ENSURING EQUITABLE OPPORTUNITIES TO IMPROVE HOW BLIND STUDENTS CONCEPTUALIZE THE NATURE OF SCIENCE

Tina Noelle Stamper

Submitted to the faculty of the School of Education
in partial fulfillment of the requirements
for the degree
Doctor of Education
In the Department of Curriculum and Instruction,
Indiana University
January 2025

Accepted by the School of Education Faculty, Indiana University, in partial fulfillment of the requirements for the degree of Doctor of Education.

Doctoral Committee

Valarie L. Akerson, Ph.D.

Gayle A. Buck, Ph.D.

Janet R. Decker, J.D., Ph.D.

Date of Defense

December 04, 2024

To my children. Everything I do in life is for you.

"For I know the plans I have for you," declares the Lord,

"plans to prosper you and not to harm you,

plans to give you hope and a future"

– (Jeremiah 29:11 NIV).

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Dr. Valarie Akerson for accepting me as her student and for agreeing to serve as my major advisor. The education she has provided for me, along with her knowledge, guidance, understanding, and support, has not gone unnoticed. I am truly grateful for the opportunities that Dr. Akerson has given me, as I believe they have enabled me to become a better writer, researcher, and educator. I would also like to thank Dr. Gayle Buck and Dr. Janet Decker for agreeing to serve on my dissertation committee. Their teaching, time, expertise, and feedback has been invaluable in helping me to achieve this goal. I fully understand that my accomplishments in this endeavor have been, in part, due to the environment that my committee chair and members have provided in empowering me to become a more successful student and practitioner.

Next, I would like to thank the faculty and staff within the School of Education at Indiana University (IU). Their passion for education and teaching has provided me with valuable insight into educational topics and issues of which I wasn't previously aware. Not only has this allowed me to become a more knowledgeable educator, but a more compassionate human being. The education I have received is second to none, and I will forever be proud to call myself a Hoosier. Additionally, I would like to thank my fellow graduate students for their professionalism and camaraderie throughout our time together. Most notably, Nicole Conrad Nelson for her feedback and collaboration on various projects.

My sincere thanks are also extended to all of those who helped in making my dissertation research project a success. In addition to my dissertation committee, I also express my gratitude to the IU Institutional Review Board (IRB) for their timely feedback and approval of my study. I am also very appreciative of my colleagues and classmates, Dr. Shellie Harshberger and Dr.

Kristen Poindexter, for providing their time in coding and for their expertise as it pertains to students in the realm of K-12 education. Most importantly, I am beyond grateful to the students who agreed to participate in my study. While I am quite sure I learned much more from them than they learned from me, I truly valued the time they were willing to invest, the effort they put forth, and the insight they provided. In addition, I would like to thank the students' parents for trusting me with their children. The connections that have been made and the friendships that have been formed are very much appreciated.

Last, but not least, I offer my wholehearted gratitude to my family. I have been blessed with parents and grandparents who have instilled in me the importance of an education, along with aunts and uncles who have provided me with exceptional examples of what it means to be an educator, in and out of the classroom. Additionally, I have been blessed with four beautiful children who are the light of my world. In speaking to all of them, your futures mean everything to me. Thank you for teaching me, for making me proud each day, and for giving me something to be passionate about. I love you all so much. And, in speaking to my husband, there are no words to express my appreciation. I will forever be grateful for the love and support you have offered so selflessly throughout our marriage and throughout my educational journey. Thank you for putting our family's needs above your own, and for keeping our household functioning over the past three years. You are a wonderful husband and father. My love for you exceeds all else.

Tina Noelle Stamper

ENSURING EQUITABLE OPPORTUNITIES TO IMPROVE HOW BLIND STUDENTS CONCEPTUALIZE THE NATURE OF SCIENCE

This study explored the impact of online explicit-reflective instruction on visually impaired students' conceptions of the Nature of Science (NOS). Blind and low vision students enrolled in grades K-12 were recruited to participate in a six-week, online, Saturday science program during which they engaged in tactile NOS activities and received explicit-reflective NOS instruction. In order to assess the students' understandings of various NOS aspects, students completed the Views of Nature of Science (VNOS) questionnaire, pre- and post-NOS instruction. Additional qualitative data were obtained from weekly exit slips, the students' verbal commentary, semi-structured interviews, and a teaching journal kept by the instructor of the science program. The study participants, as a whole, were shown to hold a majority of inadequate views on the various aspects of NOS prior to receiving any explicit-reflective NOS instruction. However, results showed that after receiving explicit-reflective NOS instruction, the students were able to improve their understandings of the creative, empirical, subjective, and tentative aspects of NOS, as well as being able to distinguish between the scientific processes of observation and inference. Results also indicated that the students found science to be fun and were willing and able to actively engage in adapted NOS activities. Based upon these findings, it is imperative that researchers identify ways to provide blind and low vision students with equitable and inclusive opportunities to comprehend NOS ideas as a means to increase their scientific literacy and to make informed decisions about the world around them.

Valarie L. Akerson, Ph.D.

Gayle A. Buck, Ph.D.

Janet R. Decker, J.D., Ph.D.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I: INTRODUCTION

The Nature of Science (NOS) is a crucial component for comprehending the science curriculum, as well as elements of different scientific processes. In addition, NOS assists students in forming their own opinions and making informed decisions pertaining to the scientific world around them (Akerson et al., 2014). The National Science Teachers Association (NSTA) echoes this sentiment by stating that NOS "is a critical component of scientific literacy that enhances students' understandings of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues" (NSTA, 2022, as cited in Nelson & Stamper, 2022, p. 306). More commonly, NOS "refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 1992, as cited in Lederman, 2013, p. 833). While a universal definition of NOS currently fails to exist (Nelson & Stamper, 2022; Schwartz & Lederman, 2002), seven key principles have been identified. According to Bloom et al. (2015), these principles stress that NOS is:

- "tentative,
- based upon empirical evidence,
- subjective and theory-laden,
- advanced through creativity and imagination of scientists,
- socially and culturally embedded,
- driven by observations and inferences, and
- based on laws and theories" (pp. 406-407).

Although these tenets of NOS often overlap with scientific processes and inquiry, it is important to understand the differences to avoid confusion. For example, while observations and inferences are scientific processes that help one draw conclusions, NOS is more concerned with the theoretical foundations of the scientific enterprise and how one comes to know what they know (Lederman, 2006).

While students do not automatically come to an understanding of NOS concepts (Akerson & Abd-El-Khalick, 2005), teachers can help facilitate the learning process through explicit-reflective NOS instruction and by beginning such instruction in early elementary grades (Akerson et al., 2011; 2014; 2019b). This is especially important, as the *Next Generation Science Standards* (NGSS) (2013) have been developed to better prepare students for post-secondary opportunities and career readiness in the fields of science. Along with *A Framework for K-12 Science Education* (NRC, 2012), the NGSS (2013) provide a vision for what K-12 science education should entail in the twenty-first century (Pruitt, 2016). Found within Appendix H of the NGSS (2013), is the NOS Matrix, which includes learning outcomes and performance expectations for varying grade levels. In addition, the NOS Matrix categorizes eight comprehensive points of NOS based upon the students' understandings associated with practices (Numbers 1-4, shown below) and those associated with crosscutting concepts (Numbers 5-8, shown below):

1. "Scientific Investigations Use a Variety of Methods
2. Scientific Knowledge is Based Upon Empirical Evidence
3. Scientific Knowledge is Open to Revision in Light of New Evidence
4. Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
5. Science is a Way of Knowing
6. Scientific Knowledge Assumes an Order and Consistency in Natural Systems
7. Science is a Human Endeavor

8. Science Addresses Questions About the Natural and Material World" (NGSS, 2013, p. 4).

In order for students to better understand NOS concepts, teachers can utilize these eight elements to design activities that provide students with opportunities to use their scientific skills and knowledge to investigate scientific phenomena. This, paired with proper instruction and the time to reflect, allows students the opportunity to enhance their knowledge of scientific concepts and to build their understandings of NOS (NGSS, 2013).

However, as Akerson et al. (2019a) note, NOS instruction is not often seen in elementary science classrooms. Reasons for this include the teacher's own misconceptions of NOS, the idea that students are not ready to learn about or comprehend NOS concepts, and the exclusion of NOS from the science curricula (Akerson et al., 2019a). And, while the NGSS (2013) has put forth the eight NOS ideas listed above, they fail to make suggestions for how teachers can include NOS instruction in their classrooms. Therefore, as Akerson et al. (2019a) allude, it can be assumed that NOS comprehension is no longer prioritized as it once was within the *Benchmarks for Science Literacy* (AAAS, 1993) or the *National Science Education Standards* (NRC, 1996).

Other possible barriers to understanding NOS concepts are issues of equity and inclusion within the science classroom. This is particularly true for blind[1] students who must experience tactilely what their sighted peers experience visually (Koenig & Holbrook, 2000). While teachers' attitudes play a large role in the inclusivity of students with disabilities (Unianu, 2012), positive strides can be made through proper training techniques and increased exposure to exceptional learners (Donohue & Bornman, 2015). Improved levels of inclusivity can also be

---

[1] As the National Federation of the Blind (NFB) has resolved to use identity-first language when referring to blind individuals (Dunn & Andrews, 2015), so too shall this dissertation.

achieved by making classroom materials accessible to the student. In the case of visually impaired students, these items of accessibility might include assistive technology devices such as screen readers (e.g., JAWS®), active braille displays (e.g., Humanware™ devices), and audio book players, as well as tactile graphics and curricular materials (Beck-Winchatz & Riccobono, 2008; Farnsworth & Luckner, 2008; Presley & D'Andrea, 2008).

Legal Considerations

While equity and inclusion within the science classroom may be viewed by some educators as a moral and ethical obligation, it is a legal obligation as well. As students with disabilities have often encountered discrimination and exclusion within the school system (Rivera & Tilcsik, 2023; Schimmel et al., 2017), federal laws such as the Individuals with Disabilities Education Act (IDEA) (2004) require states to provide such students with a free appropriate public education (FAPE) (20 U.S.C. § 1400; 34 C.F.R. § 300.101). Under the "Child Find" mandate, individual states are responsible for locating, identifying, and evaluating those children, aged 0 – 21 years, who are suspected of having a disability and in need of special education and related services (McCarthy et al., 2019; Norman, 2023; Schimmel et al., 2017; 34 C.F.R. § 300.111). If a child is suspected of having a disability, an evaluation may be requested by the child's parent(s), the state education agency (SEA), or the local education agency (LEA) (Schimmel et al., 2017). School districts are required to conduct such evaluations through "qualified personnel" (McCarthy et al., 2019, p. 172), using various strategies and means of assessment to ensure accuracy and appropriate placement of the student (Schimmel et al., 2017).

Being identified with one of the following disability categories allows for children to receive special education and related services under the IDEA (2004):

- autism

- deaf-blindness
- deafness
- emotional disturbance
- hearing impairment
- intellectual disability
- multiple disabilities
- orthopedic impairment
- other health impairment
- specific learning disability
- speech or language impairment
- traumatic brain injury
- visual impairment (including blindness)
- developmental delays experienced by children between the ages of 3 – 9 years

(Dragoo, 2020; Shaver, 2017; 34 C.F.R. § 300.8). Although the "Zero Reject" mandate prevents schools from denying an education to students with disabilities (Estes, 2003), it is also important to note that the disability must have a negative effect on the student's educational performance in order to meet the IDEA eligibility requirements and qualify for services (McCarthy et al., 2019; Shaver, 2017).

Should results of the evaluation deem a child eligible, an individualized education program (IEP) is then designed by an IEP team to meet the individual needs of the student (McCarthy et al., 2019; Schimmel et al., 2017). In accordance with the IDEA (2004), members of an IEP team should include the parent(s) of the child with a disability; at least one general education teacher (if the child is participating the in general education classroom setting); at least one special education teacher; a representative of the district who is able to dedicate district resources; an individual who is able to interpret results of the evaluation (e.g., psychologist); others who have expertise or knowledge pertaining to the child; and when appropriate, the child (McCarthy et al., 2019; Umpstead et al., 2015; 20 U.S.C. § 1414(d)(1)(B)). Collectively, the IEP team is charged with determining if "modifications to the instruction or services are necessary for the child to meet measurable annual goals and to participate, as appropriate, in the general education curriculum" (McCarthy et al., 2019, p. 174).

In addition to finalizing the IEP and obtaining parental consent, the district is also responsible for coordinating all resources and services as recorded in the IEP document (McCarthy et al., 2019). Furthermore, the district must ensure that the child is educated in the least restrictive environment (LRE), as schools are required to educate students with disabilities alongside their nondisabled classmates "to the maximum extent appropriate" (Crockett & Yell, 2017, p. 65; Mead, 2017, p. 22; 20 U.S.C. § 1412(a)(5)(A)). Should a parent disagree with the district's placement of their child, procedural safeguards exist to protect parents in their right to actively participate in the IEP process and to advocate for their child's special education and related services (Dinnesen & Kroeger, 2018; McCarthy et al., 2019). If an agreement cannot be reached, both the parents and the school district may elect to "file a due process complaint with the [SEA]" in an attempt to resolve the dispute (McCarthy et al., 2019, p. 183).

In order to ensure a FAPE, a school may be required to provide students with assistive technology and instructional materials that enable them to access the learning curriculum. This holds especially true for blind and low vision students. The IDEA (2004) regulations specifically mention visual impairment and defines it as, "an impairment in vision that, even with correction, adversely affects a child's educational performance. The term includes both partial sight and blindness" (34 C.F.R. § 300.8 (c)(13)).

Although federal law takes precedence over state law (U.S. Const. art. VI, § 2), individual states have also enacted laws to protect the rights of blind and low vision students. As an example, the State of Indiana specifically addresses blindness and defines a blind student as an individual:

> who cannot successfully use vision as a primary and efficient method for learning; and exhibits such a low degree or amount of visual acuity or visual field that vision is not considered as a primary mode of learning; or who has a medically indicated prognosis of visual deterioration (Ind. Code § 20-35-9-1).

In addition, it is presumed "that, with some exceptions, proficiency in braille reading and writing is essential for blind students to achieve satisfactory educational progress" (I.C. § 20-35-9-5). While other methods of literacy may be considered during the development of a student's IEP, "the availability of other media may not preclude braille instruction if, in the determination of a blind student's case conference committee, braille is necessary for the student to achieve to the student's potential" (I.C. § 20-35-9-5). Furthermore, it is required that blind students complete a literacy assessment "administered by a certified teacher of individuals with a visual disability using criteria established by the state board" in order "to determine the student's present level of performance in reading and writing" (I.C. § 20-35-9-6). Information pertaining to all possible options for a blind student's literacy should be made "available to the student and the student's parents" (I.C. § 20-35-9-8).

> If it is determined that braille instruction and use is appropriate for a student who is blind, the student shall be provided instruction by certified teachers of individuals with a visual disability in the frequency and intensity specified in the student's individualized

education program (I.C. § 20-35-9-7).

In addition to laws that protect blind and low vision students at the federal and state levels, policies are developed at the district level as well. Therefore, local school boards are critical to ensuring the welfare of the students whom they serve (Hess & Meeks, 2010). With that being said, school boards must abide by all legal mandates and see to it that their students' civil liberties go unviolated (McCarthy et al., 2019). This can be accomplished and carried out through the adoption of appropriate board policies. For example, the Board of School Trustees overseeing Elkhart Community Schools (ECS) in Elkhart, Indiana adopted a policy which specifically makes reference to Indiana's Title 511, Article 7, by stating that blind and low vision students are eligible for special education and related services (Elkhart Community Schools Code po2461.07, 2016; 511 I.A.C. 7-41-2). The board of ECS also adopted a policy which addresses service animals and the rights of blind students to utilize such animals on school property (Elkhart Community Schools Code po8390, 2016). The school board overseeing Penn-Harris-Madison (PHM) School Corporation in Mishawaka, Indiana also adopted a policy which protects the rights of blind and low vision students, as well as other students with differing disabilities. PHM acknowledges their obligation to provide a FAPE under the IDEA (2004) and Section 504 of the Rehabilitation Act of 1973 (Section 504) (29 U.S.C. § 794), while stating that all students will have equal access to educational opportunities (Penn-Harris-Madison School Corporation Code po2260, 2022). Adopting such policies can serve to strengthen a school's commitment to students of all ability levels, while also helping to ensure compliance with state and federal statutes.

In addition to education laws enacted at the federal, state, and local levels, Section 504 (29 U.S.C. § 794) and the Americans with Disabilities Act (ADA) of 1990 (42 U.S.C. § 12101 *et* *seq.*), are civil rights laws that protect students from discrimination based upon the type and severity of their disability. It is possible that a student experiencing a minor visual impairment may not qualify for services under the IDEA, but still receive certain accommodations under Section 504 and the ADA (Mead, 2017). Therefore, schools receiving federal funding must see to it that students with disabilities are able to access the learning curriculum through "reasonable accommodations" (Mead, 2017, p. 18).

A recent court case filed by blind students under the ADA and Section 504 was *Roy Payan et al. v. Los Angeles Community College District* (2021). In 2017, Roy Payan, Portia Mason, the National Federation of the Blind (NFB), and the NFB of California sued the Los Angeles Community College District (LACCD) due to a lack of accessible technology and instructional materials. Payan and Mason pled "denial of equal communication," "disparate treatment," and "denial of accommodation" for failing to provide accessible classroom materials in a timely manner. In 2019, the United States District Court for the Central District of California held a bench trial and found that LACCD violated Title II of the ADA, as well as Section 504, through the use of inaccessible handbooks, inaccessible websites, and inaccessible library databases. As a result, LACCD was ordered to make its materials, websites, software, and databases accessible to blind students (*Payan v. L.A. Cmty. Coll. Dist.*, 2019). However, in 2021, LACCD appealed to the Ninth Circuit Court of Appeals arguing that plaintiffs should not be allowed to sue for disparate impact of discrimination under the ADA or Section 504, as they do not apply to unintentional discrimination. The majority ruled that "Section 504 and the ADA were specifically intended to address both intentional discrimination and discrimination caused by 'thoughtless indifference' or 'benign neglect,' such as physical barriers to access public facilities" (*Roy Payan et al. v. LACCD*, 2021).

