational leaders in these areas must be able to be creative and resourceful to implement these strategies.

The second and third order seemed to be rooted more in teacher uncertainty of both the method of teaching and their own effectivity. The second order barriers were mainly focused on the lack of experience and the beliefs the teachers held about the traditional roles of students and teachers in a classroom. Not all these teachers were fully on board or felt prepared for the change to an inquiry-based teaching style, and they were hesitant to jump all in (Johnson &Tawfik, 2020), which showed the researchers a shift in mindset was needed for many of the teachers if the shift to inquiry would ever be adopted. The only consensus level three barrier noted by the researchers was design thinking in some teachers, the belief this type of learning would lead to extremely different experiences for each student (Johnson & Tawfik, 2020). This barrier seemed to be alleviated with the promise of first and second order barriers being eradicated.

At a larger scale, it is easier to view specified variables. The following study was done during a switch to IBL with teachers who had strong beliefs in the effectiveness of IBL strategies. Even in these highly confident teachers, there were some perceived barriers; however, the strong teacher's support for IBL allowed for introspective from teachers who believed that this method was effective. This group of teachers wanted effective implementation rather than a change of instructional strategy. Fitzgerald et al. (2017) studied thirty-four highly enthusiastic high school teachers and their experience with the implementation of inquiry-based learning in their science classroom. The teachers were implementing a new unit project explicitly designed to add an inquiry-based science experience for all learners in Australia and were provided funding determined adequate to implement a new unit with this teaching style. Each teacher was interviewed multiple times throughout the implementation process to determine the perceived barriers, and a graphic visualization and manipulation package "Gephi" was created. This Gephi package was able to determine the most mentioned words and phrases and related problems emphasizing the relationship between several mentioned strands.

All the teachers interviewed were highly enthusiastic about implementing inquiry-based learning practices into their classroom and school systems, but they also had ways they envisioned it could have been designed and carrier out more efficiently. As this was the biggest project to increase inquiry in the science classrooms for Australia's education system, there were naturally going to be barriers and setbacks to the implementation. The most mentioned barriers when looking at the Gephi package were the need for good professional development design, curriculum-related barriers, and diffusion throughout the population (Fitzgerald et al., 2017). Most of the discussion done by the teachers, was the need for improved experiences in professional development and the diffusion of these strategies amongst colleagues who may not be as invested in implementation of IBL practices. Fitzgerald et al. (2017) discuss the need for both inquiry-based preservice-training opportunities and professional development, and the need for exposure and support when convincing more hesitant teachers to shift their instruction to a more inquiry-based approach. Both will be addressed later in this paper in much more detail, but special interest will be given to the curriculum needs at this point.

When the needs of teachers were compiled, one of the most mentioned needs was highly developed curriculum and prior time to digest the intricacies of a large-scale shift (Fitzgerald et al., 2017). This showed a reoccurring theme from education in which shifts in approach must be accompanied by precise and timely planning. While the need for time prior was evident, Fitzerald et al. (2017) found there was also highly needed post implementation time to assure actual student needs and questions were being dealt with as they were seen. This means that there must be built in time for teachers to communicate with one another about the successes and failures of lessons or activities. A common planning time, dedicated to the specific needs of the classroom teachers, showed positive correlation with increased feeling of success (Fitzgerald et al., 2017). This takes intentionality on the part of educational leaders, to ensure teachers involved in these shifts can have specific times scheduled into their day to ensure they are meeting often and with a purpose.

The previous three studies attempted to look at the implementation of IBL systems at different levels and degrees. Chahine et al. (2020) looked at the small-scale changes two middle schools made and determined the largest two needs for proper implementation were proper training and strong curriculum. While Fitzgerald et al. (2017) and Johnson and Tawfik, (2020) looked at larger scale systems and determined some of the biggest needs were purposeful professional training, reflection time, and efficient systems of communication. Johnson and Tawfik (2020) also saw underfunded schools had a specific set of issues arose, such as technology needs and structural supports. A clear thread through all three articles was the need for training and buy-in from staff. The importance of giving meaningful time and training to learn how to pedologically shift approaches was a common theme amongst the teachers who spearheaded these shifts.

Training and Perception

The need for better science education has ensured a continual trend toward research-based approaches. When a school or system has decided to change curricular or instructional methods, an important predecessor is teacher support for the style of teaching they are asked to incorporate. A quantitative study done by Ozel and Luft (2013) looked at how 44 first year secondary science teachers' belief in and practice of IBL relate to each other. The 44 teachers came from 5 different states in the United States. The teachers' school districts represented a wide array of geographical data including schools in urban, suburban, and rural areas of the Midwest and Southwest. The teachers were chosen based on purposeful sampling from responses to specific questions pertaining to their initial thoughts on inquiry in the classroom. Ozel and Luft’s (2013) study were done through semi-structured interviews and classroom observations throughout the teacher’s first year of teaching. Each teacher had multiple researchers, all with the same training, assigned to them to ensure a representative view of the first-year teacher’s ideas and implementation of inquiry. The standard for assessing the results of interviews and observations was a rubric called “essential features of classroom inquiry and their variations” designed by the National Science Education Standards.

These teachers did not have trainings specific trainings in IBL practices. They were interviewed on the importance of inquiry and there was a wide array of responses. The data analysis done by Ozel and Luft (2013) noted very few of the teachers greatly changed their opinion throughout the year of the study. Without trainings dedicated to implementing inquiry in their classroom’s, their beliefs did not change. Despite a high self-reported importance in some teachers, most were only able to consistently implement two aspects of inquiry, asking scientific questions and priority to evidence (Ozel and Luft, 2013). This meant teachers, even those who strongly believe in the importance of inquiry, are only being observed working on those skills. In neither the interviews nor observations did the researchers in Ozel and Luft (2013) see teachers effectively working on the skills of connecting evidence to claims, connecting observations to knowledge, and communicating explanations.