In a separate case, the family of a visually impaired child filed a due process complaint in Florida claiming that their child had been denied a FAPE as a result of the child's IEP not having been properly designed or implemented, and that classroom materials were not made accessible for a visually impaired learner. After hearing testimony from the child, the child's mother, the child's teachers, and various professionals within the school district, it was concluded that the student's IEP was deficient, as it did not meet all of the student's educational needs or allow the student to make appropriate progress while taking into consideration her circumstances as a visually impaired learner. In addition, it was established that the student did not receive all classroom materials in an accessible format, nor was proper training provided on technology devices that would have enabled the student to better access course materials. As a result, it was found that the Seminole County School Board denied the student a FAPE by failing to appropriately design and implement the student's IEP. Therefore, it was ordered that the School Board provide the student with a compensatory package that addressed the services and instruction previously denied (*Petitioner v. Seminole County School Board*, 2018).

To avoid such lawsuits, it is important that teachers and other school employees be legally literate and mindful of their legal obligations to prevent violating the rights of blind and low vision students (Decker & Shaver, 2017). It is imperative that visually impaired students have access to assistive technology and tactile learning materials in order to participate in an equitable manner in unison with their sighted classmates. This may require a student's general education teacher(s) to actively collaborate with a TVI and a certified transcriptionist to ensure that braille and accessible tactile materials are produced in a timely manner. In order to ensure a school's legal compliance, it is important for administrators to be knowledgeable on the laws protecting blind and low vision students in regard to their accessibility of educational classroom materials, and to provide teachers with the necessary training to properly implement the student's IEP.

However, as discussed by Decker and Shaver (2017) within their writings, many educators and administrators are unprepared and lack the training necessary to make informed decisions pertaining to special education and the legal rights of students with disabilities. Given that school leaders are responsible for ensuring the compliance of faculty and staff with special education laws (Decker & Brady, 2015), it has been suggested that school administrators offer increased professional development opportunities for teachers and other school employees to receive legal training and to improve upon their legal literacy (Decker et al., 2019). Doing so may "prevent unnecessary anxiety, legal violations, and expensive litigation…[as well as] significantly better outcomes for [students with disabilities]" (Decker & Brady, 2015, p. 250). This is certainly something to consider, seeing as how students with disabilities are offered numerous legal protections (Decker & Brady, 2015), such as those described above. Additionally, lawsuits surrounding special education students are the most prevalent legal concern that school districts often face (Katsiyannis & Herbst, 2004, as cited in Decker & Brady, 2015).

Furthermore, lawmakers have actively sought to increase state accountability in meeting the educational needs of deaf, blind, and deaf-blind students through high quality specialized instruction. Introduced in the Senate on September 27, 2023, by Senator Edward J. Markey of Massachusetts, was the Alice Cogswell and Anne Sullivan Macy Act (2023). A favorable outcome in moving the bill forward is desired, as it would serve to strengthen the current protections offered to blind and low vision students under the IDEA by ensuring that visually impaired students are properly identified, evaluated, and better supported within the education system. Currently, as of September 2024, the bill has garnered bipartisan support and has been referred to the Committee on Health, Education, Labor, and Pensions (Alice Cogswell and Anne Sullivan Macy Act, 2023).

Problem Statement

While several NOS studies have been conducted across contexts and grade levels (Akerson & Carter, 2022), none had attempted to address how educators might provide blind and low vision students with more equitable opportunities to better conceptualize NOS ideas. This is surprising, seeing as how blind and low vision students are known to be at a disadvantage when it comes to the science curriculum, often times due to the graphical information that is traditionally displayed through pictures (Beck-Winchatz & Riccobono, 2008). In addition, previous research has indicated that a majority of blind and low vision students may not receive the resources necessary to remain at grade level alongside their sighted peers in the public education system (Mushoriwa, 2001; Wilcox-McBride, 2017; Girnus, 2018; Tom et al., 2018). According to Miyauchi (2020), these issues can be further compounded by teachers' preconceived notions and misconceptions pertaining to the inclusion of blind and low vision students within the general education classroom, particularly in the subjects of math and science. Therefore, as the child ages, they tend to navigate towards course subjects that are made accessible to them, rather than subjects that suit their academic interests and abilities; consequently, leading to an underrepresentation of visually impaired citizens pursuing college science degrees or working within the fields of science (Miyauchi, 2020). With that said, it is imperative that researchers understand ways to improve how blind and low vision students comprehend NOS concepts, and how we can arm educators with the proper tools and knowledge to provide visually impaired students with equitable and inclusive opportunities to increase their scientific literacy and to make informed decisions about the world around them.

Purpose of the Research Study

Taking the above points into consideration, the primary purpose of this research study was to identify ways that educators can provide blind and low vision students with more equitable opportunities within the science classroom to better comprehend NOS ideas. We aimed to accomplish the purpose of this study through online explicit-reflective NOS instruction and through use of the *VNOS Questionnaire*, which was administered both pre- and post-NOS instruction, to blind and low vision students. Qualitative data were also obtained through semi-structured interviews and by way of weekly exit slips, which allowed student participants the opportunity to share their lived experiences of how visual impairments could sometimes serve to hinder their abilities to understand NOS concepts. And lastly, a teaching journal was kept by the instructor-researcher in which they made notes of their thoughts pertaining to the success of each lesson, any preconceived notions that they may have been made aware of, as well as any personal misconceptions that could have served to hinder the students' abilities to understand NOS concepts.

Theoretical Framework

While this study focused on ways that educators can provide blind and low vision students with more equitable opportunities to better understand NOS concepts, the research should be viewed through a lens of ethics and equity with the underpinnings of egalitarian principles. Therefore, this study mirrored the theoretical framework suggested by De Coster & Loots (2004). While De Coster & Loots (2004) focused on making art education more meaningful for blind individuals, the same theories could be applied to that of science education. According to Mandelbrojt (1994), both art and science require creativity that allows individuals to perceive truth in the world around them. Consequently, one must consider the following three components as proposed by De Coster & Loots (2004) within their framework: (1) the visual intensity of the subject matter; (2) the cognitive ability of the blind individual to make meaning of the subject matter; and (3) the teacher as a moderator. That being said, in order for visually impaired students to better comprehend NOS concepts, we had to first consider the degree of vision necessary for gaining an accurate understanding of what was being conveyed by the scientific subject matter. Next, we had to take into consideration the blind student's ability to reason and make sense of tactile information being presented to them within the science classroom. And furthermore, we had to consider the teacher as a moderator and their ability to translate the student's tactile gathering of information into descriptive visual imagery (De Coster & Loots, 2004). Through these considerations, this research hoped to explore ways that science could be made more meaningful to visually impaired students, enabling them to better understand NOS concepts.

Research Question

In order to accomplish the purpose of this research study, while employing the theoretical framework described above, this study put forth and aimed to answer the following research question:

Research Question: How does my online explicit-reflective instruction impact visually impaired students' conceptions of NOS?

Definition of Terms

Low Vision: "the student has one or more of a wide variety of vision problems that cannot be corrected with glasses and that limit his or her ability to perform everyday activities" (Allman, 2004, as cited in Case et al., 2005, p. 3).

Teacher of the Visually Impaired (TVI): licensed and certified special education teacher who meets the educational needs of blind and low vision students (Willings, 2020).

Totally Blind: "the student does not have the ability to see and must use other senses for learning" (Allman, 2004, as cited in Case et al., 2005, p. 3). Student has a lack of visual light perception, which applies to 15% of those with visual impairments (Lee & Mesfin, 2017).

Transcriptionist: an individual certified by the National Library Service (NLS), who is knowledgeable of braille formats and able to transcribe print materials into braille (Allman, 2009).

Visual Intensity: "degree of vision used for a deeper understanding" (De Coster & Loots, 2004, p. 327) of scientific subject matter.

Visually Impaired: a term used to describe an individual with visual impairments, ranging from some usable vision to no usable vision (Allman, 2009). Applies to those who are low vision or blind, and whose daily living skills are adversely affected (Lee & Mesfin, 2017).

Positionality

Positionality refers to one's personal, lived experiences and how those experiences have generated knowledge and an understanding of the world around them (Qin, 2016). My first experience with blindness occurred as a high school student when I served as an assistant to a special education teacher in my school's resource room. During this time, I was paired with two elementary-aged students from the Amish community who were deaf-blind. While I wasn't aware at the time, this experience would serve as a valuable tool in setting expectations when my own child would become totally blind due to a rare childhood cancer of the eyes called retinoblastoma. Having been a sighted parent in the blind community now for nearly ten years, ongoing training has been achieved through state and national conventions for the blind, parent workshops, webinars, and technology showcases. Additional insight has been gained through medical professionals, legal counsel, educators of blind individuals, and members of the blind community.

Now, as a science educator, and as the parent of a minority, blind child, I have become aware of the challenges that blind and low vision students can face and the inequities that they may encounter within the science classroom. Therefore, my own experiences with blind education and my advocacy within the blind community have played a role in my research interests. My positionality has allowed me to understand the experiences, good and bad, that parents of blind and low vision children have encountered as they work to secure highly qualified resources within the public school system to educate their children in a manner equal to that of their sighted peers. Likewise, my experiences with blind and low vision adults in the blind community has provided me with insight into their experiences of being marginalized and discriminated against in post-secondary education and within the job market. While these experiences have undoubtedly affected my ability to remain entirely objective in my research interests, as I am clearly biased towards providing blind individuals with proper educational and occupational tools, I believe the vast amount of knowledge that I bring to the study of blind education far outweighs any subjectivity that may have occurred in the interpretation of my data.

Contributions and Significance of the Research Study

To my knowledge, at the time that this research commenced, it was the only study that had specifically investigated ways that educators could provide blind and low vision students with more equitable opportunities to better comprehend NOS concepts. In addition, this was considered to be a double vulnerability study, as it involved blind and low vision children as active research participants. While all children are considered to be part of a vulnerable class when conducting educational research, children with disabilities are known to face additional levels of vulnerability due to social and academic marginalization (Faldet & Nes, 2021). I believe the voices of the participants within this study have served to provide a firsthand perspective of the challenges and inequities that visually impaired students experience within the science classroom. Therefore, it is my hope that the results of this study will lead to increased discussions of how educators can better provide blind and low vision students with more inclusive and equitable opportunities to improve their NOS conceptions and build their confidence and self-esteem within the science curriculum. This, along with future research, may lead to increased academic success for visually impaired students within the science classroom, as well as a greater representation of blind and visually impaired citizens within the fields of science, both in post-secondary programming and within the job market.

Overview of the Chapters

Through online explicit-reflective NOS instruction and administration of the *VNOS Questionnaires,* this study aimed to explore ways that educators can provide blind and low vision students with more equitable opportunities within the science classroom to better comprehend NOS ideas. Exit slips and semi-structured interviews were also employed to obtain qualitative data from student participants who shared their personal experiences of how visual impairments might sometimes serve to hinder their abilities to understand NOS concepts. Additional insight was gained from a teaching journal kept by the instructor-researcher in which detailed notes were made regarding each NOS lesson, any preconceived notions held by the instructor-researcher that they may have become aware of, as well as any personal misconceptions that may have impeded the students' abilities to understand NOS concepts.

In the pages of this dissertation, Chapter One has provided an introduction to the NOS and issues of equity and inclusion that may prevent students from fully understanding NOS concepts. In particular, Chapter One brought to light issues of equity and inclusion that blind and low vision students might encounter within the science classroom, proving to be barriers in their comprehension of NOS ideas. Legal considerations were addressed, as well as a theoretical framework for making science more meaningful to the visually impaired learner. Chapter Two provides a literature review of empirical research studies discussing the importance of NOS, issues of equity and inclusion within the science classroom, and teachers' attitudes towards students with disabilities. The chapter concludes with an overview of blind students within the science classroom. Chapter Three provides an outline of the methods employed during this research study, including instruments for data collection and methods of data analysis. Chapter Four presents the findings of this research study, while Chapter Five provides a discussion of how these findings relate to previous NOS research, as well as implications for practitioners and the education of visually impaired students. Perceived limitations and benefits of this study are addressed, as well as suggestions for future research.

CHAPTER II: LITERATURE REVIEW

It has long been believed that the NOS is key to fostering students' understandings of the science curriculum (Lederman, 2010). This scientific literacy enables students to make informed decisions regarding personal and societal issues that may arise in the world around them (Akerson et al., 2014; Lederman et al., 2013). While students do not automatically come to an understanding of NOS concepts (Akerson & Abd-El-Khalick, 2005), teachers can help facilitate the learning process through explicit-reflective NOS instruction and by beginning such instruction in early elementary grades (Akerson et al., 2011; 2014; 2019b). Also important for students, is the ability to receive equitable opportunities within the science classroom. Issues of equity might include race, ethnicity, socio-economic status, age, gender, sexual orientation, perceived ability level, and nationality (Harrison-Bernard et al., 2020). With these hurdles of inequalities that exist, we must ask ourselves how educators can better provide students with proper NOS instruction through a mindset of equity, inclusion, and egalitarian principles.

In addition to NOS being recognized as a critical component for scientific literacy (Michaels et al., 2008, as cited in Akerson et al., 2014), additional themes that arose throughout the construction of this literature review included teachers' attitudes towards inclusive practices, their lack of training in regard to students with disabilities, and the role that teachers have in ensuring that their students receive equitable and inclusive opportunities within the general education classroom setting. A teacher's ability to provide an environment of equity and inclusion within the science classroom is imperative to ensuring that all students gain a better understanding of NOS. This knowledge allows students to better understand the science curriculum and to make better decisions related to their personal and social lives. In addition, NOS allows students to envision the scientific enterprise and to see how science fits into our everyday society and culture (Bugingo et al., 2022). However, as noted by Olson (2018), expectations for students to learn NOS concepts are rarely included within the science curriculum, but rather, included through ancillary materials. Therefore, in the pages that follow, this review of the literature aimed to provide an overview of the importance of NOS, issues pertaining to equity and inclusion, issues that may affect teachers' attitudes towards students with disabilities, as well as implications for ways that teachers can better engage students in NOS instruction through equitable and inclusive opportunities within the science classroom. A special focus on blind students within the science classroom is also highlighted within this chapter, as this study hoped to address a gap in the research by investigating ways that blind and low vision students can be provided with more equitable opportunities to better comprehend NOS concepts.

The Importance of Nature of Science

"Nature of Science (NOS) is a critical component of scientific literacy that enhances students' understandings of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues" (NSTA, 2023). Lederman (1992) describes NOS as an epistemology of science. In addition, students' comprehensions of NOS are vital to their understandings of the science curriculum, as well as procedures associated with scientific investigations (Akerson et al., 2014). According to Lederman (1992; 1999), NOS comprehension is a global educational goal that was first identified in 1907. However, research has shown that students continue to leave high school without having gained a proper understanding of NOS concepts due to lack of adequate NOS instruction (Akerson et al., 2011). Therefore, researchers have advocated for NOS instruction to be taught in early elementary grades as a way to help students better conceptualize NOS aspects in later educational years (Akerson et al., 2011; 2014).

While NOS instruction has been deemed essential (Akerson et al., 2014; 2019b), adequate understandings of NOS concepts are not something that comes naturally to students (Akerson & Abd-El-Khalick, 2005; Akerson et al., 2014). In fact, research has shown that students rarely receive NOS instruction unless their teachers have received prior professional training pertaining to the topic (Akerson et al., 2011). Therefore, it is necessary that teachers undergo proper professional development to ensure that they are equipped with the knowledge and tools to deliver proper NOS instruction to their students. Even so, this is often difficult to accomplish, as teachers frequently fail to consider NOS when planning their curriculum or designing lesson plans. Rather, teachers tend to align their instructional practices with their own classroom management skills, their need to deliver the basic foundational information, and their desire for students to enjoy the learning process. As a result, researchers have called on teacher preparation programs to help pre-service teachers develop their skills and abilities in a way that allows them to transfer their knowledge into practice (Lederman, 1999).

NOS Instructional Approaches

As science teachers hold naïve views on NOS, similar to those of their students (Wahbeh & Abd-El-Khalick, 2014), how do we foster increased NOS understandings while helping teachers translate this knowledge into practice? This is a complicated task, as many factors must be considered, such as the importance that an individual teacher places on teaching NOS, their availability of NOS resources, and how they perceive their students as being able to learn NOS concepts (Lederman, 1999; Wahbeh & Abd-El-Khalick, 2014). In the study conducted by Wahbeh and Abd-El-Khalick (2014), researchers were able to show that explicit-reflective instruction does well to increase one's understanding of certain NOS concepts. However, even as professional development was shown to help teachers increase their understandings of NOS, they were generally unable to translate this knowledge into practice. Therefore, we must develop ways for teachers to increase their comprehension of various NOS aspects, as well as their pedagogical content knowledge as it pertains to NOS (Wahbeh & Abd-El-Khalick, 2014).

According to Cook and Buck (2013), one way to build educators' comprehension of NOS is by modeling open forms of socio-scientific inquiry for pre-service teachers; particularly, as it pertains to NOS. Through Cook and Buck's (2013) study, researchers were able to show that explicit, reflective, and contextualized instruction was effective in teaching NOS conceptions. In addition, the contextualized instruction within socio-scientific inquiry was found to be helpful in allowing students to reflect upon the NOS tenets. Therefore, it was recommended that pre-service instruction should be inclusive of "overt discussions about how each socio-scientific inquiry within the curriculum illuminates NOS principles" (Cook & Buck, 2013, p. 19). While the authors did well to point out that not all inquiry experiences will lead to students' increased understandings of NOS, they also made a valid point that a pre-service teacher's personal relationship with environmental issues occurring in their own community may play a large role in enhancing one's views on NOS (Cook & Buck, 2013).

Other instructional approaches that have been shown to help in increasing students' and teachers' comprehension of NOS include explicit and reflective instruction, historical approaches, documentary films, a family resemblance approach, a lesson study approach, and professional development programs for educators. Of those, explicit and reflective instruction appears to be the most widely researched, as it targets all NOS aspects, helping students to reflect on the various NOS characteristics; thus, enabling them to improve their overall understandings of NOS (Bugingo et al., 2022; Schussler et al., 2013). While explicit and reflective instruction can be used in correlation with other instructional methods such as documentary films (Ağlarci et al., 2016, as cited in Bugingo et al., 2022), providing students the opportunity to participate in discussions and reflective activities allows them to better understand NOS concepts and to make their own interpretations and conclusions regarding science in the world around them (Akerson et al., 2000; Bugingo et al., 2022).

Schussler et al. (2013) further investigated the explicit-reflective approach to determine if undergraduate students' views on NOS could be improved within expository and/or inquiry-based instructional models of introductory science laboratories. Results showed that explicit reflection allowed students to make gains in their comprehension of certain NOS aspects in both the expository and inquiry-based laboratories, as long as explicit NOS instruction was included. More specifically, expository laboratories that were paired with explicit NOS instruction were shown to maximize students' understandings of the creative, tentative, empirical, and inferential concepts of NOS. However, the authors noted that this is contradictory to national reform efforts that place emphasis on inquiry-based laboratories, which may actually serve to impede students' understandings of NOS concepts in the process of teaching them how to do science (Schussler et al., 2013).

According to Akerson et al. (2014), students can learn NOS concepts if they are provided with proper instruction. Therefore, educators should set high expectations for their students in comprehending NOS ideas (Akerson et al., 2019b). In addition, teachers should be cognizant that one's socioeconomic status may also affect a student's ability to develop their understandings of NOS, as Akerson et al. (2014) found that students of low socioeconomic status exhibited a less developed comprehension of NOS aspects. Strategies proven to be useful in improving NOS conceptions include the use of student science notebooks, children's literature, and hands-on activities (Akerson et al., 2011; 2014). The use of real-world examples which allow students to engage in science through a topic that interests them, has also been shown to aid in the understanding of NOS aspects and to assist students in developing their own NOS identities (Akerson et al., 2019b). Research implies that teachers should focus on the concrete aspects of NOS while helping students draw a personal connection to science through cultural aspects which may help students gain a better understanding of NOS concepts (Akerson et al., 2014). Furthermore, NOS instruction should begin in early elementary grades, as this is thought to help build a foundation on which to learn and understand science in later years (Akerson et al., 2019b).

Issues of Equity and Inclusion within the Science Classroom

In addition to instructional approaches, teachers should also be aware of the individual needs of their students. This particularly applies to those with unique learning challenges, as one's teaching strategies would need to be adjusted to meet the diverse needs of each student. This idea can be seen in the *Science for All* initiative, which has been an educational slogan since the 1980s (Fensham, 1985; Librea-Carden & Mulvey, 2023). However, "equity in science education involve[s] understanding economic, political, and educational inequities that young people face and designing for learning opportunities that account for such harms" (Shea & Sandoval, 2020, p. 36). As noted earlier in this chapter, reasons for inequities may include race, ethnicity, socio-economic status, age, gender, sexual orientation, perceived ability level, and nationality (Harrison-Bernard et al., 2020). In an effort to improve student success rates, multiple student-focused strategies have been employed (O'Leary et al., 2020). However, even with positive outlooks on inclusive classroom practices there appears to be difficulty in the implementation, as practicality often outweighs the principles of inclusion (Eloff & Kgwete, 2007).

In addition, further roadblocks will arise when attempting to teach science in an equitable manner. These barriers might include a mixture of "epistemic, pedagogical, cultural, and social" issues (Braaten & Sheth, 2017, p. 135). This begs the question of how teachers can combine equitable learning opportunities with ambitious instructional practices within the science classroom. This can be done through disruptive pedagogies, as status quo pedagogies only assist in dividing students by race, ethnicity, and gender, and are not helpful in building a more just society (McGee Banks & Banks, 1995). However, disruptive pedagogies are complex, even for teachers who wish to combine ambitious science teaching with equitable learning opportunities. Ambitious science teaching requires teachers to disrupt normal science teaching practices that are typically employed in schools. On the other hand, teaching for equity requires teachers to be aware of those students who are privileged and those who are marginalized, making concessions for each on an individual level. In addition, teaching for equity involves students being active in the learning process by constructing their own ideas regarding scientific topics (Braaten & Sheth, 2017).

Combining ambitious science teaching and teaching for equity within the science classroom must be balanced with political and societal expectations of the students. For example, state and national standards may cause some teachers to stress the importance of learning scientific facts or mastering certain knowledge or skills within the classroom. However, in more casual learning settings, such as summer science programs, teachers may be able to focus on learning experiences that allow students to investigate, theorize, discuss, and question scientific principles. Therefore, during informal learning programs, teachers may be able to help students overcome marginalization that is experienced in the typical school setting by redefining what counts as science and who can do science by making cultural connections to the students' identities (Braaten & Sheth, 2017). Various aspects of equity and inclusion will be addressed within the subtopics that follow.

Culture, Race, and Ethnicity

"Understanding how children of different cultures, races, and ethnicities see and interpret the NOS is critical" (Walls, 2012, p. 3), as minority students' experiences often differ from that of their white peers. In Walls' (2012) study, when asked to describe who scientists are and what they look like, African American students described a white male who was older, smart, happy, and who wore professional attire, a lab coat, and glasses. They envisioned scientists working in a laboratory setting and doing experiments to understand how the natural world works. When presented with a group of photographs and asked to select the scientist, the students saw white men as being the scientists. However, interestingly, when asked to draw pictures of scientists, these same children chose to draw pictures of African American or non-white scientists, oftentimes being described as self-portraits. When asked to describe where they learned about science, all of the students mentioned in-school or non-school programs, such as television, movies, museums, libraries, and their own homes. Students also expressed an overall positive attitude toward science and said that they enjoyed collaborating with their friends when completing science activities (Walls, 2012).

Similar to the work of Walls (2012), Shea and Sandoval (2020) investigated how culture affects one's ability to learn science in an equitable manner. Researchers focused on the efforts of Latinx educators to design an equitable afterschool science program for students within a rural setting, taking into consideration unjust histories and cultural practices. They specifically looked at the role that pedagogy plays in regard to the variables of dignity and belonging, as well as accounting for place, and the cultural, historical, and political aspects of life within an agricultural setting. It is believed that "creating more equitable science pedagogies necessitates examining the large-scale political and economic histories that inform moment-to-moment activities involved in teaching and learning science" (Erickson, 1998, as cited in Shea & Sandoval, 2020, p. 28).

It is perceived that out-of-school-time learning experiences allow students to build their identities as users and producers of science while also making scientific connections with what they've learned in school. In order to achieve equity in the science classroom, educators must account for socioeconomic and political aspects that affect and further marginalize young learners of minority populations. As both Latinx youth and educators have described feelings of being unwanted by their communities through racist and xenophobic messaging, providing these individuals with a place that they feel safe and "at home" is imperative to meeting the needs and interests of marginalized students (Shea & Sandoval, 2020). In Shea and Sandoval's (2020) study, a "studio" served as a safe space where students could experience affirmation, ask questions, and use their imaginations. As many of these students are used to hearing the word, "no," within their communities and throughout their day-to-day lives, educators within the studio worked to tell the students, "yes," as a way to break the cycle of non-stop, negative messaging. Results of this study showed that an educator's understanding of political and historical injustices helped to inform their decisions regarding pedagogical strategies, as well as helping young people to connect with science within their communities. This would indicate that creating a safe place for students, while teaching with words of affirmation, and an understanding of students' lived experiences can help assist students in their feelings of dignity and belonging when trying to learn and understand science (Shea & Sandoval, 2020).

Gender

Ìdin and Dönmez (2017) investigated teachers' views of gender equity within the science classroom. Gender equity refers to treatment which may be different, but equal in regard to meeting the needs of both males and females as it pertains to their “rights, benefits, obligations, and opportunities” (Ìdin & Dönmez, 2017, p. 119). While teachers believe that gender equity is important for all students to achieve, they also believe that gender equity is not present in teacher preparation programs or within science textbooks, pointing to gender-related topics and gender-biased messages, as well as gendered curriculum and stereotypical images of what men and women are envisioned to do within science-related careers. Therefore, science teachers play a large role in the facilitation of gender-equitable opportunities within the science classroom. This is an important task, as it may guide science-related career decisions made in the future by current students (Ìdin & Dönmez, 2017). Unfortunately, these career decisions translate into an underrepresentation of women choosing science-related degree paths or working in the field of STEM. This is concerning, as America’s scientific workforce contributes to our competitiveness within the global job market. Currently, in the United States, women obtain a low proportion of undergraduate STEM degrees and hold less than 25% of STEM-related jobs; but interestingly, earn 33% more than women working in non-STEM-related careers (Beede et al., 2011).

Therefore, it is important to know how teachers view stereotypical career choices as they relate to gender because girls are typically guided towards jobs in nursing or education, while boys are guided towards engineering or mechanics. However, teachers may not hold adequate knowledge regarding gender equity that would allow them to make valuable strides in conversations with their students pertaining to this topic. Therefore, it is recommended that teacher preparation programs train pre-service teachers on issues related to gender equity, while in-service teachers receive professional development on the same (Ìdin & Dönmez, 2017). Other suggested methods to address the lack of training on this issue include long-term, proactive strategies such as pay incentives for trained teachers, community and parental involvement, and staff support services (Eloff & Kgwete, 2007).

Age

The research of Andersson and Gullberg (2014) further investigated gender, with the addition of age, as factors in understanding science during their work with preschool-aged students. As young children naturally explore and investigate the world around them, it is believed that these characteristics can be applied to science. However, this requires curriculum planning on behalf of the teacher and a pedagogical content knowledge in science subject matter (Andersson & Gullberg, 2014). Unfortunately, past research has shown that pre-school and early elementary teachers exhibit inadequate science content knowledge (Appleton, 2008, as cited in Andersson & Gullberg, 2014). In addition, pre-school teachers avoid teaching science as they feel they do not hold accurate content knowledge and cannot answer their students' questions as they pertain to science (Smith & Neale, 1989, as cited in Andersson & Gullberg, 2014). Therefore, Andersson and Gullberg (2014) utilized a feminist approach throughout their study to give the teachers and students a voice in allowing them to feel valued and listened to. The study aimed to determine if an increase in gender awareness would affect the ways in which teachers taught science. Teachers chose to participate in the study as an effort in professional development (Andersson & Gullberg, 2014).

Within Andersson and Gullberg's (2014) study, a floating-sinking experiment was employed to allow the preschoolers to investigate density by determining which items they believed would float or sink. Results of the data were then analyzed based upon "science activities in the preschool" which aimed to develop the children's conceptual knowledge of science, and the teachers' professional development skills. A feminist approach was utilized in the analysis to focus on the students' and teachers' strengths in science, rather than their weaknesses. Results showed that students' learning was insignificant during the science experiment, and they developed some misconceptions. It was believed that the teacher did not fully understand the concept of density and needed to partake in further professional development in regard to increasing her knowledge in science subject matter. However, allowing the students to work in a systematic manner and to investigate by planning their own experiments lead to an increase of scientific knowledge and personal satisfaction, aided by the teacher posing stimulating questions. As this was a positive learning experience built on feminist ideologies, it helped to build self-confidence in both teacher and students throughout the scientific learning process (Andersson & Gullberg, 2014).

Age is also an important factor to consider when investigating students' conceptions of NOS. In Walls' (2012) study, third grade students were able to "see themselves not only as capable and confident learners and users of science, [but] they also think that 'doing it' is fun" (p. 11). In addition, they were able to realize science as a valuable tool that assists humans in learning about the natural world. They recognized experiments as a process that one follows to figure something out, and were able to connect the idea of mixing "potions" with popular culture that they'd seen on television or film. These third-grade students were able to describe an invention as something that hadn't previously existed, while they believed a discovery was finding something that was known to exist, but might be difficult to find, such as fossils or dinosaur bones. Similar to studies by Akerson et al. (2011; 2014; 2019b), the results of this study indicate that very young children are able to comprehend certain NOS aspects through explicit and reflective instruction (Walls, 2012).

Ability Level

It is important that students of all grade levels be able to develop an adequate understanding of NOS, as doing so enables them to make informed decisions and to better learn and comprehend science topics (Akerson et al., 2011; 2014). However, should students of all abilities be afforded this same opportunity? The answer is affirmative, but policymakers and teachers must be willing to help facilitate the learning process. Currently, very little research exists to address special education students' abilities to understand NOS concepts (Librea-Carden et al., 2021; Librea-Carden & Mulvey, 2023). In a study by Akerson et al. (2014), researchers found that a low-achieving student was able to build on their NOS understandings and discuss NOS ideas; however, held less sophisticated understandings when it came to imagination and creativity. In the same study, a medium-achieving student was able to define and write about NOS aspects, but could not explain reasons for the tentative aspects of NOS. In contrast, a high-achieving student was able to discuss, write about, and reflect upon his own NOS comprehension. While the students differed in the sophistication of their NOS comprehension, it was determined that explicit-reflective NOS instruction enabled students of differing abilities to improve their understandings of NOS concepts (Akerson et al., 2014).

Librea-Carden and Mulvey (2023) specifically investigated NOS and its potential within special education teaching. The study involved ten pre-service special education teachers who were enrolled in a 15-week, K-8 science methods course. The participants were noted as focusing their efforts on the education of deaf students, or those with mild-to-moderate special education needs. Upon completion of the study, all pre-service teacher participants were shown to have improved their understandings of targeted NOS aspects. As a result, the authors called on special education teachers to employ equitable science teaching methods and NOS instruction to actively engage special education students in science learning (Librea-Carden & Mulvey, 2023). Librea-Carden and Mulvey's (2023) study built upon that of Librea-Carden et al. (2021) where researchers concluded that "learning about NOS may be particularly helpful in developing supportive, inclusive classrooms in which students' differences are celebrated and science learning is accessible" (p.962).

Teachers' Attitudes Towards Students with Disabilities

While political and policy changes sometimes hinder the progress of inclusivity (Donohue & Bornman, 2015), "one of the main barriers in the practice of inclusive education is represented by the teachers' attitudes towards inclusion and its principles" (Unianu, 2012, p. 901). Factors affecting teachers' attitudes towards students with disabilities can range from the degree and nature of the students' disabilities to the teachers' past experiences and capabilities of working with special needs children. As general education classroom teachers are often unaware or unfamiliar with the main characteristics of children with disabilities, preconceived notions and prejudices are likely to exist (Unianu, 2012).

Therefore, pre-service and in-service teacher training has been realized as important for the inclusion of students with disabilities into the regular, or mainstream, classroom setting. According to Sharma and Sokal (2015), teachers play a key role in promoting perspectives of inclusive education. However, teachers' attitudes on inclusive teaching are known to be directly related to their classroom experiences with their students. Pre-service teachers' ideas on inclusivity appear to be quite negative, while more experienced teachers are able to view inclusion in a more positive light due to seeing improvement in their students' learning. Currently, very little is known on how to help teachers translate their positive attitudes into effective classroom practices (Sharma & Sokal, 2015). However, one key variable may be teacher efficacy. While it is thought that good teaching practices can produce positive outcomes, a teacher may believe their capacity is to teach a certain group of students, rather than another (Tschannen-Moran & Hoy, 2001). In addition, even special education teachers report a higher self-efficacy in teaching students with specific learning disabilities, as opposed to those students with more severe disabilities (Smith, 2000). According to Wertheim and Leyser (2002), teacher preparation is important in this regard, as teachers with higher levels of self-efficacy also show a more positive attitude regarding inclusive classroom practices. However, it should be noted that some teacher preparation courses in inclusivity have a medical focus. Students enrolled in these courses tend to gain a more negative perception of inclusivity as they may view special education as a medical issue rather than an educational one (Sharma & Sokal, 2015).

While teachers who have more frequent contact with disabled people tend to view students with disabilities in a more positive light, other mainstream classroom teachers believe children with disabilities are not their responsibility (Unianu, 2012). Of course, various laws and policies would state otherwise, as inclusive schooling has become a goal of many school districts across the globe due to the fact that inclusivity exposes students early on to diversity and a more just society (Donohue & Bornman, 2015; Vaz et al., 2015). Some countries view inclusivity as a human rights issue to ensure that their students become productive members of society (Donohue & Bornman, 2015). However, meeting the needs of diverse students within a mainstream classroom has proven to be complicated (Spektor-Levy & Yifrach, 2019). Rather than relying on the medical-pathological model of education, inclusive education is based upon the social justice model that seeks to provide all students with equitable learning opportunities regardless of ability level (Unianu, 2012; Vaz et al., 2015).

Nevertheless, it would appear that teachers feel ill-prepared to teach in inclusive classroom settings due to a lack of appropriate training pertaining to inclusive education (Hay et al., 2001; Unianu, 2012). These feelings of inadequacy appear to be overcome through years of experience within the teaching field, as older teachers who have experienced various types of students seem to be more confident in their ability to adapt educational materials to the needs of individual learners. Other factors that have a positive effect on a teacher's willingness to practice inclusivity within their classroom include education level and past experience working with children of differing ethnic backgrounds. It has been found that teachers with a higher level of education or increased professional qualifications, as well as those who have previously worked with students of differing ethnic backgrounds have a more positive outlook on inclusive practices within their classrooms (Unianu, 2012).

Teachers' attitudes and intentions towards students with disabilities are key to the students receiving equitable and inclusive experiences, as this requires the teachers to make alterations to their normal implementation of curricular materials in order to accommodate the educational needs of disabled students (Anderson & Mitchener, 1994, as cited in Spektor-Levy & Yifrach, 2019). Therefore, it is important that educational researchers try to understand teachers' preconceived notions and misconceptions which might influence their desire to work with children who have disabilities. One item of influence may be the type of disability and the level to which the child is disabled; however, this may be due to individual differences in teachers and students, as information regarding this subject is met with mixed reviews. A study by Donohue and Bornman (2015) found that teachers were generally positive towards working with students with Down Syndrome and less comfortable working with students exhibiting other disabilities. Other studies have shown that intellectual disabilities and autism are difficult for teachers to handle in a mainstream classroom, while students with physical disabilities are viewed as less stressful to manage (Avramidis & Kalyva, 2007; Donohue & Bornman, 2015). Further studies have concluded that teachers were generally more positive towards teaching students with physical and sensory disabilities, and less positive towards students exhibiting emotional disorders, and cognitive, learning, or behavioral impairments (Avramidis & Norwich, 2002; Unianu, 2012; Vaz et al., 2015). This is concerning, as currently, the most prominent group of special needs students receiving their education through mainstream public schools are those with specific learning disabilities (McGinnis & Kahn, 2014; Spektor-Levy & Yifrach, 2019). In accordance with the Every Student Succeeds Act (ESSA) (2015), these students are expected to perform on par with their non-disabled classmates. Therefore, it is essential that teachers be willing to support these students through appropriate instructional methods and teaching enactments (Spektor-Levy & Yifrach, 2019).

MacFarlane and Woolfson (2013) investigated the attitudes of teachers in regard to children with social, emotional, and behavioral difficulties, through utilization of the Theory of Planned Behavior as a framework for their study (Ajzen, 1991, as cited in MacFarlane and Woolfson, 2013). It is important to note that students exhibiting social, emotional, and behavioral difficulties are most often male, of low socio-economic status, and achieving at lower educational levels compared to that of their peers, which may also prove to be a barrier to successful practices of inclusivity. While the inclusion of these students was theoretically welcomed, it was also viewed as being practically problematic due to the neutral or negative views of teachers. Researchers found that teachers’ beliefs, feelings, subjective norms, and perceived behavioral control could predict a teacher’s behavioral intentions towards children with disabilities. Teachers who had more positive beliefs and a perceived higher level of behavioral control were seen as having a higher level of intention to include students with social, emotional, and behavioral difficulties within the general education classroom setting. In addition, teachers with a high level of subjective norm were more likely to practice inclusivity within their classrooms. However, teachers' past experiences working with students exhibiting social, emotional, and behavioral difficulties tended to decrease their positivity towards the inclusivity of these students and their willingness to work with them (MacFarlane & Woolfson, 2013).