The analysis of data showed the teachers, even those who were highly enthusiastic about implementing inquiry, did not have the skills or training to implement all aspects of inquiry. However, it also showed the teachers who talked about, and believed in IBL practices had a much higher willingness to try to incorporate inquiry into their classrooms. Ozel and Luft (2013) only looked at the changes in one year of teaching, but they suggest looking at how the relationship between implementation and relative belief of the importance of inquiry change throughout several years of these teachers' careers with proper and consistent training (Ozel & Luft, 2013). Additional trainings can come in many forms and can have vast ramifications for the skills and beliefs of teachers.

If the beliefs about inquiry-based instruction affect the amount of inquiry teachers are willing to add to their lessons, the next search would be to see if the attitudes and effectiveness of educators can change on inquiry-based instruction. In a qualitative study done by Herrington et al. (2016) the relationship between inquiry-based training and a teacher's concept of inquiry and the relative importance in the classroom is reviewed. This study looked at research experiences for teachers (RETS) as part of a bigger PD program called Target Inquiry (TI) and how it effected a teacher’s beliefs, attitudes, and values surrounding having lesson plans changed to implement inquiry. Herrington et al., (2016) took thirteen science teachers from West Michigan from various science disciplines with a broad range of experience. The RET’s lasted six weeks, matched their research with their interests, and had sustained and consistent follow up. The data were collected in semi-structured one-hour, face-to-face interviews prior to the training and after the training. Verbatim translation of the interviews was used for the analysis. The researchers were looking at a difference in reported belief, attitude, or value.

According to the results of data analysis done in Herrington et al., (2016) in the pre-RET interview, only three teachers were able to point to any specific inquiry activity they had participated in, while the other ten talked about inquiry practices in generalities when asked where inquiry had been done in their classroom. This shows the teachers needed knowledge and implementation training. Nine of the thirteen teachers reported wanting to improve their student's ability to think critically and act like scientists, while the remaining four indicated they hoped to help their students develop skills for life.

In the post-RET interview, all teachers at least partially changed their beliefs, and all mentioned they had learned techniques in implementing inquiry in the classroom (Herrington et al., 2016). Each teacher's opinion changed in a different manner. This showed these types of experiences can have many meanings assigned to them. According to Herrington et al. (2016) in post-RET interviews, seven of the thirteen teachers mentioned specific plans to change lessons to incorporate IBL. The introduction to a new style of method can change the educational trajectory of a teacher's career. The biggest change was in two male middle school teachers with vastly different levels of experience, who mentioned they plan on actively shaping their school's science policy to implement inquiry throughout the district (Herrington et al., 2016). This indicates experience is not a direct factor in the belief and ability to change the belief that inquiry can be useful in the classroom. According to Herrington et al., (2016) of all the statements made in post-RET interviews only 12% of all comments made were considered negative towards inquiry, and many of those negative responses were rather with school culture and difficulty of getting others to buy into instructional change. This shows most comments made by all teachers involved were overwhelmingly positive.

Once teachers at a school are on board with and trained in IBL practices, the implementation can begin. There are parts of implementation though, which must be planned effectively, not just in curriculum, but also culture. The need for this cultural shift in professional development towards equity and inquiry was looked at in the qualitative study by Riordan et al. (2019). It is important to tie curriculum, practices, and professional development to the goals of a school. Secondary teachers often do not work completely alone on many transformational curriculum changes. It can be very helpful for educators to have ample time dedicated to improving and showing inquiry on a level that influences them, to give them a better understanding of the benefits and best practices of inquiry-based learning. It also important for educational leaders to model the changes an administration or district tries to make. A qualitative study done by (Riordan et al., 2019) looks at how professional development with an emphasis on creating a culture of inquiry can increase the inquiry seen in classrooms. If educational leaders want to bring positive initiatives to all students, they must ensure all teachers and staff have professional development opportunities in these initiatives.

In this study, Riordan et al. (2019) looked at two schools, which they gave the pseudonyms of Midway and Highland who were identified as needing a large shift in equitable practices and outcomes. They interviewed six school leaders, seven teachers and seven students from the two schools, for a total of twenty interviews. They focused on how the administrators, teachers, and students felt the school district did in providing opportunities for both staff and students to receive highly functioning and equitable information, training, and opportunities to grow. Riordan et al. (2019) looked at results of interviews and observations of both professional development opportunities and school day practices. They then coded many responses and observations to try to find themes of data.

The study found five major themes in achieving equity and inquiry: Centering equity in professional development, equity centered pedagogy in professional development, creating a school culture of inquiry and belonging, inviting students voices to understand teachers' professional learning, and prioritizing teacher and student ownership in all learning opportunities (Riordan et al., 2019). This study stressed the importance of including inquiry, not only in an individual classroom setting, but also in every aspect of learning spaces of a school.

It is not always an easy task to shift the entire frame of any school function, including professional development, but the importance of adding inquiry as a tool in professional development can be huge. Both schools had professional development norms put in place within the past five years. Midway had a robust system of professional development that modeled inquiry and gave teachers the opportunity to propose and solve questions with multiple levels of support in and guidance (Riordan et al., 2019). This allowed for multiple opportunities for staff to experience inquiry as learners. The observers experienced zero in-class observations in which inquiry was not at least used once (Riordan et al., 2019). This shows with the right set-up and focus on inquiry implementation, all classes, including science, can effectively implement the practices of inquiry into every lesson. While Highland, which focused professional learning opportunities more on prescribed problems and solutions, found less teacher satisfaction, less inquiry in the classroom observations, and less feeling of belonging for the information students received (Riordan et al., 2019). This shows just like in the classroom, it was important to sculpt and design learning opportunities to shift and adjust to the people they are servicing rather than a predetermined set of circumstances and outcomes.