Other issues that have been noted as affecting teachers' desires to work with disabled students include lack of knowledge, skills, training and support, lack of appropriate facilities and assistive devices, and possible negative effects on both the special needs students and those of typical learning capabilities (Swart et al., 2000, as cited in Hay et al., 2001). It is also important to note that many teachers feel an inclusive environment benefits the social development and peer acceptance of a disabled learner, as opposed to their intellectual development. Therefore, ensuring that students with disabilities are engaged in the learning process is not a priority for some teachers. Thus, it is fair to ask if lack of academic progress seen in students with disabilities is due to their lack of learning or the lack of sufficient instruction by teachers who set low academic expectations for these students (Donohue & Bornman, 2015).

Not only can such ableism lead to the exclusion and marginalization of people with disabilities (Sharma & Hamilton, 2019), but, according to Hehir (2002), "there is considerable emerging evidence that unquestioned ableist assumptions are handicapping disabled children and are a cause of educational inequities" (p. 5). With that said, ableist assumptions made by teachers towards students with disabilities only serve to strengthen preconceived notions held against a disability, as well as low levels of educational achievement and future job attainment (Hehir, 2002). Hence, in an effort to counteract ableism within the classroom, proper accommodations should be carefully chosen to allow students with disabilities to access the general education curriculum and to demonstrate their knowledge on high-stakes standardized tests (Hehir, 2007). While teachers are beginning to recognize the importance of fostering an appreciation for diversity (Lalvani & Broderick, 2013), research would suggest that dysconscious ableism prevents educators from providing a truly equitable learning experience for all of their students (Broderick & Lalvani, 2017). As ableism provides an inhospitable environment for disabled individuals (Hehir, 2007), "the judgements teachers make about students' ability to learn, clearly limits what is possible for students to achieve" (Florian, 2009, p. 534, as cited in Broderick & Lalvani, 2017). This is difficult to overcome, seeing as how disability is viewed negatively in both social and cultural contexts (Taylor, 2012).

While some teachers may view inclusive practices as unpractical, or within a negative light, there are many positive attitudes that exist as well. For instance, teachers feel more self-confident about their abilities to work with disabled students after they have received proper instructional training and after having received exposure to disabled learners. In addition, "various types of supports, including teacher's aides, smaller class sizes, special equipment, test accommodations for the learner, flexible teaching schedules, and extra non-instructional time to help teachers to adjust their workload" have also had a positive effect on teachers' attitudes towards inclusive education (Donohue & Bornman, 2015, p. 44). Therefore, it would appear that policy makers and school administrators play a large role in helping teachers to feel comfortable supporting students in an inclusive environment. Cooperation between general education classroom teachers and special education teachers is also key to success in ensuring that educational frameworks are developed to meet the needs and differences of all school children (Spektor-Levy & Yifrach, 2019; Unianu, 2012). This cooperation can be confusing to some, as past educational frameworks required teachers to teach either typically developing students or special needs students, but not both (Donohue & Bornman, 2015). Therefore, a majority of teachers are neither ready, nor prepared to teach in an inclusive classroom setting. However, research shows that they are willing to learn through proper training techniques (Hay et al., 2001).

Blind Students in the Science Classroom

The number of visually impaired students within the general education classroom setting continues to rise (Miyauchi, 2020). However, blind students still experience a number of barriers to their educational learning (Bualar, 2018; Boza-Chua et al., 2021). For instance, many educators do not know how to transform their classrooms into an inclusive environment for blind students, nor do some educators believe they should be responsible for providing blind students with accessible materials (Bualar, 2018). However, accessibility is a necessity to ensure that blind students are able to access all learning materials and actively engage in classroom activities (Lintangsari & Emaliana, 2020). Without proper educational supports, blind students are often forced to abandon their educational endeavors, comprising 60% of students who drop out of school (Boza-Chua et al., 2021). As noted by Klimentyeva et al. (2021), an inclusive environment allows visually impaired students the ability to master classroom materials, to make strides in personal and professional pursuits, and to become active participants in creative projects.

However, according to Supalo et al. (2014), blind students are often paired with a sighted partner within the science classroom, who then serves as an “assistant” to make observations, perform tasks, and record written data. This partnership often serves to discourage blind students from pursuing additional STEM-related educational pursuits and career paths; thus, leading to an underrepresentation of blind individuals in various STEM fields (Supalo et al., 2014). A teacher of the visually impaired (TVI) can assist general education science teachers in making the science curriculum accessible to blind students through the use of braille and text-to-speech software; however, TVIs are typically limited in their own scientific knowledge (Supalo et al., 2014).

Chapter Summary

In summary, NOS is an epistemology of science (Lederman, 1992) that is critical in helping students understand science content and the scientific world around them (Akerson, 2014). As it appears that students do not come to an understanding of NOS on their own accord (Akerson & Abd-El-Khalick, 2005), it is imperative that teachers assist in the comprehension of NOS aspects beginning in early elementary grades, which has been shown to improve students' understandings of science as they advance throughout school (Akerson et al., 2011; 2014; 2019b). As minority students may experience inequalities or lack of inclusion due to race, ethnicity, socio-economic status, gender, and disability, etc. (Harrison-Bernard et al., 2020), it is important for science teachers to provide a space of positivity where students are free to ask questions and investigate in ways that connect them with their own cultural heritage (Shea & Sandoval, 2020).

In addition, teachers' attitudes towards students with disabilities may serve as a barrier in the learning process (Unianu, 2012). Therefore, teachers must be self-aware of their preconceived notions and misconceptions surrounding various disabilities, while also being cognizant of their legal obligations to provide such students with equitable opportunities within the science classroom (Donohue & Bornman, 2015; Vaz et al., 2015). While many teachers may feel ill- equipped to teach science (Smith & Neale, 1989, as cited in Andersson & Gullberg, 2014), positive learning experiences within the classroom can serve to build self-confidence in both teachers and students (Andersson & Gullberg, 2014). Professional development opportunities are also key to providing teachers with the appropriate knowledge in both subject matter and pedagogical content (Lederman, 1999; Wahbeh & Abd-El-Khalick, 2014). Through proper teaching techniques and positive learning experiences we can ensure that students, regardless of minority status or (dis)ability level, are able to meet their full potential which will hopefully translate into productive members of a more just society.

This study hoped to address these issues, specifically as they apply to blind students within the science classroom. As a gap in the research was identified, this study aimed to provide insight into the challenges that visually impaired students might face within the science classroom, and ways that educators can provide blind students with more equitable opportunities to improve their conceptions of NOS. In the following chapter, the methodology used to carry out this study is described in detail.

CHAPTER III: METHODOLOGY

Throughout this chapter, I have discussed the methodology that was utilized for investigating how blind and low vision students might conceptualize the NOS. A presentation of the research design has been provided, followed by an introduction to the roles and context, the research participants, as well as strategies utilized for data collection, interventions, and data analysis. As noted in Chapter One, this study aimed to determine ways that educators can provide blind and low vision students with more equitable opportunities to better comprehend NOS concepts. Therefore, looking through a lens of equity and inclusion, with consideration for egalitarian principles, this study hoped to answer the following research question:

Research Question: How does my online explicit-reflective instruction impact visually impaired students' conceptions of NOS?

Research Design

To determine how blind and low vision students might conceptualize the NOS, an action research methodology was proposed. According to Lewin (1946), action research allows practitioners to evaluate current practices, generate new insights, and modify existing plans through strategic evaluation and fact-finding. Elliott (1994) described action research as the creation of practical knowledge generated by teachers. It allows practitioners to reflect upon their current teaching practices and to make improvements pertaining to their future teaching strategies (Elliott, 1994). Action research has also been defined as "a practical approach to professional inquiry in any social situation" (McGinty & Water-Adams, 2006, as cited in Morales, 2016, p. 158). Laudonia et al. (2018) further expanded upon the definition of action research as it specifically applies to science education, explaining that it leads to improved teaching practices, professional skill sets, and curriculum development. Although a lack of connection can sometimes exist between educational research and practical teaching strategies (Laudonia et al., 2018), action research can help bridge that gap through the development of concrete classroom tools (Bjønness & Johansen, 2014). While Dymond et al. (2006) utilized participatory action research to design an inclusive high school science course, it was proposed that this study employ an action research methodology similar to the emancipatory action research employed by Abels (2015) in their exploration of inquiry-based science education to promote emotional engagement in special needs students. I believe this was the correct choice for the study detailed in this dissertation because the research, action, data collection and evaluation were all being initiated and conducted by the classroom educator (Grundy, 1982, as cited in Laudonia et al., 2018; Laudonia et al., 2018; Mamlok-Naaman & Eilks, 2012).

To support the data obtained through action research, additional methods of obtaining qualitative data were employed. According to Devetak et al. (2009), qualitative research is an exploration of words as opposed to numbers and focuses on the verbal descriptions provided by study participants. Libarkin and Kurdziel (2002) described qualitative research as an unconstrained approach to study phenomena. In addition to observations and interviews, qualitative data may be obtained from "detailed field notes, tape and video transcripts, and written documents" (Libarkin & Kurdziel, 2002, p. 80). Therefore, in an attempt to answer the research question posed above, this study also made use of open-ended questionnaires which included the *Views of Nature of Science* (*VNOS*) *Form D* (See Appendix A) and *Form D+* (See Appendix B), as well as weekly exit slips (See Appendix C). Additional qualitative data were obtained through semi-structured interviews, transcribed verbal commentary, and notes made within a teaching journal by the instructor-researcher throughout the course of this research study.

Roles

The action research was initiated, designed, and carried out by the instructor-researcher, who also served as the author of this paper. The instructor-researcher has more than ten years of experience as a science educator within the realm of higher education, as well as numerous years of experience working with PK-12 students in informal, volunteer, community settings. While the instructor-researcher is sighted, they do have personal experience and knowledge in interacting with blind and low vision individuals of varying ages and abilities, as detailed in the Positionality section of Chapter One.

Context

This action research was carried out through an informal, Saturday science program similar to that seen in the studies by Akerson and Donnelly (2010) and Akerson et al. (2011). An online option was proposed to account for geographical differences of where the students lived, as well as any transportation issues that may have been encountered by visually impaired study participants. The online science classroom that was proposed for this study served as a safe space where students could experience affirmation, positive messaging, dignity, and belonging as they attempted to learn and do science, similar to the environment described by Shea and Sandoval (2020). Students must have been visually impaired to participate in the program; however, there was no cost to do so. All supplies needed to complete the NOS activities within the Saturday science program were provided to the students free-of-charge prior to the start of this research study.

Over the course of a six-week time period, blind and low vision students participated in six, one-hour science sessions that engaged them in tactile learning in an effort to make science more meaningful, while also receiving explicit-reflective NOS instruction. Following each one-hour science session, an additional one hour was allotted for students to reflect, converse, and complete open-ended questionnaires. The instructor-researcher designed and facilitated each two-hour session throughout the six-week period. If a student needed to be absent during any of the weekly science sessions, an individual make-up session was scheduled and completed.

Participants

Participants who completed this study included the instructor-researcher and a group of nine visually impaired students. The instructor-researcher was a middle-aged, white female, who had more than ten years of experience working as an onsite and online science instructor at an institution of higher education located in the Midwestern United States. At the time of this study, the instructor-researcher held a master's degree in biology and was in their third year of a doctoral program for which they were majoring in curriculum & instruction and specializing in science education. Student participants included those individuals who were totally blind or whose vision was not correctable through the use of glasses or contact lenses. All student participants were enrolled in grades kindergarten through twelve (K-12) within the United States, and fully participating in the general education classroom curriculum. Study participation was not limited by a participant's sex, culture, race, ethnicity, or geographical location.

While ten students had initially agreed to participate in the research study, one student withdrew during the second week of the program without having attended any of the online Saturday science sessions. The demographics of the remaining nine students who completed the program are shown in the table below (See Table 1).

Table 1

Demographical Information of Student Participants

Student Number	Pseudo Name	Gender	Ethnicity	Age Range	Grade Level	Geographic Region
1	David	Male	White	7-9 years	2^{nd}	Midwest
2	Bethany	Female	White	7-9 years	3^{rd}	Pacific Coast
3	Laila	Female	White	7-9 years	3^{rd}	Midwest
4	Aiyana	Female	American Indian	10-12 years	5^{th}	Gulf Coast
5	Whitney	Female	White	10-12 years	5^{th}	Midwest
6	Amber	Female	White	10-12 years	6^{th}	Northeast
7	Meiling	Female	Asian American	10-12 years	6^{th}	Midwest
8	Rachel	Female	White	10-12 years	6^{th}	Southeast Atlantic Coast
9	Cathy	Female	White	17-19 years	12^{th}	Midwest

Recruitment Strategies

As blindness is a low incidence disability (Hayden & Prince, 2023), a convenience sampling method was utilized to recruit visually impaired students who, at the time of this study, were enrolled in grades K-12 within the United States and engaged in the general education classroom curriculum. Convenience sampling was chosen, as it is a simple and common form of non-probability sampling that allows participants to self-determine if they would like to participate in a qualitative study (Stratton, 2021). Students were made aware of the study and invited to participate based upon their personal and public affiliation with organizations providing extension, outreach, and training for blind individuals. For those students who wished to participate in the study, and who were under the age of 18 years, initial contact was made with the student's primary parent or guardian. Upon initial contact, the research study was explained, and students were asked to participate in six weekly online science sessions during which they would receive explicit-reflective NOS instruction. In addition, potential student participants were made aware of the request to complete open-ended questionnaires, which would include the *VNOS Questionnaire*, pre- and post-NOS instruction, as well as weekly exit slips. Students in grades K-6 were asked to complete the *VNOS-Form D* (Lederman & Khishfe, 2002), while those in grades 7-12 were asked to complete the *VNOS-Form D+* (Lederman & Khishfe, 2002, as cited in Cofré et al., 2017). Potential student participants were also made aware that each weekly science session would be audio and video recorded through Zoom. And lastly, all students and their parents were made aware that their participation in the research study was completely voluntary and that they could choose to leave the research study at any time.

Intervention

The following dates within the timeline were utilized for completion of the research study (See Table 2).

Table 2

Timeline for Research Study

Timeline	
Date	Task(s) Completed
January 11 – February 22, 2024	• Identified potential research participants and explained the research study. • Obtained signatures on consent/assent forms.
February 24, 2024	• Students completed *VNOS-Form D or D+*. • Conducted first science session. • Students completed exit slips.
March 2, 2024	• Conducted second science session. • Students completed exit slips.

March 9, 2024	• Conducted third science session. • Students completed exit slips.
March 16, 2024	• Conducted fourth science session. • Students completed exit slips.
March 23, 2024	• Conducted fifth science session. • Students completed exit slips.
March 30, 2024	• Conducted sixth science session. • Students completed exit slips. • Students completed *VNOS-Form D or D+*. • Prepared for semi-structured interviews.
April 1 – 13, 2024	• Concluded all individual make-up sessions and semi-structured interviews.

Over the course of a six-week time period, the instructor-researcher engaged students in six weekly NOS activities and explicit-reflective NOS instruction. All NOS activities were adapted from those suggested by Lederman and Abd-El-Khalick (1998). The activities were selected to be introductory in nature (Akerson et al., 2000), to engage students in tactile experiences, and to make science more meaningful to the visually impaired learner. Activities that required a high level of visual intensity (e.g., *The Hole Picture!*) were not selected to avoid causing stress and frustration amongst the students. The following NOS activities were utilized throughout the six-week study (See Table 3).

Table 3

NOS Activity Schedule

Activity Schedule	
Lesson & NOS Aspects	NOS Activity
Lesson #1: All Ideas Matter! • Observation, Inference, Creativity, and Tentativeness	Activity #1 • *Tricky Tracks!*
Lesson #2: Work as a Paleontologist! • Observation, Inference, Creativity, and Tentativeness	Activity #2 • *Real Fossils, Real Science*

Lesson #3: Does Context Matter? • Subjectivity, and Social and Cultural Context	Activity #3 • *That's Part of Life!*
Lesson #4: What Do You "See"? • Subjectivity, and Social and Cultural Context	Activity #4 • *Young? Old?*
Lesson #5: Model Construction • Black Box Activities	Activity #5 • *The Tube*
Lesson #6: Let's Look for Patterns! • Black Box Activities	Activity #6 • *The Cube Activity*

All planned activities were adapted to make them accessible for visually impaired learners. For example, the *Tricky Tracks!* activity was adapted by providing students with an embossed copy of each set of tracks on braille paper, rather than showing students a visual overhead copy (See Appendix D). The *Real Fossils, Real Science* activity was adapted by allowing students to construct an organism out of clay, rather than asking them to draw and color an organism from which they believed their fossil came (See Appendix E). The instructions for *That's Part of Life!* were provided in braille (See Appendix F), and the *Young? Old?* activity was made accessible by providing the picture on textured and embossed braille paper. As the picture of the *Young Woman, Old Woman* (McNeil & Rubin, 1977, p. 89, as cited in Lederman & Abd-El-Khalick, 1998, pp. 104-106) may have required too high a level of visual acuity for some students, this study relied on the picture called, *Is it a duck or a rabbit?* (Atkinson, 1975, p. 102, as cited in Lederman & Abd-El-Khalick, 1998, p. 103) due to its simplified nature (See Appendix G). Adaptation was not necessary for *The Tube* activity (See Appendix H), and *The Cube Activity* was adapted and made accessible by embossing the mystery cubes with braille letters and/or numbers where appropriate (See Appendix I). Detailed descriptions and instructions pertaining to the activities described above can be found in the chapter by Lederman and Abd-El-Khalick (1998).

Data Collection

The following table lists the research question for this study, and the data collection instruments that were utilized in an attempt to answer this question (See Table 4). All participants were assigned a pseudonym to protect their identity throughout the data collection process, and all forms and questionnaires were delivered to each student participant in their preferred mode of communication (i.e., read aloud, braille, or accessible electronic form).

Table 4

Data Collection Instruments

Research Question	Data Collection
1. How does my online explicit-reflective NOS instruction impact visually impaired students' conceptions of NOS?	• *VNOS-Form D or D+* • Exit slips • Semi-structured interviews • Students' commentary • Instructor-researcher's teaching journal

Similar to the study by Walls (2012), for which the author investigated African American students' views of NOS, the data collection methods for this study utilized multiple instruments guided by the ideology of critical hermeneutics. According to Kinsella (2006), hermeneutics seeks to *understand* rather than to *explain*. Walls (2012) describes critical hermeneutics as purposefully "identifying as well as rectifying societal inequities" (p. 6). The instruments that were used in this study for data collection are described below.

VNOS Questionnaires

Student participants were asked to complete the *VNOS Questionnaires*, pre- and post-NOS instruction. Based upon the schedule utilized for this study, this occurred on February 24th and March 30th, 2024, respectively. Students were presented with the *VNOS-Form D* or the

VNOS-Form D+ depending upon their grade level. Students in grades K – 6 were asked to complete the *VNOS-Form D*, while students in grades 7 – 12 were asked to complete the *VNOS-Form D+*. The *VNOS-Form D* was chosen based upon the study by Akerson and Donnelly (2010) which was designed to explore elementary students' views on NOS. Cofré et al. (2017) utilized the *VNOS-Form D+* to evaluate biology teachers' understandings of NOS after partaking in a professional development program. While the *VNOS-Form D* has seven open-ended questions, the *VNOS-Form D+* has ten (Ayala-Villamil & García-Martínez, 2020). Approximately 45 minutes were allotted to complete the *VNOS Questionnaires*, and students were allowed to choose individually how they preferred to do so, whether it was read aloud, presented in braille, or through use of an accessible electronic form.

Exit Slips

After each of the six weekly science lessons, students were asked to complete an exit slip where they shared their views on each science lesson and how it might have been improved to meet the needs of blind and low vision students. Based upon the schedule utilized for this study, this occurred on March 2nd, March 9th, March 16th, March 23rd, and March 30th, 2024. Approximately 15 minutes were allotted to complete the exit slips and students were allowed to choose individually how they preferred to do so, whether it was read aloud, presented in braille, or through use of an accessible electronic form.

Semi-Structured Interviews

Semi-structured interviews were conducted by the instructor-researcher on an individual basis with all nine research participants. Interviews began after the sixth research session, and upon completion of the *VNOS Questionnaires,* post-NOS instruction. Student answers provided on the *VNOS Questionnaires* and weekly exit slips served as the question base throughout the interview process. During the interviews students were provided with their initial answers on the open-ended questionnaires and allowed to expand or clarify their answers if they so desired. Each semi-structured interview was audio and video recorded through the Zoom platform.

Student Commentary

Students' verbal commentary was obtained through audio and video recordings which were collected during each online session. Students' commentary included classroom interactions amongst the students, questions posed by the students, statements made by the students, and answers provided during times of classroom discussion between the instructor-researcher and the study participants.

Instructor-Researcher's Teaching Journal

Six entries were made by the instructor-researcher within a teaching journal immediately after each online classroom session. Each entry detailed the instructor-researcher's personal thoughts on each session, observations of the students' reactions to each science lesson, and how the instructor-researcher believed methods of explicit-reflective NOS instruction might be improved for visually impaired learners.

Data Analysis

The following table states the research question for this study, the data collected, and the corresponding analysis employed (See Table 5).

Table 5

Data Analysis

Research Question	Data Collected	Analyses Employed
• How does my online explicit-reflective NOS instruction impact visually impaired	• Responses on *VNOS-Form D* and *VNOS-Form D+*, pre- and post-NOS instruction	• VNOS coding rubric

students' conceptions of NOS?	• Responses on weekly exit slips • Semi-structured interviews • Students' commentary • Notes from instructor-researcher's teaching journal	• Thematic analysis

Data analysis began upon conclusion of the six-week science program. An interpretive phenomenological approach was employed to best understand the lived experiences of the student participants (Alase, 2017). These analyses are described in the sections that follow as they were utilized to interpret the data collected throughout the six-week science program. The research question that drove this study is posed below.

Research Question: How does my online explicit-reflective NOS instruction impact visually impaired students' conceptions of NOS?

VNOS Coding Rubric

To answer the question above, data were collected using the *VNOS Form-D* and *VNOS Form-D+*, pre- and post-NOS instruction. The *VNOS Questionnaires* were initially analyzed and coded by the author of this research study. Student responses on the questionnaires were coded as "inadequate," "adequate," or "informed," as seen in the coding schemes presented by Akerson and Donnelly (2010) and Akerson et al. (2014). To avoid subjectivity in the coding process, two additional individuals were asked to independently code the questionnaire responses. Aside from being licensed educators in the Midwestern United States, the additional two coders were also doctoral students majoring in curriculum & instruction and specializing in science education. One of these individuals provided their expertise as it applied to elementary students, while the other provided their expertise as it applied to middle school and high school students. Codes assigned by the three individuals were compared in order to come to an overall consensus.

Thematic Analysis

"Thematic analysis (TA) is a method for identifying, analyzing, and interpreting patterns of meaning ('themes') within qualitative data" (Clarke & Braun, 2017, p. 297). TA is a flexible method that can be paired with critical frameworks to allow researchers to look for patterns using codes and themes (Clarke & Braun, 2017). In this research study, TA was employed to analyze all artifactual evidence which included responses generated through exit slips and semi-structured interviews, as well as students' verbal commentary, and entries made within the instructor-researcher's teaching journal. All verbal commentary obtained through audio and video recordings were transcribed prior to evaluation.

To clarify, artifactual evidence obtained from exit slips, semi-structured interviews, and verbal commentary was evaluated using TA to identify trending statements and themes that helped aid the researcher in determining how visually impaired students may conceptualize the NOS, and how educators might provide blind and low vision students with more equitable and inclusive opportunities to understand NOS concepts. Written entries documented in the instructor-researcher's teaching journal were also evaluated using TA in order to determine how preconceived notions or misconceptions of visually impaired students might lead to inequities that may hinder these students from understanding the NOS, and also how educators can provide these students with more equitable and inclusive opportunities to understand NOS concepts.

Reliability

Triangulation

Triangulation in research requires the researcher to obtain data from two or more sources in order to provide a more complete picture of the topic at hand from differing perspectives (Heale & Forbes, 2013). In this study, triangulation of data was achieved through responses generated by students on the *VNOS Q*uestionnaires, as well as weekly exit slips, the study participants' verbal commentary, and journal entries made by the instructor-researcher throughout the course of this research study.

Member Checking

Member checking allows research participants the ability to clarify and expand upon their words, and to approve the narratives utilized by the researcher (Carlson, 2010). In this research study, semi-structured interviews were conducted individually between the instructor-researcher and all student participants. During these interviews, a student's transcribed verbal commentary and individual responses on open-ended questionnaires were read to them verbatim. According to Carlson (2010), this was an appropriate predetermined method for member checking due to the visual limitations exhibited by study participants. Students were then given the option to clarify, expand, or change their words within their own narratives. This helped to ensure that the instructor-researcher fully understood what the participants were trying to convey through their responses generated on the open-ended questionnaires and throughout the weekly science sessions. All participants were asked for their permission to utilize their words and narratives for the purposes of this research study in hopes that their lived experiences would assist in providing more equitable opportunities for visually impaired students within the science classroom.

Limitations of the Research Study

The primary goal of this study was to determine ways that educators can provide blind and low vision students with more equitable opportunities to better understand NOS concepts. Therefore, the focus of this research was on students with *visual impairments,* rather than additional contributing factors. While the student participants in this study were meant to provide a general representation of the visually impaired community, in no way should they be viewed as all-encompassing of that community. Degree and duration of visual impairment were not considered within this study, nor was ability level(s) as a result of secondary or tertiary disabilities. However, it should be noted that none of the student participants within this study were known to have had any disability other than visual impairment.

Ethics

This study received approval from the Institutional Review Board (IRB) at Indiana University. Data was only collected from those study participants who were made fully aware of the study procedures, and who had provided their informed consent or assent to willingly participate. Due to the nature of visual impairments and accessibility issues that may arise, student participants could choose to have a parent or guardian accompany them during the online science sessions. In order to protect their identity, all study participants were provided with a pseudonym to use when providing data on questionnaires and exit slips. Study participants were also made fully aware that their participation in the study was voluntary and that they could choose to withdraw from the study at any time.

Chapter Summary

In this chapter, I have presented the research design, as well as the roles, context, and recruitment strategies utilized to obtain study participants. Intervention activities were outlined, along with methods for data collection and data analyses. Methods of ensuring ethics and reliability were also put forth. The results of this study have been presented in the following chapter, as they pertain to visually impaired students' conceptions of NOS.

CHAPTER IV: FINDINGS AND RESULTS

As noted in previous chapters, the primary purpose of this action research study was to identify ways that educators can provide blind and low vision students with more equitable opportunities within the science classroom to better comprehend NOS concepts. Therefore, this chapter has provided a comprehensive overview of results which serve as an account of data obtained throughout the course of a six-week, online, Saturday science program, during which blind and low vision students received explicit-reflective NOS instruction. In the sections that follow, I have attempted to answer the research question by first offering a presentation of the student participants' pre-instructional views on NOS. Second, I have presented data as it applies to the implementation and effectiveness of the instructor-researcher's online explicit-reflective NOS instruction, and third, I have ended with the students' post-instructional views on NOS. All data presented is representative of the nine visually impaired students who completed the online science program, and pseudonyms have been selected to protect their identities.

Research Question

The research question that drove this study is as follows:

Research Question: How does my online explicit-reflective instruction impact visually impaired students' conceptions of NOS?

Students' Pre-Instructional Views on NOS

In this section I have presented the students' pre-instructional views on NOS as they pertain to the empirical and tentative aspects of NOS, observation and inference, and the creative and subjective aspects of NOS. Two additional NOS aspects, social and cultural embeddedness and theories and laws, will also be presented based upon answers provided on the *VNOS-Form D+* by the sole senior student in the research participant group. Pre-instructional data pertaining to the latter two NOS aspects was not collected from the younger group of students, as the *VNOS-Form D* does not pose questions that target those aspects, and the structure of the informal science program did not allow for pre-NOS instructional interviews to be conducted. Table 6 illustrates the NOS aspects targeted by each question posed on the *VNOS-Form D* and the *VNOS-Form D+* (See Table 6).

Table 6

NOS Aspects Targeted by the VNOS Questionnaires

Targeted NOS Aspect	*VNOS-Form D* Question Number	*VNOS-Form D+* Question Number
Empirical	1, 2	1, 2, 4d
Tentative	3, 4, 6	3, 4b, 5, 9
Observation and Inference	4, 6	4a, 5, 6,
Creative	4, 7	7
Subjective	5	4c, 7,
Social and Cultural Embeddedness	-	10
Theories and Laws	-	8

Table 7 conveys the number of visually impaired students holding inadequate, adequate, and informed views on each NOS aspect, prior to receiving any NOS instruction (See Table 7).

Table 7

Study Participants' Pre-Instructional Views on NOS

NOS Aspect	Grades 2 – 6 (Completed *VNOS-Form D*) n = 8			Grade 12 (Completed *VNOS- Form D+*) n =1		
	Inadequate	Adequate	Informed	Inadequate	Adequate	Informed
Empirical	4	4	0	0	0	1
Tentative	6	1	1	0	1	0
Observation and Inference	4	3	1	0	0	1
Creative	5	1	2	0	1	0
Subjective	4	1	3	0	0	1
Theories and Laws	-	-	-	1	0	0
Social and Cultural Embeddedness	-	-	-	0	1	0

While the senior student in the research group was shown to hold a majority of adequate and informed pre-instructional views on NOS, the study participants as a whole were shown to hold a majority of inadequate views on the various aspects of NOS prior to receiving any explicit-reflective NOS instruction. In the following subsections, each NOS aspect is discussed independently in order to provide examples of the students' responses on the *VNOS* forms and to illustrate their pre-instructional views on NOS.

Empirical NOS

In regard to the empirical aspect of NOS, students' comprehension was displayed through their responses to two question items on the *VNOS* questionnaires. Four of the eight students in grades 2 – 6 were shown to hold inadequate views, while four students in the same grade levels were shown to hold adequate views. When asked, "What is science?" responses coded as inadequate seemed to reference the idea of *things*, but failed to acknowledge the need for observation and experimentation. For instance, David stated, “Science is based on ancient things.” Meiling’s thinking seemed to concur with this idea as she replied, “I think science is like studying things.” A third student, Whitney, also believed that science was, “The study of things.” Those students who were shown to hold adequate views also mentioned the idea of things, but added the additional element of *experiments*. For example, Amber responded with, “It’s where you experiment things and test things.” Aiyana’s response was similar in stating that science involved, “Studying and solving experiments.” Our senior student, Cathy, provided an informed response by adding the additional aspect of *observation*. She explained that science was, “The study of nature and physical things using observations and experiments.”

When asked how science differs from other subjects, the students provided a variety of answers. For instance, David responded that, “You don’t have to read very much in science [and] there isn’t a difference from math.” Laila implied that science was more fun or exciting when she replied, “The other subjects are boring.” Additional comments put forth the ideas that science was more “interactive” or “hands-on” when compared to other subjects. While all of these responses were coded as being inadequate, adequate views emerged as well. For example, Aiyana stated that, “Science is the study of earth and space,” while Rachel explained that, “Science is different because in science we learn how things work and look.” An informed view was conveyed by Cathy when she responded that, “You use more experimental tactics and problems for science. You also use math and logic in science.” An additional response item on the *VNOS-Form D+* also showed Cathy’s informed understanding of the empirical NOS when she explained that “more information” gained from research and experimentation could also be used to persuade or convince other scientists.

Tentative NOS

In regard to the tentative aspect of NOS, six of the eight students in grades 2 – 6 were shown to hold inadequate views, one student was shown to hold an adequate view, and one was shown to hold an informed view. When asked, “Do you think what scientists know might change in the future?” five students conveyed inadequate views when they said that it would, but failed to provide a reason as to why. Only one student, Laila, was clearly unsure and responded with, “I don’t know.” Meiling provided what was coded as an adequate view when she responded, “Yes. Technology can get better, and it can tell you better things to do when storms are coming. It can also tell us about the past that we don’t know about yet.” Bethany provided what was considered to be an informed response for a third grader when she simply replied, “Scientists might learn something else.”

Additional insight pertaining to the students’ understandings of the tentative NOS was displayed through their responses when asked about the weather. Half of the students believed that weather people were “certain” or “positive” when it came to predicting the weather. Only two students mentioned that predictions could change based upon current and ongoing changes in the weather. This theme was also seen when students were probed by being asked, “How certain are scientists about the way dinosaurs looked?” Answers were fairly consistent with students responding that scientists were “pretty sure” or “pretty certain,” while others simply stated, “I don’t know.” None of the students seemed to recognize that new information could lead to new ideas.

Cathy, our senior student, explained that, “[Scientific knowledge] could evolve like most everything. It definitely probably could evolve into something different.” However, when asked about the weather, she failed to recognize that new information could lead a weather person to change their previous predictions. Instead, she believed it was just “hard” to make future predictions pertaining to the weather. Nonetheless, Cathy was able to recognize that new information could cause a theory to change after being developed by scientists. When asked if theories ever change, Cathy responded by stating, “It probably does change, at least some of them, because there might be new scientific theories or scientific things proven that go with those events and scientific findings.”

Observation and Inference

With respect to observation and inference, half of the eight students in grades 2 – 6 were shown to hold inadequate pre-instructional views. Of the remaining participants, three of the students held adequate views, and one held an informed view. When asked, “How do scientists know that dinosaurs really existed?” all of the students except two mentioned dinosaur bones and/or fossils. Rachel, a sixth grader, provided what was considered to be an informed view by explaining, “They know because they found fossils/remnants of dinosaur bones and feces. They aren’t sure how dinosaurs used to look, but they know the shape because of their skeletons.”

Cathy, our senior student, was also shown to hold informed views in regard to observation and inference. As with the younger students, Cathy mentioned fossils as a way for scientists to know that dinosaurs existed. However, she mentioned footprints as well. Her response noted, “They found fossils of those creatures. They also found footprints.” An additional question, pertaining to observation and inference, posed on the *VNOS-Form D+* asks, “Does the model of the layers of the Earth exactly represent how the inside of the Earth looks?” Cathy again was shown to hold an informed view by responding:

> I am not for sure certain that the diagrams and representation of how scientists think the earth’s layers look are fully correct. They probably do look a little different than we think

they do because we haven't gotten as far down as we may be able to in the future.

Although none of the students specifically used the words *observe, observation*, *infer,* or *inference*, Rachel's and Cathy's responses indicated a basic understanding that inferences can be made when observations may not be attainable.

Creative NOS

In considering the creative aspect of NOS, five of the students in grades 2 – 6 exhibited inadequate views, one student was shown to hold an adequate view, and two held informed views. When asked, "Do you think scientists use their imaginations when they do their work?" two of the students, David and Bethany, responded that they did but were unable to provide an example of when; thus, exhibiting inadequate views. Three other students also conveyed inadequate views when they cited *facts* as a reason that scientists would not use their imaginations. For example, Meiling responded with, "No. Because they have to use factual information, and imagination doesn't give factual information." Aiyana provided a similar response when stating, "No. Because they have to listen to the facts." Rachel provided what was considered to be an adequate view when she responded, "Yes. I think they're using it when they're thinking about their hypothesis." Informed responses were provided by Whitney and Laila. Whitney responded, "Yes. They use their imaginations when they are thinking about different scenarios for events and sometimes when doing experiments." Laila's response was similar in stating, "Yes. They have [to] imagine what dinosaurs and other things that lived long ago might look like."

Our senior student, Cathy, provided additional insight within her explanation pertaining to scientists and their use of creativity. Her response, coded as adequate, reads as follows:

I think they do because just about every job you do you have to have some kind of

> creativity in any field. They probably do use their imagination and creativity, not maybe every day but at least once or twice a week doing their job and figuring out what is scientific.

Furthermore, Cathy appeared to recognize how one would use creativity in making an inference. When asked how certain scientists are in regard to how dinosaurs looked, Cathy responded, "They're probably not fully certain of what they look like. I think it was based off of creativity, and the use of what they thought would look good."

None of the students mentioned creativity or imagination as a way for scientists to create or invent something new, such as technology.

Subjective NOS

With respect to the subjective aspect of NOS, half of the eight students in grades 2 – 6 were shown to hold inadequate pre-instructional views. Of the additional students, one of the participants held an adequate view, and three held informed views. In regard to the extinction of dinosaurs, students were asked, "If scientists all have the same facts about dinosaurs, why do you think they disagree about this?" A variety of inadequate views were noted. For example, David simply stated, "I don't know," while Bethany said, "It's just their opinion." Aiyana referred to the Bible when she responded, "Biblical differences. I believe in the flood." Amber was the only student to exhibit an adequate view and simply stated, "Because everyone thinks differently." Whitney exhibited an informed view by responding, "I think scientists disagree because they all look at different scenarios." Rachel's in-depth response also conveyed an informed view on the subjective aspect of NOS when she stated:

> One theory is that a comet hit the Earth, and the world went into an Ice Age. Dinosaurs died because of this, or so some say, but there isn't much clear evidence that a comet hit

the planet, so the scientists are divided, with their theories and opinions.