The importance of this study is in showing the insight into implementation at a school-wide scale.. One teacher or a group of teachers can implement inquiry into their classroom, but it is most effective when the entire school and district develop specific training opportunities not just on implementing inquiry, but incorporating inquiry into every aspect, including professional development. Riordan et al. (2019) concluded teachers are the tools of implementation for all initiatives, and introducing those initiatives into teachers' learning opportunities can increase the effectiveness of those shifts.

The timing of training can vary from preservice to the final few years of a teacher's career. A qualitative study highlighting the importance of pre-service teachers being involved in the inquiry process as learners was done by Kang et al. (2017) who looked at the relationship between eight student teacher's beliefs, experiences, and frequency of using inquiry tools when going between a student and a teacher. These teachers, all from Southern California, were all previously in a different profession and were going back to school to teach science. Kang et al. (2017) believed they were in a unique position to investigate as individuals who were both teachers and students at different parts of their days.

These eight student teachers were asked to fully participate in an inquiry-based lesson, design a lesson plan they would teach involving inquiry, and then record their teaching to assess use of inquiry. The lesson plan they were asked to design to teach was not taught in the classroom, as it did not fit the content any of the student teachers were currently covering. Kang et al. (2017) suggested having these teachers as active participants in all three parts of the learning process, would allow them as to relate the struggles and successes they felt as students into their design and planning as teachers.

After their initial lesson in which the pre-service teachers were introduced to inquiry, each was asked a series of questions about inquiry to gauge their excitement about introducing inquiry into the classroom. They were given a score from one to four on their level of interest in inquiry, all of which scored a three, interested in inquiry but had questions, or a four, fully committed inquiry teachers. They were then asked to create a lesson plan with one other student in their class and then analyze another pair's inquiry-based lesson. They finally then recorded their teaching, and Kang et al. (2017) noted the number of times they used inquiry techniques and the types which were used. This was to see the difference in intent to teach inquiry and actual practice of teaching inquiry.

The research wanted to see if the techniques they had been introduced through became part of their classroom routines. Of the eight inquiry tools, seven were considered strongly used in the classroom, and only one technique was hardly seen in any of the recordings. This shows a strong correlation between experiencing and being trained in inquiry and using inquiry in practice (Kang et al. 2017). This is a large percentage of techniques showing through in instruction, which points towards the importance of experiencing inquiry in a learning setting prior to teaching using these practices.

This study found a teacher's experience being involved in the practice of inquiry can truly help them feel comfortable and effectively implement inquiry-based learning into their classroom (Kang et al. 2017). Like the previous studies, the conclusion showed there were strong correlations between the success of implementing these practices and proper exposure and training with these practices.

In the studies done by Ozel and Luft (2013), Herrington et al. (2016), both suggest there are a lot of different opinions, beliefs, and ideas around what inquiry is and if it is effective. While the studies by Riordan et al. (2019), and Kang et al. (2017) shows the benefit of teachers being involved in the inquiry process as a means of learning how to implement IBL practices. All four state the belief of effective inquiry education lies within training teachers in the practice of science inquiry. Whether it is looking at first year teacher's ideas and implementation or looking at post inquiry-based training beliefs and implementation, we see the more confident teachers are with the importance of inquiry and the more well trained they are with inquiry the more effective they are to put it into practice.

Effectiveness of Guided Inquiry on Students

None of the training or implementation matters if there is no research showing this type of science education being effective. As mentioned earlier, the NSTA wants students to not only capture the knowledge generally associated with high school science classes, but they also want them to be able to partake in the process of inquiry and understand the nature of science. There are several ways students can take part in science skills including applicable skills for the science workforce. The next several studies look at how guided inquiry can affect students. These studies emphasize the educational benefits of guided-inquiry and the positive trend with attitude towards science of students exposed to this type of learning style.

None of this would be useful to students if there was no difference observed in traditional instruction versus IBL. In a quantitative study by Tornee et al. (2019), this difference was researched between a more traditional method of information delivery and an inquiry-based approach. In this study, two classes of students were recruited from three classes of Grade 11 students at one school in Northeastern Thailand. One class of 34 students were taught in a guided-inquiry style, while the other class of 31 students was the control group for traditional style instruction. Tornee et al. (2019) looked at the students' learning achievement (chemistry knowledge, science process skills, and scientific attitude), their problem solving, and their cognitive functioning. These were tested by a test prior to and after the lesson was administered using a mixed-plot design.

To ensure the variables were minimized, Tornee et al. (2019) designed two different lesson plans, both of which were designed to achieve the same learning outcomes. The experimental group had seven steps including stimulating interests, giving students the opportunity to determine what they want to learn, setting up their own experiments, and the opportunity to work through the lesson with hands-on experiences connected to their daily lives. Any questions the students asked would become part of the learning objectives of those students. The more traditional experience was designed where a teacher introduced the concepts, a lab was set up for them to conduct, and their teacher then explained the concepts they were supposed to learn. Any questions the students were answered with information already relayed to the students.

The results of Tornee et al, (2019) saw both sets of students saw significant improvement in all learning targets they were tested on, but the experimental group was significantly higher in science learning outcomes and problem solving. This shows although both can be effective, the class in which inquiry instruction was used showed significantly higher results than the traditional instruction. The researchers believed one of the largest differences between the actual day-to-day effectiveness of the classes was the student's ability to connect information to real-life situations and add questions which were not in the original learning outcomes in the experimental classroom. Tornee et al, (2019) showed implemented guided inquiry can truly help student's skills in science. They believe the ability of students to ask questions and change direction for their own individual journey greatly changed their investment in a lesson. Students benefited from the ability to investigate questions that are within the realm of the content but also one's individual students can relate to information they find important. Consistent with other studies found throughout this paper, Tornee et al. (2019) concluded one of the major difficulties in this shift into a more inquiry-based curriculum is teacher training and time to implement these changes.