Cathy, our senior student, also provided what was considered to be an informed view on the subjective aspect of NOS when she responded, “Because scientists have their own theories and thoughts on what has happened with dinosaurs or other experiments and that’s just kind of how humans are in general.”

While Aiyana’s response served to provide an example of her own subjectivity, none of the students made mention of how one’s personal knowledge or beliefs might allow them to provide a different perspective throughout the process of scientific investigation.

Social and Cultural Embeddedness

As noted earlier, pre-instructional data pertaining to social and cultural embeddedness was only collected from our senior student in the research group. When asked, “Is there a relationship between science, society, and cultural values?” Cathy responded by stating, “There probably is a relation between all those things because [there] probably is science found in a lot of different experiences, cultures, and events.” While this was considered to be an adequate view, Cathy failed to articulate that a scientist’s work may be affected by the society and culture of which they are a member.

Theories and Laws

As with social and cultural embeddedness, pre-instructional data pertaining to theories and laws was only collected from our senior student in the research group. When asked on the *VNOS-Form D+*, “Is there a difference between scientific theory and scientific law?” Cathy responded, “I think scientific theory is just theories and wondering of what could happen in science, and scientific law is the basis of what people in that career follow or abide by.” As Cathy failed to provide a clear understanding or distinction between theories and laws, this response was coded as being an inadequate view. However, it should be noted that this was considered to be Cathy's only inadequate pre-instructional view on NOS.

Implementation and Effectiveness of Teaching Strategies

In this section I have described the teaching strategies that were utilized to provide students with instruction on the various aspects of NOS. The instructor-researcher selected activities from those suggested by Lederman and Abd-El-Khalick (1998) and adapted them for visually impaired learners in order to introduce and explicitly teach each weekly targeted NOS aspect. Periods of reflection were also utilized to engage students in weekly group discussions and allow them to answer questions which explicitly emphasized the NOS aspects targeted during each science session. Student commentary, excerpts from the instructor-researcher's teaching journal, and themes obtained from weekly exit slips are also presented to allow for additional insight.

Explicit-Reflective NOS Instruction

During the first week of the science program, the instructor-researcher began by asking students if any of them had heard of the NOS prior to taking part in the research study. Only one student said that they had by responding, "I don't know much about it, but I've definitely heard about it." The instructor-researcher then provided an explanation of NOS, before asking students to introduce themselves and attempting to establish an environment of rapport and belonging.

The instructor-researcher then lead the students through the *Tricky Tracks!* activity (Lederman & Abd-El-Khalick, 1998). While this was used as an ice-breaker activity and to introduce the students to the NOS, Lederman and Abd-El-Khalick (1998) also noted how the activity could be used to assist students in distinguishing between observation and inference, as well as acquainting them with the creative and tentative aspects of NOS. Therefore, after asking the students to take out their papers for Lesson #1, the instructor-researcher attempted to introduce the students to the concept of observation by stating, “I want you to think about what you *observe* on that paper.” After giving the students time to investigate the sets of tracks, the instructor-researcher again stated, “I want you to tell me what you *observe* on this piece of paper.” As the students took turns stating their observations, the instructor-researcher noticed that they were focusing on the texture and shape of the embellishments, rather than recognizing the shapes as animal tracks or prints. Therefore, time was taken to explain footprints to the students before introducing the concept of inference.

After the students gained an understanding that they were looking at footprints on their papers, the instructor-researcher emphasized the concept of inference by saying, “So, now we have to *infer* what made the prints.” This was followed by asking the students to share their own stories of inference based upon the observations they were making. While none of the students utilized the terms of observation or inference when speaking, their commentary was indicative of their own creativity when sharing stories of how and why the animal tracks may have been made. When asked what they observed and inferred, students shared some of the following story lines:

Bethany: “I think these birds are chirping and walking and getting to know one another. Then one bird flew away.”

Laila: “Two dinosaurs were going, and then they found a really good nesting spot, and then they had a fight, and then one of them lost and walked away.”

Meiling: “I think two dinosaurs were gonna go get food and since one of them got the food, the other one has to go away and find its own food.”

Whitney: "I think that there was two dinosaurs and they were walkin' along a path, and then they met at a watering hole and then one of 'em ran away."

After the students had all shared their observation and inference stories, the instructor-researcher concluded the session by again emphasizing and explaining observation and inference. This was followed by one of the students asking for clarification on the difference between an inference and a hypothesis. While the instructor-researcher was generally pleased with how the first science session went, she was notably surprised by the lack of incidental learning that blind children experience. An excerpt taken from the instructor-researcher's teaching journal, as it pertains to Activity #1 reads:

> While a sighted child would see footprints in the sand, or animal tracks on a hiking trail or within the snow, blind children miss out on these details. Some of the children didn't know that animals made tracks/prints at all, while other students thought that all tracks were the same based upon a stereotypical paw print (i.e., one large circle with four smaller circles arching above the larger one). As a result, they were surprised to learn that each species' paw print is different, and scientists could tell the difference between animals based upon the prints they leave behind. In addition, it had to be explained to one child that animals only leave footprints when they are walking on the ground, not when they are flying in the sky. Due to this newfound knowledge, students appeared to focus heavily on the animal prints, rather than recognizing the true intent of the lesson, which was observation and inference.

Also noticed during the first science session was the role that parents played in helping their children make connections to the subject(s) being discussed. When the students were asked if they could recall a time when they had seen animal prints in the past, one student turned to their mother offscreen and asked, “Have I?” Another parent could be heard asking their child, “Remember when we went to that museum?” This would suggest that visually impaired learners make connections based upon places and experiences they have encountered, rather than visual or pictorial memory.

Results obtained from weekly exit slips also suggested that the clearest concept learned during Lesson #1 was the fact that animals make footprints, and footprints differ between species. Only one student made mention of the terms, *observation* and *inference*. Due to the time spent explaining footprints, the instructor-researcher lacked the ability to introduce the tentative and creative aspects of NOS.

Lesson #2 was again intended to emphasize observation and inference, as well as the tentative and creative aspects of NOS. The session began with the instructor-researcher asking the students to reflect upon the previous week’s session. When asked if the students could name two concepts that they had learned from the previous week, Aiyana was immediately able to recall, “Observation and inference.” When asked what an observation was, Aiyana went on to explain, “An observation is like something that you can see, you can touch, you can feel. So, basically, like, ‘I observe that the rock is smooth.’ Like basically, what you can see or what you can feel.” When asked what an inference was, Laila was able to explain, “It’s like a guess that you make.” The instructor-researcher concluded the reflective period by again providing clarification on the difference between an inference and a hypothesis. As this was a question from the previous week, the instructor-researcher wanted to ensure that all of the students had a proper understanding before moving forward.

To begin the *Real Fossils, Real Science* activity (Lederman & Abd-El-Khalick, 1998), the instructor-researcher again emphasized the concept of observation by asking the students to *observe* their fossils. The students were then asked to make inferences based upon their fossils, and from which organisms they believed their fossils came. As the students worked diligently with their clay to build their organisms, the instructor-researcher asked, “So you’re working as scientists right now to make inferences based upon your observations. So, would you say that this takes creativity and imagination?” All of the children responded affirmatively and recognized that creativity was used in the process of attempting to identify which organisms their fossils came from.

After the students had completed their organisms, they shared with the class what they had built, the habitat that they believed their organism would have lived in, and what it may have eaten. The instructor-researcher then shared with each child the true identification of their fossils. This was used to introduce the word, *tentative.* While some of the students were incorrect in their inferences surrounding their fossils, the instructor-researcher told them the story of the iguanodon dinosaur and explained how scientists had originally reconstructed the skeleton incorrectly by putting the dinosaur’s thumb on his forehead. This story was used to emphasize that inferences are tentative based upon the current data or information that one has (Lederman & Abd-El-Khalick, 1998).

A key realization that came to light during the second science session is the way in which students were making inferences based upon their geographical location. After completing Activity #2, the instructor-researcher wrote in their journal:

> Students also exhibited a level of knowledge based upon geographical locations of where they lived. For instance, one child, who lives in a coastal area, believed that she had a crab claw fossil. While this was incorrect (it was a mosasaur tooth), it showed that blind and low vision students make inferences based upon experiences and items that they have

felt or *touched* in the past. This is not unlike sighted students who make inferences based upon items they have *seen* in the past.

The children appeared to find enjoyment in the activities as well, with the instructor-researcher noting that the students "were actively and positively engaged in the discussions throughout our time together." A predominant theme that arose during Lesson #2 was the idea that science is *fun*. While the students were molding their clay during the *Real Fossils, Real Science* activity (Lederman & Abd-El-Khalick, 1998), Whitney explained that the science lessons weren't work for her, but "fun." David agreed by stating, "It's also fun for me!" Rachel also stated that the lessons were "fun" and expressed her interest in fossils by asking, "Can you send us more fossils, because they're cool?!"

In regard to exit slips for Lesson #2, a majority of the students stated that *inference* was the concept that was made most clear to them.

Lesson #3 was meant to introduce students to subjectivity, as well as social and cultural context. As in the previous week, the session began by asking the students to reflect on past lessons and recall words or concepts that they had learned. While the students were readily able to recall observation and inference, only two students were able to remember the word tentative. Meiling was able to describe tentative by saying, "When something changes." The instructor-researcher then reminded students of their fossils from the previous week along with the story of the iguanodon in order to illustrate the tentative aspect of NOS.

Upon conclusion of the reflection period, the instructor-researcher asked the students to take out their *That's Part of Life!* stories (Lederman & Abd-El-Khalick, 1998). After having the students take turns reading portions of the story, the instructor-researcher said, "Okay, so that's the story we have and your job is to investigate, as scientists, what this story is about." As students were having trouble deciphering the passage, the instructor-researcher provided them with clues. The students were also told that they could work in groups or utilize others in their homes, such as parents or older siblings, in order to decipher the passage. As many of the students had never done the laundry before, this activity served as an ideal opportunity to introduce the students to the aspect of subjectivity, as well as social and cultural context. David explained that he had to work with others in order to figure out what the story was about. He said, “Well, I haven’t done laundry before. I’ve only carried loads of laundry, so I don’t really know what it’s like to do laundry.” Laila explained that she used clues to decipher the passage, saying, “When you said your parents usually might do this about once a week, I kind of thought, well, they kind of do some of these things once a week.”

Notes made within the teaching journal after the third science session indicated that past experiences and people are important in helping visually impaired children make connections to the subject matter. While *That’s Part of Life!* is a story puzzle passage about doing the laundry (Lederman & Abd-El-Khalick, 1998), many of the children had not yet experienced this household task, and therefore, were unable to make a valid connection. However, the instructor, parents, and older students were indispensable in helping the younger students to make this connection by providing clues as to how the laundry was done in their own homes. In addition, the instructor-researcher noted the following as it pertained to the process of determining what the story passage entailed:

> I noticed that [the students] were attempting to use the words ‘observation’ and ‘inference’ to explain their thoughts. Many of them were doing so correctly. In addition, students were able to recognize that others who have more experience with certain things can help them solve similar issues.

Notes made within the teaching journal also indicated that the senior student in the group fully understood how one could use context clues to assist in deciphering scientific data and in making inferences.

The instructor-researcher ended the session by explaining to the students that past experience and knowledge is important in order to view things within the proper context, and to make appropriate inferences based upon the clues or data available. Themes that arose on the exit slips from Lesson #3 were students' understandings and use of the words, *observation, inference,* and *tentative*.

The *Young? Old?* activity completed during the fourth science session brought to light the concept of perspectives (Lederman & Abd-El-Khalick, 1998). As in previous weeks, Lesson #4 began with the instructor-researcher asking students to reflect over the past weeks' information. When the students were asked if they could recall what they had learned during Lesson #1, they immediately replied, "Observation and inference!" When the instructor-researcher asked if everyone would make the same inferences based upon their observations, Meiling said, "No, because each person has a different imagination." Rachel concurred by explaining that inferences may differ between people when, "We don't have, like, all the information." As the period of reflection went on, students also recognized that imagination and creativity were used by scientists when, "They're observing fossils…and putting them together like a puzzle." The students also recognized that one's current knowledge, past experiences, and context clues could be useful in solving problems.

When students were asked to observe the picture of *Is it a duck or a rabbit?* (Atkinson, 1975, p. 102, as cited in Lederman & Abd-El-Khalick, 1998, p. 103), the ideas that came forth included:

Rachel: “It kind of looks like a tree, or some plant. It kind of looks like broccoli. I love broccoli by the way!”

Laila: “I think it might be a foot.”

Cathy: “It does kind of look like a foot, and a rabbit head, but it could also be like a bird head if you flip it upside down.”

Amber: “I was thinking it was a misshapen rabbit because it doesn’t really have a tail.”

As the instructor-researcher listened to the student’s observations and inferences, she noticed, as in Lesson #1, that the students were focusing heavily on the texture of the paper. She realized this made it difficult for students to make an appropriate inference. Therefore, the instructor-researcher asked the students if their inferences would be different if the image had been provided with fur or feathers on it. The students said that it would, and, while they expressed the importance of texture in helping them to determine what an object is, they also indicated that this was a source of anxiety and fear for them. The instructor-researcher wrote:

> I allowed the students time to express and discuss their feelings and discomfort regarding the touch of certain objects. We were able to connect this with science by discussing how we must be able to trust others who are giving [us] certain information. Otherwise, we might get incorrect information and come to an incorrect conclusion.

Regardless, when students were asked why they were all seeing something different coming from the same image, some of the explanations provided were:

Laila: “We all have different experiences.”

Cathy: “We all have different aspects of creativity.”

Amber: “Everyone thinks differently.”

The instructor-researcher then took the opportunity to explain that one's past experience and knowledge, along with their perspective are important in making an inference. This led many of the students to understand that they could offer a different perspective from that of someone who is sighted. The exit slips from Lesson #4 showed an overwhelming use of the word *perspective,* with students exhibiting an understanding that one's perspective and past experiences can provide new ideas which may lead to differing *inferences*. As one student noted on their exit slip, "I like the discussions between everyone because that helps me learn too, to hear other perspectives makes me think more about my thoughts."

During weeks five and six of the science program, the instructor-researcher used Black Box activities to model observation and inference, imagination and creativity, the tentative and empirical aspects of NOS, as well as theories and laws (Lederman & Abd-El-Khalick, 1998). As in previous weeks, Lesson #5 began with a reflection period where students were asked to recall topics from previous weeks' lessons. During reflective discussions, the students were readily able to recall and accurately describe observation and inference, as well as provide an explanation regarding the tentative aspect of NOS. Students also recognized that scientists use imagination and creativity along with their own past experiences during the investigative process. The instructor-researcher wrote:

> [The students] are able to recall the words, 'observation,' 'inference,' 'tentative,' and explain in detail what these words mean. They are also able to recognize and explain that scientists base their inferences upon past experiences, work together to find a solution, and that context clues are used in the process.

Upon completion of the reflective period, the instructor-researcher led students through *The Tube* activity (Lederman & Abd-El-Khalick, 1998). As the science sessions were conducted in an online format, each student was provided with their own pre-built model of the tube, as well as supplies to re-construct their own version of the model. To begin, the instructor-researcher asked all of the students to investigate their pre-built models by pulling on the ropes, shaking the tube, etc. The students then took turns explaining what they observed occurring within their tubes. Some of their observations pertaining to the ropes within their tubes included:

Whitney: “When I pull mine, the other ropes, like, tighten kind of. Maybe they’re in a cross shape, and they’re connected together. So, when you pull one the other one gets smaller.”

Cathy: “I think they’re like connected in some way because I don’t think the one rope would just pull the other if they were just straight up and down with each other.”

Aiyana: “I kind of think there’s something in the middle.”

All of the students agreed that there was something rattling in the tube that they could hear, but failed to recognize that it was connecting the ropes at the center of the tube. The students were then asked to use the supplies they were provided to try and recreate the original models that they were given. While some of the students were able to construct a similar model, others were unable to figure out how the ropes were to be connected in the center of the tube. Upon completion of the activity, the instructor-researcher had the following conversation with the students:

Instructor: “So, I want to ask you something. If we never opened this toilet paper roll to look inside, could we ever tell that our models are the exact same copies?

David: “No.”

Aiyana: “No.”

Instructor: “So, what would [scientists] be doing?”

Meiling: “Inferring.”

Aiyana: “Inferencing.”

Instructor: “Right. They’re making inferences as to what is going on. Very good. And, with that said, can scientists ever be truly certain of how a phenomenon actually works?”

Whitney: “No.”

David: “No.”

The instructor-researcher concluded the session by reminding students that while scientists can make inferences pertaining to phenomena, models are rarely exact copies and as a result, current ideas are tentative and can change with new information. In addition, Lesson #5 was indicative of helping students understand the concept of different phenomena and the construction of models; particularly, in regard to creativity and imagination. The instructor-researcher noted in their journal:

> I explained that even scientists who are sighted can’t *see* all things, and have to imagine what might be occurring, and while they may construct a model that is quite close to reality, we can’t ever truly be sure that it is an exact representation.

While this appeared to be surprising to some of the students, the journal entry indicated that visually impaired students are capable of utilizing their other senses, particularly hearing, when investigating various scientific phenomena. The word *phenomenon* also seemed to be a concept that a majority of students noted as being least clear on the Lesson #5 exit slips. However, students were able to relay that you “can’t look inside” a phenomenon, and as a result, models can’t be exact copies.

Week six, *The Cube Activity*, was used to illustrate how scientists might look for patterns when investigating different phenomena (Lederman & Abd-El-Khalick, 1998). Notes made within the instructor-researcher’s teaching journal revealed that this activity was quite simple for the younger students, but more challenging for the older ones. As the younger students worked in a separate breakout room from the older students when examining their cubes, the instructor-researcher asked one of the younger participants, upon reconvening, to describe their cube’s pattern to the older ones. This, along with clues provided by the instructor-researcher, aided the older students in deciphering the pattern shown on their cubes. Again, this is indicative that others are important in helping visually impaired children make connections to the subject matter being discussed.

Explicit instruction was necessary to help the students recognize that observing patterns is helpful to scientists when determining what the weather might be, as some of the students simply thought the information was programmed into different means of technology. A conversation between the instructor-researcher and one of the third grade students is shown below:

Instructor: “How do you think weather people would predict the weather based on patterns?”

Laila: “[The box] kind of goes through the alphabet a little. So, it’s kind of like a pattern.”

Instructor: “It’s a pattern. That’s right! So, do you ever sit with your parents in the morning or at evening and they might turn on the weather or the news on TV?”

Laila: “No.”

Instructor: “Or, do you have a Google in your house that you might say, ‘Okay, Google, what’s the weather today?’”

Laila: “Well, I have an Alexa.”

Instructor: “Okay, that’s similar. Very good. So, do you ever ask Alexa what the weather is that day?”

Laila: “Yes.”

Instructor: “So, how do you think Alexa is able to tell you what the weather is?”

Laila: “People have to figure it out and then program it to go to the Alexa.”

Instructor: “That’s absolutely correct, but how do you think the people know what the weather is going to be to tell Alexa?”

Laila: “People have to figure it out.”

While the conversation continued, and David joined in, both students recognized that scientists use “a lot of different tools” to see when storms are coming. However, they failed to readily articulate how these tools are useful in collecting data to look for patterns and make predictions. Regardless, notes within the teaching journal indicated that all of the students, by the end of the lesson, “were able to recognize that scientists may use these types of patterns to investigate the weather or other environmental phenomenon.” The theme of *patterns* also arose on the Lesson #6 exit slips, with students referring to patterns as a way for scientists to make *observations* and *inferences*; particularly, as they pertain to weather patterns.

Students’ Post-Instructional Views on NOS

In this section the student participants’ post-instructional views on NOS have been presented as they pertain to the empirical and tentative aspects of NOS, observation and inference, the creative and subjective aspects of NOS, as well as social and cultural embeddedness, and theories and laws. As the *VNOS-Form D* does not pose questions that target social and cultural embeddedness and theories and laws, post-instructional data for students in grades 2 – 6 pertaining to those aspects was solely obtained from exits slips, the students' verbal commentary, and the instructor-researcher's teaching journal. To retain conformity and avoid subjectivity in the process of data analysis, information obtained from the younger group of students in regard to social and cultural embeddedness and theories and laws was not coded; therefore, data presented on those two aspects is not shown in the table below, but rather in the corresponding subsections that follow. The table below conveys the number of visually impaired students holding inadequate, adequate, and informed views on each NOS aspect after having received explicit-reflective NOS instruction (See Table 8).

Table 8

Study Participants' Post-Instructional Views on NOS

NOS Aspect	Grades 2 – 6 (Completed *VNOS-Form D*) n = 8			Grade 12 (Completed *VNOS- Form D+*) n =1		
	Inadequate	Adequate	Informed	Inadequate	Adequate	Informed
Empirical	1	5	2	0	0	1
Tentative	1	1	6	0	0	1
Observation and Inference	0	2	6	0	0	1
Creative	0	2	6	0	0	1
Subjective	1	2	5	0	0	1
Theories and Laws	-	-	-	0	1	0
Social and Cultural Embeddedness	-	-	-	0	1	0

As illustrated in the table, the study participants as a whole were shown to hold a majority of informed views on the various aspects of NOS after having received explicit-reflective NOS instruction. In the following subsections, each NOS aspect has been discussed separately in order to provide examples of the students' responses on the *VNOS* forms and to provide an overall picture of their post-instructional views on NOS.

Empirical NOS

In regard to the empirical aspect of NOS, five of the eight students in grades 2 – 6 were shown to hold adequate post-instructional views, while two students in the same grade levels were shown to hold informed views. Only one student retained their inadequate view. When asked, "What is science?" responses were much more in-depth and detailed than seen in the pre-instructional data. While the "study of things" was still mentioned, students were able to weave additional aspects into their answers. For example, David was shown to improve his view when he responded that, "Science is chemical reactions and fossils and robots and animals and the body." Also shown to improve her view from inadequate to adequate after having received instruction, was Meiling, who replied, "Science is like when you study fossils and life and things that have happened in the past." Aiyana stated that science is "The study of real life and exploring it. The study of reality." Rachel conveyed an informed view when she responded, "Science is the study of world behaviors, which means everything that happens on Earth and how it happens." Our senior student, Cathy, retained her informed view, but was also able to incorporate the idea that "different inferences and theories" are a part of science.

When asked how science differs from other subjects, the students again provided a variety of answers. It was apparent that the students were trying to express concepts they had learned throughout their time in the six-week science program. For example, Whitney responded, "When you are learning science usually you have to make inferences about things and sometimes you have to work in groups and do experiments. You also have to make observations." This response was coded as informed, and was an improvement on Whitney's pre-instructional response, which was coded as adequate. Bethany, a third grader, was able to improve her view from inadequate to adequate by stating, "We do experiments in science," an idea that she hadn't previously conveyed prior to receiving instruction. Our senior student, Cathy, again tried to incorporate words that she had learned throughout the science program. When explaining how science differed from other subjects, Cathy responded, "…you use more inference and observation in science." She also mentioned that "creativity" is involved in science. Amber was the only student shown to retain her inadequate view by stating again that science was just "more hands-on activities."

Tentative NOS

In regard to the tentative aspect of NOS, six of the eight participants in grades 2 – 6 were shown to improve their views after having received explicit-reflective instruction. Six students were shown to hold informed views, one student was shown to hold an adequate view, and one student continued to exhibit an inadequate view. Changes in the students' views on this aspect were clearly apparent, as they were able to provide detailed examples of why the knowledge of scientists might change in the future. A majority of the students cited "more information," "more knowledge," "more technology," and "more details" as a reason that scientific knowledge may change over time. Whitney, the only student to retain her inadequate view, clearly stated, "Yes," when asked if she thought what scientists know might change in the future. However, similar to her pre-instructional response, she failed to provide a reason as to why. Follow-up during the semi-structured interview failed to produce further clarification; hence, her response was again coded as inadequate.

Cathy, our senior student, retained her informed view, but again improved it by trying to incorporate words and concepts introduced throughout the six-week science program. She responded, “Yes, it does change. It always changes [because] science is tentative. It’s always changing and always evolving.” In addition, she continued to hold an informed view when asked if a theory ever changes after being developed by scientists. Again, Cathy correctly incorporated the word “tentative” and responded, “Yes, theories are always evolving and changing. They are tentative.”

Students also exhibited their knowledge of the tentative aspect of NOS when asked about the weather. Students were able to convey an understanding that weather people are “not certain” when predicting the weather, and as a result, predictions may change. Rachel said, “I think they’re not certain because wind is always changing direction, so the [weather] patterns might change. I think there’s a chance that they’re right and a chance that they’re wrong, and most of the time they’re right.” This theme also came to light when students were asked, “How certain are scientists about the way dinosaurs looked?” Students now recognized that scientists were “not completely certain” due to the “educated guesses” and “inferences” that were being made. Laila exhibited this view when she responded, “They feel tentative because they have to use inferences to guess and see.” Cathy, our senior student, put forth an understanding that evidence we’ve not yet found or seen, “…is going to be different than how we think it looks.”

Observation and Inference

With respect to observation and inference, six of the eight students in grades 2 – 6 were shown to improve their views post-instruction. Of the participants in grades 2 – 6, two of the students held adequate views, and six held informed views. None of the students were shown to retain an inadequate view in regard to observation and inference. While pre-instructional responses seemed to focus on bones or fossils as a way for scientists to confirm the existence of dinosaurs, post-instructional answers were now indicative of the students' understandings of inference. For example, Amber, who had previously conveyed an inadequate understanding of observation and inference, now conveyed what was considered to be an informed view. When asked, "How do scientists know that dinosaurs really existed?" Amber responded with the following:

> They have evidence of dinosaur footprints. They are certain because of fossils, and the footprints also help them figure out how big they might have been, how heavy, or the shape of the feet. In regard to skin, they can't be certain for sure, but I'm sure scientists have a guess.

Meiling also provided what was considered to be an informed response when she replied with the following:

> Scientists have dug up fossils and they have probably seen dinosaur footprints. They are not completely certain about how dinosaurs looked because the bones don't have fur or hair on them. When they observe the pieces, they can always infer what the dinosaurs could have looked like.

Creative NOS

In considering the creative aspect of NOS, six of the eight students in grades 2 – 6 were shown to improve their views after receiving explicit-reflective NOS instruction. The two remaining participants who were not shown to improve their views were already noted as having informed views during the pre-instructional assessment. Through post-instructional responses, six students were shown to hold informed views, while two participants were shown to hold adequate views. The senior student, in grade 12, was also able to improve her view from adequate to informed.

While students' pre-instructional views cited the necessity of factual information as a reason that scientists would not use their imaginations and creativity, post-instructional views were indicative of participants' understandings that imagination and creativity are utilized in the process of scientific investigation and experimentation. For example, Bethany put forth an understanding that scientists use creativity, "When they build something." Whitney stated, "Scientists use their imaginations when making inferences and when observing objects and things." Rachel also believed that scientists used creativity and imagination, "…when they're making their inferences and hypotheses." Several students mentioned dinosaur bones as a reason that scientists might need to use their creativity. This idea was shown in Meiling's response when she responded, "…when they dig up a dinosaur, they have to imagine where the bones go to build it."

Although students recognized the importance of creativity in the process of scientific investigation, they also understood the importance of empirical evidence to support one's imagination. This was implied by Amber when she responded, "They can't always use their imagination because they can't just make something up about a dinosaur or something else." Cathy's response also indicated that while scientists have "creative skills," they still have to "…come up with facts and research and evidence."

Subjective NOS

With respect to the subjective aspect of NOS, half of the eight students in grades 2 – 6 were found to improve their views. Post-instructional responses conveyed that five students held informed views, two held adequate views, and one participant retained an inadequate view. Three students in grades 2 – 6, as well as our senior student, were shown to hold informed views during the pre-instructional assessment. Hence, the reason for lack of noted improvement in regard to those students' views.

Concerning the subjective aspect of NOS, students were asked, "If scientists all have the same facts about dinosaurs, why do you think they disagree about this?" While pre-instructional responses tended to focus on "opinions" and "theories," post-instructional responses seemed to focus on "perspectives." Amber conveyed an informed view when she responded, "I think they disagree because everyone has different perspectives and different ideas." Rachel provided a similar response in saying, "I think they disagree because everyone has their own perspective and information that they have previously learned." Whitney also believed scientists might disagree, "Because they look at different perspectives of the situation." While Aiyana again mentioned the Bible as a reason that scientists might disagree, she also acknowledged that, "Different scientists have different hypotheses," which was considered to be an adequate view. Only Bethany retained her inadequate view by stating, "Maybe they are guessing."

Social and Cultural Embeddedness

During the pre-instructional assessment, Cathy was able to convey an adequate view when she acknowledged that there was "probably" a relationship between science, society, and cultural values. While Cathy was not shown to improve her view during the post-instructional assessment, she was shown to retain her adequate understanding. When speaking in respect to science and religion, Cathy stated, "There are people that believe in both, or one or the other, but there can be a relationship between them." As with her pre-instructional view, Cathy recognized a connection but failed to express that a scientist's work may be affected or influenced by their personal beliefs.

As the younger students did not answer questions on the *VNOS – Form D* pertaining to social and cultural embeddedness, results regarding this aspect were lacking. However, certain students did recognize that being a member of the blind community would cause them to focus on different things, or find importance in different things, than a sighted scientist might. For example, Meiling explained on an exit slip that, "Sighted people use their eyes and blind people use their hands." Rachel commented during Lesson #4 that blind people might be able to catch details that a sighted person would miss. Her statement was as follows:

> I wanted to say that blind, sometimes blind people, when they feel something, it takes them longer to feel it than people who see it. So, they, the people who look at it with their eyes, they might see it, but they won't go into as much detail as we might, because we can feel it. We feel it for longer and they're just glancing at it.

David also explained during Lesson #4 that while blind people might view things differently than sighted people, tactile experiences could also be used to gain common ground. He explained when making observations:

> But [blind people] could also feel it, so like, they could also, like, run their hand down the outline of it. So, they could probably, they might get the same idea as the sighted people…Sighted people don't use their fingers all the time. So, like, blind people could like feel the roughness of the inside [of an object].

The students' comments indicated their belief that blind people could be valuable contributors to the field of science by noticing things that sighted people might miss.

Theories and Laws

While Cathy was unable to exhibit an informed understanding of the differences between theories and laws, she was able to convey an adequate understanding which was an improvement over her inadequate pre-instructional view. Even though Cathy was unable to make a direct connection with the role that inferences play in the construction of theories, she was able to recognize that theories may change. She stated, “Theory is something that is maybe a possibility or something that is unknown and changing.” In addition, Cathy failed to convey that scientific laws are based upon observations and repeatable experimentation. However, she was able to recognize that, “Law is probably more structured and not many guesses.” She also noted on an exit slip:

> Not every experiment can be figured out. Sometimes it’s harder to figure out what is going on within the experiment they are doing or the information they are figuring out. Either because it’s dangerous or it’s not possible to see what is going on.

As with social and cultural embeddedness, the younger students did not answer questions on the *VNOS – Form D* pertaining to theories and laws. Therefore, results regarding the students’ understandings of theories and laws are lacking. While the younger group of students did not articulate the difference between theories and laws, they made several related comments on their Week 5 exit slips. In regard to models, David wrote on his exit slip, “You can’t look inside, but you have to learn to inference what is inside or how it’s made.” Laila had a similar response in noting, “You can make a guess, and your guess can be correct or incorrect.” Whitney exhibited her understanding of the need for models in noting, “We can’t always look at phenomenon in nature.” Meiling and Rachel both exhibited their understandings that models may not be an exact replica of the real thing when they noted, respectively, “That models aren’t always correct copies of what you’re trying to do,” and “That scientists will never know with certainty that their models are correct.”

On Week 6 exit slips, five students exhibited an understanding that patterns are used in science. David noted that, “Scientists can watch for patterns in weather,” while Whitney simply stated, “That patterns are regularly used in science.” Meiling noted her understanding that “…scientists use patterns to find new information and make inferences about the weather, for example.” In addition, Rachel exhibited an understanding that science can sometimes be complex when noting, “Patterns are easy to hide…[and] hard to figure out.”

Chapter Summary

This chapter provided an overview of results from data collected throughout the course of an action research study, during which blind and low vision students received explicit-reflective NOS instruction by participating in a six-week, online, Saturday science program. Results presented are a representation of student answers provided on pre- and post-instructional *VNOS* questionnaires, as well as qualitative data obtained from weekly exit slips, semi-structured interviews, students’ verbal commentary, and notes made within the instructor-researcher’s teaching journal. All data were analyzed to provide a wholistic representation of students’ pre- and post-instructional views on NOS, as well as the effectiveness of the instructor-researcher’s explicit-reflective NOS instruction. Combined results were then utilized to answer the research question for this study which was, “How does my online explicit-reflective instruction impact visually impaired students’ conceptions of NOS?”

In Chapter Five, an overall summary of results has been presented, followed by implications of the study, limitations and benefits of the study, as well as suggestions for future research.

CHAPTER V: DISCUSSION AND CONCLUSION

The primary purpose of this action research study was to identify ways that educators can provide blind and low vision students with more equitable opportunities within the science classroom to better comprehend NOS concepts. As stated in the introductory chapter of this dissertation, several NOS studies have been conducted in the past, but none had ever addressed how blind and low vision students might conceptualize the NOS. Therefore, this study aimed to bridge the gap in previous research by using a convenience sampling method (Stratton, 2021) in order to recruit blind and low vision students to participate in a six-week, online, Saturday science program where they received explicit-reflective NOS instruction (Akerson & Donnelly, 2010; Akerson et al., 2011). An emancipatory action research methodology was employed (Abels, 2015), while attempting to make science more meaningful to visually impaired students based upon a theoretical framework of ethics and equity with the underpinnings of egalitarian principles (De Coster & Loots, 2004). Therefore, with the above goals in mind, the following research question guided this study:

Research Question: How does my online explicit-reflective instruction impact visually impaired students' conceptions of NOS?

In efforts to answer the research question posed above, data were collected from nine visually impaired students recruited from across the United States who completed the six-week, online, Saturday science program, as well as the instructor-researcher who designed and led each weekly science session. Qualitative data were obtained over the course of the six-week science program from a variety of sources, including student responses on pre- and post-instructional *VNOS* questionnaires, weekly exit slips, semi-structured interviews, verbal commentary of the study participants, and the instructor-researcher's teaching journal. Answers provided on *VNOS* questionnaires were coded as "inadequate," "adequate," or "informed," as seen in the coding schemes presented by Akerson and Donnelly (2010) and Akerson et al. (2014). Thematic analysis was employed to analyze all other sources of qualitative data (Clarke & Braun, 2017).

Results of this study showed that online explicit-reflective instruction, along with tactile NOS activities, enabled blind and low vision students to improve their views on the creative, empirical, subjective, and tentative aspects of NOS over the course of the six-week period, as well as being able to distinguish between the scientific processes of observation and inference. Therefore, this study should be viewed as an initial foundation on which to build future studies that explore ways in which educators can assist blind and low vision students in building and improving their conceptions of NOS.

Chapter Summary

In this chapter, a summary of overall results has been presented followed by a discussion of how these results relate to past NOS research, as well as the research question that guided this study. Implications for educators are addressed, as well as perceived limitations and benefits identified within this study. Remarks that highlight the results of this study are presented along with insight into possibilities for future research concerning visually impaired students and their conceptions of NOS. This chapter ends with a conclusive summary of the dissertation.

Summary of Results

In this study, explicit-reflective online instruction, paired with tactile NOS activities, was found to positively affect visually impaired students' conceptions of the NOS. Prior to receiving any NOS instruction, the research participants, as a whole, were shown to hold a variety of inadequate views on NOS. This was particularly true for the tentative and creative aspects of NOS, as students believed that scientists were typically "sure" or "certain" when coming to their conclusions and were unable to utilize imagination or creativity because they needed to rely on factual information. In regard to the empirical aspect of NOS, pre-instructional data showed that some students lacked an understanding that observations and experimentation were used in the scientific process. An initial lack of understanding was also seen as it pertained to observation verses inference, as students were unable to decipher between the two. Additional misconceptions were exhibited in regard to the subjective aspect of NOS, as students failed to realize that past experiences and personal beliefs could help someone offer a different perspective in order to more accurately translate scientific data. While pre-instructional data were not attainable from younger students in regard to theories and laws, data obtained from a high school student exhibited an inability to accurately articulate a difference between the two.