It was also vital to see research done on a larger scale. Koksal and Berberoglu (2014) looked at the effect of guided inquiry using 300 public school sixth grade students. Seven public schools were randomly selected from 141 in two different districts of Ankara. In a quantitative study, Koksal and Berberoglu (2014) looked at the difference in science knowledge, inquiry skills, and attitudes towards science between classes taught in a more traditional unit plan versus a guided-inquiry unit plan. Each of these tested variables were assessed in a specific assessment designed to test the outcome of both lessons. One of the most important parts of this study was the training received for the experimental groups' teachers. Koksal and Berberoglu (2014) mentioned the specific needs of inquiry-based instruction as new to many teachers and stated it was necessary to train these teachers accordingly.

Throughout the timespan, both sets of students gained in all three measurements tested. This shows there is a positive correlation between both styles of teaching and positive changes in the three variables, but an analysis of the tested variables showed a significant increase in the experimental group compared to the control group (Koksal and Berberoglu, 2014). This again supported that although both were effective, inquiry-based learning had a significant advantage. The most significant increase was in science process skills, which shows the students are improving their science skills, and attitudes towards science and means the students are liking science more after the inquiry-based lesson. The effect on science knowledge was smaller, but still achieved ($p < 0.05$) (Koksal and Berberoglu, (2014). If we are looking at the effectiveness of these lessons, all three measures can be considered. The importance of measurable improvements can lead to the shift in belief towards this type of instruction might be needed.

In an increasingly digital world, research has begun to be targeted towards ensuring IBL practices can be done through online and remote learning. A mixed-method study done by Chen and Wang (2020) looked at how an online inquiry lesson can affect student outcomes. They took forty-eight seventh graders in two classrooms learning about buoyancy. An online, guided-inquiry lesson was delivered by both teachers, with assistance mainly for technical difficulties. The students were given the learning target and then privately filled out a pretest to assess prior knowledge. They were finally asked to perform an inquiry simulation including multiple steps of the scientific method. The students then were assessed by a post-test with the same learning targets as the pre-test.

The researchers used a t-test to determine the increase in score through the IBL lesson plan. Using the t-test score of 0.001, Chen and Wang (2020) determined the lesson had been effective at reaching the learning target for the students; however, they wanted to know more about the individual gains by each student or groups of students. They conducted personal interviews with the five students with the largest and smallest increases when comparing their test scores. These studies were done to gain a sense of possible struggles and successes students could face. The biggest difference in the high and low performers was the comfortability with inquiry as a learning guide. The students who had received high marks were able to walk through the inquiry processes and reasonings while the underperforming students struggled with the steps of inquiry (Chen & Wang, 2020). This shows vertical alignment with inquiry could potentially help students become more familiar with the inquiry process and thus be more successful in inquiry lessons.

All three studies showed an increase in scientific knowledge and Tornee et al. (2019) and Koksal and Berberoglu (2014) showed a shift in attitudes towards science as a subject. Chen and Wang (2020) showed that this type of instruction can be done through multiple platforms With all showing positive results from inquiry-based instruction, the trend towards inquiry in science classrooms seems to be supported. When looking at the broad reach of public education. It is important to give consideration at how this equitably helps specific groups of students.

Equitable Outcomes

Part of the goal of the NSTA is to ensure all learners receive a high-quality science education. Part of achieving this goal is to ensure the science classroom does not perpetuate achievement gaps in historically underrepresented groups in STEM fields. The next few studies will look at the increase in equitable outcomes of inquiry-based learning in science classrooms and education.

It is important to ensure inquiry- based approaches reach all students. According to the research done by Dasguta and Stout (2014), women only make up 34% of the workplace in science. This is a challenge proper science education must systematically look at and address. This means it is vital for all changes in STEM education to look at how it affects our female students. In a mixed study Kim (2011) looked at how IBL affected thirty-five female students who were entering the eighth grade.

The thirty-five female students in this study from fifteen urban middle schools were selected because eighth grade is often when girls tend to lose interest in science (Kim 2011). The students were recommended by teachers based on their personal interest in the program. The participants were limited to thirty-five students to ensure quality inquiry-based experiences. They followed a camp using InSTEP which is a program designed for inquiry learning. The students attended a week-long summer camp and were mainly Hispanic, White, and African American, while some other cultures were represented. The first language of 51.4% of students was English, 31.4% had Spanish as their first language, and 5.7% had French as their first language. Performance level at their school was not considered in selection.

Due to the study's two parts, increasing attitude towards science and content knowledge in science, two different types of analysis were done. The first set of data Kim (2011) looked at was the attitude change in the students. Looking at the qualitative post-camp interviews, 77% of the students had changed from negative to positive after attending the InSTEP program. The other 23% had not increased due to already considering science a positive experience. In the content knowledge questions on the pre-test versus post-test, there was a strong change in the students' knowledge. All seven concepts taught showed significant ($p < .05$) increases indicated. This study by Kim (2011) showed trends in both increasing science knowledge and attitudes towards women in STEM. If it is possible to teach in a way all students were reached, including those who are historically underrepresented in the STEM fields, then those instructional strategies should be greatly considered.

Some implications seen in this study are girls continue to have anxieties about future science classes despite their increase in attitude towards science. Some limitations (Kim 2011) noted was the small sample size and the lack of a control group in this specific study. Looking at other camps with different structures may be beneficial.

In the world of public education with numerous races, cultures, socio-economic classes, and many more student groups involved, it is vital to ensure all groups of students' needs are met. In a mixed-method study (Secker, 2002) a look at how different groups of students, who traditionally show achievement gaps in science can be supported. The study used data from the National Education Longitudinal Study sponsored by National Center for Education Statistics =, U.S. Department of Education, to determine the effects of inquiry on science knowledge (seeker, 2022). The 4,377 students stied were students in 1,406 classes who had demographic data available, were tenth grade students, had achievement data available, and had their biology teacher, often taught to tenth grade students, questionnaire available (Secker, 2002). This sample size shows a very large amount of data to use as a foundation.

When this analysis was done, there were three main things considered: inquiry practices used in the classrooms, growth from eighth grade to tenth grade, and the teacher's personal connections and belief in their student's ability to succeed in science were noted. All of these were collected from a combination of test scores, personal identifiable information, and in-depth questionnaires filled out by the teachers. These factors were chosen because there seemed to be some initial indications these factors showed a correlation between growth and learning of all students (Secker, 2002). When looking at how to categorize the data, the two categories of race/ethnicity and gender were used as ways to compare groups of students. White and Asian students were grouped as "Group 1" due to their historical high representation in STEM fields. All other students were put in "Group 2" who represented underrepresented groups. Gender was also looked at to see changes in scores and achievement. Both types of demographic information were looked at both synchronously and asynchronously.

When looking at inquiry, the first analysis was the relationship between teachers who used inquiry approaches and the academic success of their students. All student groups in classrooms whose added inquiry score was one or more standard deviation above normal performed better than those who were not at or above one standard deviation above average (Secker, 2002). Anytime large increases across multiple groups of students are observed is positive. With the large sample size of this study, there was a significant number of teachers in this category, and every group was helped by these students. Which showed, when implemented effectively, inquiry can be transformational for equitable education.

Looking at the results of other teachers, it shows when not implemented as effectively or routinely, there is much more variation in the amount student success increased by inquiry lessons. In classrooms who did not reach a level of one or more standard deviations above average, there were large discrepancies in the success of different students based upon some of the data collected. Students who do not fit the category of "Males from group 1" had a large array of result differences from eighth grade to tenth grade (Secker, 2002). These are the student's science educators must give equitable access to, and this data says when running into these achievement gaps, solutions should be investigated. There is large variability in the success of the student depending on a few variables outside of the inquiry in the class including the teacher's belief all students can learn and teacher beliefs of preparedness (Secker, 2002). This shows that inquiry is not a fix-all, but that if used effectively and often, it greatly decreases the effect of other variables.

An increasingly visible sub-set of the students in education today identify as LGBTQ+ individuals. Many of these students see science as something which cements genders and stifles fluidity (Rende Mendoza & Johnson, 2023). This shows a disconnect with the curriculum may make it harder for students to feel the work they are doing in science matters to them .This is a major problem and in hope to find a solution, Rende Mendoza and Johnson (2023) did a qualitative study on how representation and the correct use of inquiry can help students who identify with this group feel more ownership and have a meaningful experience with their science curriculum.

This study had ten science teachers who identified as transgender or non-binary. Rende Mendoza and Johnson both collected data through in-depth, semi-structured interviews, reflective statements, and content analysis of instructional materials to see if students were being encouraged to learn and connect to science in a meaningful way. The emphasis of this study is to see how different types of instructions align with the four categories of resisting essentialism: Interrogating and accessing power, affirming diversity, teaching with accuracy and scientific precision, and knowledge and personal epistemologies. Rende Mendoza and Johnson (2023) wanted to ensure all students, especially those in the LGBTQ+ community could feel a strong connection and tie meaning to their science education.

Afterwards, the researchers reviewed all interviews and instructional materials, a clear correlation between representation and inquiry were aligned with more inclusive classroom practices. “Participants connected the nature of science perspectives to gender-inclusive science teaching through Inquiry-based learning approaches” (Rende Mendoza & Johnson, 2023, p. 24). This shows through inquiry, there can be a higher correlation to the relationship students who may not always see themselves in science classrooms can connect to the curriculum and resources.

All three studies show using inquiry effectively, especially when consistently and effectively implemented, can greatly improve the results of all students. It is not just a type of educational approach that positively affects one group of students. Kim (2011) shows the importance of involving girls in science environments allows them to take ownership of their own learning and education. Seeker (2022) shows all subgroups of students can benefit from being in a classroom with a teacher who goes above and beyond for inquiry-based instructional practice, and Rende Mendoza and Johnson (2023) show a connection to inquiry-based learning and the personal ownership of science content and instruction. Teachers must be constantly attempting to connect to their students and provide them with multiple different supports and structures.

Interest in Science Careers and Confidence

When teaching science to students, there has historically been a percentage of students who do not feel confident in science (Boedeker et al., 2023). Confidence in science can help a student engage and succeed. If the goal of science education is to teach students to have the skills of a scientist, then increased interest in science careers should be considered a success. The following two studies will be a look at how teaching inquiry in science classrooms can lead to an increase in student's interest on careers in science.

The pandemic may have changed the way education is addressed forever. In a mixed-method study, Boedeker et al. (2023) looked at 24 elementary and 26 high school science teachers and their implementation of an IBL COVID-19 public health lesson implementation and their effect on student learning and confidence. The high school teachers were focused on for the purpose of this paper. 1,271 students aged fourteen-fifteen participated, all of which were in schools in Houston, Texas.

The lessons the teachers delivered were all focused on public health and the microbes known to affect people's daily lives. It was presented in the Spring of 2021 in multiple methods including synchronous on-line, hybrid, and full in-person learning. Twenty-five lesson plans were provided, but two were focused on increase of attitude and science knowledge for public health. The students were given a pre-test and a post-test, which both had science content questions on the desired learning targets and attitude towards science and science content questions. Science content gained saw a significant increase in the assessment provided, but perhaps the more intriguing result was the significant change in the student's confidence in their understanding of COVID-19 and vaccine science (Boedeker et al., 2021). This shows a change in confidence, which had not been measured in any of the previous studies.

The confidence gained by these students was obvious to the teachers, who reported a much higher interest in medical fields after the implementation of these lessons. Over half of the teachers believed these two lessons alone, created more interest in science careers or education, and none of the teachers who responded to the prompt concerning interest in medical field or further medical study believed the lessons negatively affected the students' feelings towards medical research (Boedeker et al., 2021). This showed a strong correlation between exposer to IBL practices and the level of student interest in science fields. It was a great tool to increase the feeling of confidence and excitement about public health.

With the increase of inquiry leading to higher excitement about scientific fields and information, the specific variables involved with the increase can be researched. In a mixed-method study by Rubino-Hare et al. (2021), the variables associated with increase in interest to science and science careers was studied. The purpose of this study was to discover the relationships existed between engagement and science practice, spatial reasoning, and 21st century skills through geospatial inquiry lessons GILs. The participants were six through twelfth grade S.T.E.M. teachers across the United States, who were mainly suburban and rural educators. They were asked to provide a lesson plan, which they received an inquiry-score on, and have their students pretest and posttest.

One of the biggest factors found to determine student interest was their belief in their teacher. This came through in a unique way that showed students who believed in their teacher's abilities, also had teachers who scored high on their rubric score for lesson plans (Rubino-Hare et al., 2021). This was important because it established student's belief in teachers who are capable of planning and implementing inquiry. When the researchers looked at the variables associated with increased chances of student interest in science after the implemented lessons, a few stood out. One of the most obvious was previous science-exposure, especially with a trusted adult. This then led to the importance of vertical alignment in science curriculums. When students have seen similar concepts, they become more excited about the topic (Rubino-Hare et al., 2021). The more excited the students became during the lesson, the more likely they were to respond favorably to the questions about exploring science. When the teachers added spotlights on possible careers in science related to the concepts being taught, the correlation increased.

The previous two studies by Boedeker et al. (2021) and Rubino-Hare et al. (2021) highlighted a connection to IBL practices and an increase in confidence, science interest, and especially an interest in pursuing scientific careers. For many science teachers, sparking an interest in science is a goal that they try to achieve, and the implementation of IBL practices seems to help attain that end.

Review Proposed Problem

It is extremely important to ensure students are receiving the highest possible form of science education. The previous research looked at answering the research question: In light of what is known about pedagogy in the contemporary educational setting, how can educational leaders assure each student receives an equitable, high-level science education by training teachers in inquiry-based learning and effectively implementing inquiry into the classroom setting? The research showed three threads education leaders can use to guide the journey of implementing IBL practice. The barriers must be known and addressed, trainings in these methods must be effective and help with teacher's doubts, and IBL helps all students with academic achievement and opinions towards science, including students traditionally underrepresented in STEM fields. These three threads all connect to both the individual research question of this paper and the program's essential learning outcome.

Review of Importance of the Topic

As science standards become increasingly focused on doing science as a skill, it is ever more important for teachers to not only teach their students content but also the skills necessary to be active scientists. With the NSTA (2021) stating, "Science teachers must be experts in teaching the content, nature of science, and inquiry", educational leaders must help lead the charge in the shift towards inquiry. They must provide relevant and rigorous training for implementation and provide resources for teachers, both curricular and support to ensure a smooth transition. They should advocate for IBL if teachers are originally hesitant and guide them through the transition. It is the duty of teachers to provide their students, who will be tomorrow's inventors, engineers, and healthcare professionals with the best science education.

Summary of Findings

Throughout this paper, the studies presented discussed barriers and solutions to implementations, supported purposeful pre-service and in-service teacher development, and the benefits to all students. Chahine et al., (2020) and Johnson and Tawfik (2022) both looked at smaller-scale implementation barriers, and the general sense of teachers who have encountered these shifts. These studies found teachers who believed in their work and capabilities, received proper training, and received curriculum supports they could successfully transition to effective IBL approaches. All three studies done, including Fitzgerald et al., (2017) showed the importance for extended reflection time for implementation.

Although barriers were seen in all studies, the individuals undertaking this transformation noted solutions that were effective. The most effective way schools had overcome the barriers presented were by truly working on the importance of professional development for both teacher success and feelings towards IBL. Ozel and Luft (2013) and Kang et al., (2017) looked at how increasing the knowledge about inquiry through modeling can help pre-service teachers strive as they take on the challenge of inquiry. Herrington et al., (2016) and Riordan et al., (2019) looked at how current teachers' attitudes and effectiveness can drastically change with proper training. Both types of training showed increase in attitude towards and competency in IBL strategies and their delivery.

The final theme, and the most important when considering the shift to IBL, is the effectiveness for all students, which was shown through Tornee et al., (2019) and Koksal and Berberoglu (2014). Which is very important when shifting entire educational systems. It is also vital; however, IBL practices were shown effective for engaging and teaching historically underrepresented students in S.T.E.M. fields by Kim (2011), Seeker (2022), and Rende Mendoza and Johnson (2023). Reaching all students, despite their background, is extremely important in public education. The final study relates to the importance of inspiring students, by seeing the effect of inquiry lessons on their interest in pursuing science further. Studies by Buedeker (2021) and Rubino-Hare et al., (2021) showed a strong correlation with adequate inquiry and interest in science fields.

With all three themes established, a clear vision for educational leaders and the goal of shifting towards IBL practices can be found. According to Tornee et al., (2019) and Buedeker (2021), a clear connection between student academic success and the interest in science is present. Educational leaders must ensure these practices which research has shown increases content knowledge and excitement are used. Implementing new strategies can have barriers, and educational leaders should be aware of any potential barriers. Chahine (2020) and Fitzgerald et al., (2017) found professional development and the shift in educators' mindset are two of the largest barriers of implementing IBL systems. Educational leaders must then plan for proper training and providing adequate resources in the shift to IBL instruction. Ozel and Luft (2013) and Herrington (2016) looked at the increase in confidence and implementation abilities after proper trainings, curriculums, and reflection. These articles gave clear evidence of the importance of strategic professional development when shifting methods of instruction.

Conclusion

When viewed together, the clear picture of the effectiveness of inquiry, the barriers presented, and the importance of overcoming those barriers is evident. It is important to ensure the students in one's classroom or school system are receiving the best education possible. Theme one showed barriers to implementation and gave educational leaders insight into what can be done to make transition smoother. Theme two looked at overcoming the most common barriers, of the need for proper professional development and training to increase teacher competence and shift teacher's opinions. Then thread three looked at the effectiveness of guided inquiry and the importance of listening to research and shifting science education to a more student-based IBL approach.

Chapter three will look at the meaning of the summarized research and the insights gained through this analysis. It will also describe how this can shape the practice of an educational leader. It then suggests studies for future research and avenues that can be studied.

Chapter 3: Insights, Applications, and Future Studies

The previous chapter looked at the fifteen research articles which can be found in the Tracking Matrix found in Appendix A. The research articles were analyzed to answer the question: In light of what is known about pedagogy in the contemporary educational setting, how can educational leaders assure each student receives an equitable, high-level science education by training teachers in inquiry-based learning and effectively implementing inquiry into the classroom setting? The articles painted three clear themes which can aid an educational leader in helping guide others into effectively implementing IBL practices in science classrooms. It also looked at how the research answered the program's essential question: In light of what is known about pedagogy in the contemporary educational setting, how shall educators lead equitably and inclusively in order to positively impact student development and learning? This chapter will be focused on sharing the insights learned from the research, applying the information learned from the research in their educational settings, and suggesting future studies to further analyze the effective implementation of IBL practices to help student achievement and belonging.

Insights Learned

It is paramount to ensure that all changes in the schools or district are handled smoothly and have research-based reasons for implementation. The actual process of change in school culture will often fall onto the leaders to ensure everything is done with good intent, the why is communicated to the shareholders of the school, and the teachers, staff, and students all feel supported in their shift towards a new curricular design.

Throughout the previous research, the first insight that was gleaned was the inherent difficulties in making large or small changes in education. Research done, looked at small- and large-scale transitions in inquiry-based learning practices, and found there are many barriers in implementation of new pedagogical strategies. The most common barrier was proper training for two main reasons, to ensure the teachers and staff who are asked to implement this change have the capabilities to instruct in a new pedological fashion, and staff felt the shift was meaningful and worthwhile. Another obstacle found was ensuring teachers feel supported with two large resources, the actual curriculum and materials, which many teachers believe they need specific help designing, and time to digest and reflect upon the teaching which they will do and have done. It is the job of true leaders, to lead when it is not always easy, but when it is often the hardest, which is why it is important for educational leaders to know about the potential barriers possible and be equipped with the tools and resources to overcome these barriers.

The next insight found in the research, was the effectiveness of proper training on both the effectiveness of teachers and their opinions about the teaching of inquiry and the practices associated with this style of learning. This is effective at pre- and in-service levels, meaning there are many points in time training can be used and implemented. Educational leaders on licensing boards and higher education members who design the pathways of pre-service teachers can help ensure all teachers come in with this training. Educational leaders at school, state, and federal levels, can ensure there are opportunities for science teachers, and all teachers willing to try IBL practices in their classroom can participate in and count towards re-licensure processes. This not only helps with the effectiveness, but it will also show the teachers the backing of these practices by decision-makers in the educational field.

The final insight, and the most important when a shift of curriculum and pedological practices is concerned is the effectiveness of this type of instruction. This has shown positive results many times in the research, and not only on the highest of learners, but on marginalized and traditionally underrepresented individuals in the STEM fields. It shows all students can learn science effectively and equitably, if they are involved in doing rather than involved in receiving information. The research also showed a shift in attitude towards sciences and science careers when instructed in IBL practices. This then increases the interest in science and can shift student engagement to much higher levels.

The insights gained throughout this research are clear and precise correlations to IBL practices and their effectiveness. It is vital to engage all students, and to use effective strategies which students find meaningful. Educational leaders must be prepared to help transition today's science classes into inclusive, effective, and engaging spaces through IBL.

Application to Educational Practice

Armed with this knowledge, educational leaders must act. They must be leading the charge in adopting, implementing, and supporting teachers and students into shifting in a scientific inquiry culture. The insights learned are extremely important, but it is equally important to enact policies, procedures, and practices which ensure these strategies are being adopted and adapted for classrooms and the unique learners present in the educational system.

Any school shifting to this must know about the barriers and solutions to those barriers. Barriers will arise, some new and some old, but it is imperative to have systems in place designed to minimalize the barriers as much as possible. Before a shift to entire IBL practices in any system, the educational leaders in the space should contact schools and programs which have already shifted to this type of instruction and ensure their experience is used when planning. The more input from educators who have enacted these practices the better. No roll-out of curriculum will be perfect, and leaders can learn from people who have experienced it before. Once the barriers and potential solutions are known, involve the people who will be implementing the instruction in the process of planning to overcome these barriers. Let the teachers know what others have experienced and how they have overcome those experiences, and then give teachers and educators a voice in planning to overcome those barriers. It is also vital to have active routes of reporting real-time barriers the educators and students face. There will be unplanned problems and unplanned successes. Ensure there is a place for both to be communicated, discussed, and potentially solved for future scenarios.

The clearest need was the need for support in training and providing support as educational leaders. This can be done in many ways. It can be done on very large levels, ensuring teaching inquiry becomes a requirement for science education licensures. This would be then added to teacher training programs, ensuring teachers start with this skill, and refine it before they are instructing students. Another potential route is increasing training for current teachers at all levels. An educational leader such as an instructional coach or principal, could set up professional development given as an option to all science teachers or staff interested in using inquiry in their own classrooms. This could involve many different routes, whether it is involving experts and teachers who have already effectively implemented inquiry or designing and leading a course in how to implement IBL into the classroom. At larger levels, it could become a required training for re-licensure for science teachers in state boards. This would be a commitment by state boards to ensure all teachers are being trained in these practices, ensuring all students have access to the research-backed strategies.

Implementing the curriculum and strategies this educational concept need will not always require leaders to reconstruct large portions of curriculums. Standards have already largely shifted, requiring teaching science as a set of skills, with the content as a means of teaching these skills. It is vital to ensure the standards, and the needs of the students are being met by planning, designing, and implementing a curriculum fitting both IBL practices and one which reaches all standards required. This can be done in many ways, from local levels, ensuring the culture of the community is involved including community outreach projects and concepts. It can be accomplished at larger-state levels, where state-educational boards are adapting standards ensuring inquiry and exploration in the science classroom. It can also be done by educational organizations then incorporated into the schools through purchased curricular materials. Each school or district may be different and have different choices or routes better suited for their needs and implementation.

Suggestions for future research

Throughout chapter two of this paper, there were many different studies done, in many different locations, structures, and environments which have tried adopting individual IBL lesson plans or complete inquiry-based learning courses and structures. One of the clearest areas for future research are the support level at which inquiry is most effective.

A future research study could be done on the appropriate level of guides in the inquiry process. Most of the research been done to this point is to compare a more traditional style of information dissemination and how inquiry-based learning can increase student outcomes, but there are many different layers of inquiry in the classroom, there are days a teacher may ask their students to participate in the parts of the scientific method on their process to reaching a learning target, there are also days where teachers may have students actively engaging in several aspects of inquiry, or there are times an entire unit or class is based on inquiry and the journey of exploration. Future studies could focus on the balance between guided inquiry and open-inquiry, and the effectiveness of both approaches at reaching proficiency in state-standards associated with the lessons being taught.

Studies could also be done on the use of a continual stacking inquiry curriculum within a district. There seemed to be promise that students who had prior experience with inquiry felt more comfortable using the terms and achieved slightly higher results, so future research could target the importance of vertical alignment among grade levels at a district. This would show how teaching through inquiry can grow a student's ability to do science in multiple settings. It also allows for looking at a scaffolded approach for inquiry learning and how the skills could be worked on throughout the entirety of the scientific educational pathway of a student.

The final study this paper will suggest is to look into the future of these students. A study could be done on students who receive IBL science instruction in high school, and their relative success in higher education or science fields. There were studies which showed a clear connection between IBL strategies and student's interest in science fields, but a look into how these practices prepared them for college classes and eventual jobs in the science field could be done. This would need to be a large study with large numbers of participants, but it could really show if these practices affect the scientists of tomorrow.

Conclusion

What should a science classroom look like? It should be a space each student feels inspired to search for information, shows a desire to learn, and be active members of the process of inquiry. It should be a place where students and teachers ask and answer questions, where they dive deep into learning through multiple high-level inquiries, and a place everyone feels they can make a difference. It is no longer enough to provide students with information, it is time science education shifts to teaching through inquiry and teaching through experience. Today's students will be solving tomorrow's problems. They need an education which ensures they have experienced science as active participants. Educational leaders must lead the charge in providing an equitable experience in the contemporary educational setting by ensuring each student receives an equitable, high-level science education by implementing inquiry in their schools and districts. Leaders must effectively identify barriers and solutions, provide training and professional development for the shareholders involved, and design and implement an effective inquiry-based curriculum which reaches all students. J. Robert Oppenheimer leader of the Manhattan Project said "There must be no barriers to freedom of inquiry. There is no place for dogma in science. The scientist is free, and must be free to ask any question, to doubt any assertion, to seek for any evidence, to correct any errors." There must be a place for inquiry in today's science classroom, and every student deserves the freedom that comes with inquiry.

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Appendix A

Article Tracking Matrix

Articles: author(s) name and year of publication	**Method** Qualitative/ Quantitative/ Mixed-Methods	**Barriers to Inquiry Based Learning**	**Teacher Perspective and Training**	**IBL Classroom Results**	**Sub-Theme Equitable results for students**	**Sub-Theme Increase Interest in Science Careers**
Boedeker et al., (2021)	Mixed-Method					X
Chahine et al., (2020)	Mixed-Method	X				
Chen & Wang (2020)	Mixed-Method			X		
Fitzgerald et al., (2017)	Qualitative	X	X			
Johnson & Tawfik (2022)	Qualitative	X				
Herrington et al., (2016)	Qualitative		X			
Kang et al., (2017)	Qualitative		X			
Kim (2011)	Mixed-Methods				X	
Koksal & Berberoglu (2014)	Quantitative			X		
Rende Mendoza & Johnson (2023)	Qualitative				X	
Ozel & Luft (2013)	Quantitative		X			

Riordan et al., (2019)	Qualitative		X			
Rubino-Hare et al., (20240	Mixed- Method					X
Secker, (2002)	Mixed- Method				X	
Tornee et al., (2019)	Quantitative			X		