After having received explicit-reflective NOS instruction, data showed an improvement in students' overall views on NOS over the course of the six-week science program. A marked improvement was seen in the students' views on the tentative and creative aspects of NOS, with students exhibiting a post-instructional understanding that science can change with new information, and that creativity is used in the process. Students also exhibited an improvement in their ability to correctly articulate the difference between an observation and an inference. Furthermore, improvements were seen in regard to the empirical and subjective aspects of NOS, as students were able to recognize that science is based upon observations and experiments, and that someone may be able to offer a different perspective based upon past experiences. While the *VNOS-Form D* did not pose questions targeting theories and laws or social and cultural embeddedness, student commentary was indicative of students' understandings that patterns could be used in the process of making scientific inferences, and models may not be an exact representation of the natural phenomena that they are meant to represent. Commentary also indicated that students were aware that their identity within the blind community allowed them to offer a different outlook or perspective from someone who is sighted.

While suggestions on exit slips were lacking on how to improve the science lessons for visually impaired students, notes made within the instructor-researcher's teaching journal were indicative of various aspects of blind education that were not previously considered as a sighted educator. These realizations were brought to light each week, and in turn, revealed themes which the instructor-researcher utilized to provide clarification and improved learning opportunities for the study participants to comprehend NOS ideas. Overall, notes within the instructor-researcher's teaching journal highlighted the lack of incidental learning that blind and low vision students encounter, as well as the explicit instruction that is necessary in order to avoid confusion and to provide a complete understanding of the subject matter at hand. And, while visually impaired students are aware that they can offer a different perspective from someone who is sighted, they may rely on others to help them make connections based upon past experiences and familiarities, as opposed to visual and pictorial memories.

Discussion of Results

In the subsections that follow, I have first discussed the effectiveness of my online explicit-reflective NOS instruction as it was shown in this action research study. In addition, blind and low vision students' understandings of the various NOS aspects have been discussed independently in order to provide insight into how the results of this study align with the research question. Furthermore, this study's findings are compared with some of the findings from past research in order to provide a general understanding of how blind and low vision students' comprehension of NOS concepts might compare to those of sighted students who were also engaged in explicit-reflective NOS instruction. And lastly, I have reflected upon my own instructional methods and made recommendations for how to improve teaching strategies that might allow blind and low vision students to better comprehend NOS ideas.

Explicit-Reflective NOS Instruction

Throughout this study, online explicit-reflective instruction was utilized to introduce weekly NOS activities to visually impaired learners over the course of a six-week science program. Widely researched, explicit-reflective instruction targets all NOS aspects and helps students to reflect upon them, thus enabling an improvement in their overall comprehension of NOS (Bugingo et al., 2022; Schussler et al., 2013). In addition, students who are allowed the opportunity to participate in discussions and reflective activities have also been shown to improve their understandings of NOS concepts (Akerson et al., 2000; Bugingo et al., 2022).

Similar to the studies of Akerson et al. (2000) and Quigley et al. (2011), the explicit-reflective instruction utilized in this study was found to be an effective means of improving blind and low vision students' views on NOS. However, it should be noted that a great deal of time was spent in selecting NOS activities that required a low level of visual intensity and could be easily adapted for blind and low vision students. In addition, reflective discussions and weekly exit slips allowed the instructor-researcher to determine which concepts the students had a clear grasp on, as opposed to those that needed more clarification. Had the NOS activities not been appropriately adapted for tactile learners from their original format as proposed by Lederman and Abd-El-Khalick (1998), it is fair to assume that the online explicit-reflective instruction provided in this study would likely have been seen as far less beneficial for blind and low vision students. In the following paragraphs, the success of each adapted NOS activity has been discussed as they were employed to target the various aspects of NOS.

Empirical NOS

In this study, the empirical NOS was emphasized to students by allowing them to act as scientists during each weekly science session. Pre-instructional views showed that half of the students who completed the *VNOS-Form D* lacked an understanding that science involved observation and experimentation. However, post-instructional views exhibited students' knowledge that experimentation, observations, and inferences were used in the investigative process. None of the students who participated in this study mentioned science as a way to make improvements or to invent something new, as seen in the results of Quigley et al. (2011). With all things considered, this may be due to the difference in activities that were utilized in both studies. While the activities selected for this study focused heavily on observation and inference, none of them required the students to improve or create anything, as did the activities selected by Quigley et al. (2011). Although online explicit-reflective instruction was found to be beneficial in helping the students in this study to improve their overall understandings of the empirical NOS, it should be considered that some NOS activities may not be conducive to an online format, especially if it is required that group work be centered around a shared item. Nonetheless, it is worth noting that different NOS activities may well result in students' various understandings of the empirical NOS depending upon the procedures involved.

Tentative NOS

The tentative aspect of NOS was introduced to students during the second week of the science program through the *Real Fossils, Real Science* activity (Lederman and Abd-El-Khalick, 1998). Pre-instructional data showed that none of the students believed new information could lead to new ideas, and that scientists were "pretty sure" or "certain" when making their predictions. Post-instructional data indicated an improvement in these views, as students now exhibited an understanding that new information could lead to new ideas or result in different inferences being made. Post-instructional responses also showed students' understandings that scientists are “not completely certain” in regard to their predictions but do their best to make inferences based upon the evidence that they have at the time. These results appear to be similar to the findings of Akerson and Volrich (2006), where students exhibited an understanding that “new investigations” and “more evidence” could lead scientists to “change their minds” (p. 389).

Observation and Inference

The processes of observation and inference were emphasized to students during the first and second weeks of the science program by engaging them in the *Tricky Tracks!* activity and the *Real Fossils, Real Science* activity (Lederman & Abd-El-Khalick, 1998). Prior to receiving any explicit-reflective NOS instruction, none of the students in this study attempted to use the words, “observation” or “inference” within their pre-instructional answers on the *VNOS* questionnaires. However, during the second science session some of the students were able to recall the words, as well as provide a general definition or description of each. By week three, all of the students were attempting to utilize each of the words in their own interpretations of observations and inferences that were being made.

The instructor-researcher recognized that the process of observation poses several challenges for blind and low vision students, as they are unable to actively and continuously observe as a sighted individual would. Whereas a sighted child is readily able to observe places and things through the visual world around them, this is simply not a possibility for those children who have experienced vision loss. For example, a blind child is unable to observe or recall the scenery of places they have been, the pictures, charts, or graphs presented within textbooks, or the videography present in educational programming. Obviously, without proper observations it is nearly impossible to make an appropriate inference. Therefore, it is imperative that blind and low vision students be given adequate time to explore science materials through tactile observations, when safely able to do so. In addition, this study showed that others who have shared past experiences with blind and low vision students are actively able to help them make connections to scientific subject matter. Teachers can help make these connections by reminding blind students of experiences or objects encountered during class field trips, or through tactile items presented in class.

Creative NOS

The creative aspect of NOS was introduced to students during the second week of the science program by engaging them in the *Real Fossils, Real Science* activity (Lederman & Abd-El-Khalick, 1998). Pre-instructional data exhibited students' initial beliefs that scientists were unable to be creative due to the necessity of relying on factual information. In addition, students failed to recognize that creativity and imagination could be used to invent new technology or create something new. However, post-instructional views showed students' improved understandings that creativity can be used when formulating a hypothesis, making an inference, or constructing certain items, such as dinosaur skeletons.

While completing the *Real Fossils, Real Science* activity (Lederman & Abd-El-Khalick, 1998), students expressed their enjoyment of being able to utilize their own creativity and imagination in the building process. As all of the students appeared to enjoy this activity, and found it to be "fun," it should be noted that the adapted tactile NOS activities utilized during this study proved to be an ideal way to actively engage blind and low vision students in scientific subject matter, even when using an online format.

Subjective NOS

The subjective aspect of NOS was emphasized to students during the third and fourth weeks of the science program by engaging them in the *That's Part of Life!* activity as well as the

Young? Old? activity (Lederman & Abd-El-Khalick, 1998). Pre-instructional views on the subjective aspect of NOS showed that students failed to recognize that personal knowledge or beliefs might cause scientists to disagree when presented with the same facts. However, post-instructional data exhibited students' understandings that scientists might disagree because they are all looking at the same information from a different perspective. As in previous activities, the *That's Part of Life!* activity brought to light the importance of past experiences in helping blind and low vision students make sense of scientific subject matter. While visually impaired students miss out on opportunities of incidental learning in the world around them, it is imperative that others provide assistance in making sense of objects or data so that observations can be made within the proper context and that reasonable inferences can be produced.

Social and Cultural Embeddedness

Social and cultural embeddedness was emphasized to students during the third and fourth weeks of the science program by engaging them in the *That's Part of Life!* activity as well as the *Young? Old?* activity (Lederman & Abd-El-Khalick, 1998). While pre-instructional data for the oldest student in the group showed an adequate understanding, they exhibited an inability to recognize that a scientist's culture and society may influence their research and work. However, post-instructional data did show that this student was able to recognize that there was likely a connection between science and religion. A similar connection was made by a fifth-grade student as well, who referenced the Bible as a reason that scientists might view things differently. Nevertheless, the study participants were able to recognize that as members of the blind community, they may view things differently than sighted individuals would. Data collected regarding this tenet of NOS was insufficient to determine if the study participants, as a whole, were able to improve their views pertaining to social and cultural embeddedness.

Theories and Laws

Theories and laws were emphasized to students during the fifth and sixth weeks of the science program by engaging them in *The Tube* and *The Cube*, which are both considered to be Black Box Activities (Lederman & Abd-El-Khalick, 1998). As the *VNOS-Form D* does not pose questions which target theories and laws, pre-instructional data for participants in grades 2 – 6 were not obtainable. However, pre-instructional views held by a participant in grade 12 showed an inadequate understanding of how theories and laws differed from one another. While post-instructional data showed that this student was able to improve their views on theories and laws to an adequate understanding, answers provided appeared to be hedged with uncertainty as the student used words such as “maybe” and “probably” when describing theories and laws.

Concepts surrounding theories and laws appeared to be difficult for the students to grasp. While students were easily able to gain an understanding of observations, inferences, and the tentative aspect of NOS, all students struggled to understand phenomena. Nonetheless, students were able to recognize through *The Tube* activity that scientific models are not exact replicas of the items they are meant to represent (Lederman & Abd-El-Khalick, 1998). In addition, *The Cube Activity* helped students understand how patterns can be used when making inferences (Lederman & Abd-El-Khalick, 1998), particularly when predicting the weather. Had time allowed, an additional class session could have been used to more effectively connect these concepts and assist students in distinguishing between theories and laws.

Instructor’s Reflections and Recommendations

When reflecting upon the teaching strategies utilized within this study, I was generally pleased with the results that were produced. As students were shown to improve their overall views on observation and inference, as well as the tentative, creative, empirical, and subjective aspects of NOS, between pre- and post-instructional assessments, it is fair to say that the explicit-reflective instruction provided in this action research study was both appropriate and beneficial in nature. This is supportive of past research conducted by Akerson et al. (2000) and Quigley et al. (2011), which also found explicit-reflective instruction to be beneficial in improving students' views on various NOS aspects. In addition, the NOS activities selected from Lederman and Abd-El-Khalick's (1998) proposed activities proved to be easily adaptable for blind and low vision students to readily participate in the science sessions, just as any sighted child would.

As noted in the discussions above, it is important to consider that not all NOS activities may be suitable for an online learning environment, especially if group work is to be involved. In this study, Lederman and Abd-El-Khalick's (1998) *Young? Old?* activity seemed to be the most challenging activity for students to decipher due to the singular texture that was utilized in the adaptation process. Therefore, it is recommended that multiple textures be employed that mimic the true representation of the item(s) being portrayed (e.g., feathers for a duck and fur for a rabbit). However, as noted in the implications below, time and cost may be limiting factors in the adaptation process. Therefore, these items of consideration should be addressed when selecting NOS activities to adapt for blind and low vision students.

When examining the students' understandings of theories and laws, as well as social and cultural embeddedness, less progress was made when compared to the students' understandings of other NOS tenets. In this regard, the results of this study differed from those of Johnston and Akerson (2022), who noted "substantial improvements" in high school students' comprehension of social and cultural embeddedness and "substantial growth" in high school students' comprehension of theories and laws (p. 50). Reasons for this may be twofold. First, a majority of the students recruited for this study were in grades 2 – 6 and therefore, completed the *VNOS* –

Form D which did not target questions pertaining to social and cultural embeddedness or theories and laws. As a result, it was difficult to obtain a true representation of these students' views on these aspects. Second, may have been the way in which I presented the information. As noted above, the *Young? Old?* activity (Lederman & Abd-El-Khalick, 1998) was difficult for students to grasp due to the texture utilized, and *That's Part of Life!* (Lederman & Abd-El-Khalick, 1998) proved to be similar in difficulty due to students' inexperience in doing the laundry, which was the main topic of the activity. As our high school student in this study was not shown improve their views on the social and cultural embeddedness of NOS, it is fair to say that improvements could have been made in regard to my delivery of information.

While *The Tube* and *The Cube Activity* (Lederman & Abd-El-Khlaick, 1998) allowed students to improve their knowledge in regard to phenomena, scientific models, and the use of patterns when making predictions, there was no indication that student participants in grades 2 – 6 made any improvements in their understandings of theories and laws. Only the senior student in this research study was able to improve their views on theories and laws by being able to explain that theories are likely to change, while laws are "more structured." Again, it may be a fair assumption to say that improvements could have been made to my method of delivery.

Although the activities employed within this action research study to target social and cultural embeddedness and theories and laws provided students with valuable insight, it is recommended that future research and teaching make adjustments to the methodology and/or interventions utilized in this study. For instance, the six-week timeframe scheduled for this study was a relatively short amount of time to cover seven NOS aspects. Therefore, I would recommend that additional time be allotted to cover all seven NOS aspects, or certain NOS aspects be eliminated from the activity schedule. In addition, the age and grade level of study participants were unknown when designing this study. Therefore, the activities selected for this study were intended to accommodate students of various ages in grades K – 12. Although combining elementary students with a high school student was successful in this study, I would recommend that future efforts focus on separating students by grade level (e.g., grades K – 6 and grades 7 – 12) in order to more readily make age-appropriate connections to the various NOS aspects.

Overall, I believe the online classroom utilized in this study proved to be a beneficial environment for blind and low vision students to improve their views on NOS. Similar to the work of Shea and Sandoval (2020), I believe the students in this study were given a safe space to explore science in meaningful ways while receiving positive affirmation in the process. While I acknowledge that some activities were more successful than others in building the students' conceptions of NOS, positive strides were made and students had fun in the process.

Implications

Based upon these results, this study has implications for practitioners and their education of blind and low vision students. While this is the first known study to investigate visually impaired students' conceptions of NOS, results of this study suggest that educators can successfully utilize strategies of online explicit-reflective instruction to assist blind and low vision students in improving their views on NOS. Although this study offered a unique opportunity for blind and low vision students to learn about NOS aspects, which were specifically targeted within an informal online setting, it could be assumed that the same teaching strategies may well be employed within a formal educational classroom. While teachers may hold preconceived notions and misconceptions pertaining to the inclusion of blind and low vision students (Miyauchi, 2020), these issues can be ameliorated through professional development opportunities that focus on inclusive education (Unianu, 2012). Although it is reasonable to assume that not every teacher will have experience working with visually impaired students, active collaboration with a highly qualified TVI and a certified transcriptionist can help to ensure that equitable opportunities to learn NOS concepts are made available to visually impaired students through accessible classroom learning materials that are tactile in nature.

While this study showed that online explicit-reflective instruction paired with activity-based learning within a supportive and encouraging environment had a positive impact on blind and low vision students' views on NOS, time and cost should be considered when adapting the NOS activities. As Lederman and Abd-El-Khalick's (1998) original *Tricky Tracks!* and *That's Part of Life!* activities were particularly time-intensive to adapt for blind and low vision students, they may not be practical to reproduce for large numbers of students at a given time. While the adaptations of activities made within this study should be viewed as prototypes, it is also worth noting that they were made with frugality in mind for a smaller group of students. Tools such as a braille embosser, swell paper, and a fuser may help to avoid excess time in reproduction; however, the cost of such items may not be economically feasible for all educators.

Of course, students rely on educators to deliver classroom activities in an accessible format regardless of cost. Therefore, collaborative efforts between the student, their parents, and the student's teacher can help to ensure that the student's educational needs are met and that they are able to make appropriate connections to the educational topics at hand. As past research has shown blind students to comprise sixty percent of those students who drop out of school (Boza-Chua et al., 2021), it is imperative that all parties involved be legally aware of the federal educational and civil rights laws surrounding blind students to see to it that the child is provided with appropriate resources to access the classroom materials. While this study in no way suggests that informal educational opportunities should be used as a substitution or replacement for one's formal science education, it does suggest that informal learning opportunities can be used to enhance or supplement a visually impaired child's formal education to learn NOS concepts in a beneficial way.

Limitations and Benefits

While this study aimed to fill a gap in the research by investigating how online explicit-reflective instruction impacted blind and low vision students' conceptions of NOS, several limitations were recognized. As noted earlier, the results of this study are only indicative of the nine visually impaired students who completed the six-week science program. While the study participants were meant to provide a general representation of the blind and low vision community, in no way should they be viewed as all-encompassing of that community. This study did not consider degree and duration of visual impairment, nor did it consider added measures of academic achievement or ability levels as they pertained to students' secondary or tertiary disabilities. In addition, this study did not consider additional contributing factors such as race, culture, ethnicity, gender, or socioeconomic status of the students' families. Additional limitations were perceived in relation to the context of this study, as the science sessions were held in an informal educational setting, utilizing an online format, over a six-week period. It is reasonable to assume that a formal, onsite classroom setting, with an in-person format, over a longer duration of time, may yield differing results.

Although several limitations were realized, benefits of this study were seen as well. For instance, this is the first known study to specifically address blind and low vision students and their conceptions of NOS. Therefore, this study should be seen as a starting point from which to design future studies that position and recognize blind and low vision individuals as capable and competent contributors to the field of science, both academically and professionally.

Suggestions for Future Research

As this was the first-of-its-kind study, there are many more questions to answer regarding visually impaired students and their conceptions of NOS. While the context of this study involved an informal, online setting, it would be interesting to investigate if results could be replicated within a formal onsite classroom. In addition, the sample size of this study was quite small with a total of nine students, all of which exhibited no other known disabilities. While their participation provided a valuable foundation on which to build, a larger sample size is needed in the future in order to assess blind and low vision students' understandings of NOS concepts according to grade level. Additional aspects that were not considered in the present study, such as gender, race, ability level, and socioeconomic status should also be considered in future research studies. As Ariyaratne (2023) explored chemists' views on NOS, it would be interesting to explore the NOS views of blind and low vision adults who are either enrolled in college STEM courses or employed within the various fields of STEM.

Although this study focused on the NOS views of visually impaired students within the United States, the recruitment process drew the attention of TVIs from as far as Ghana in West Africa. Their willingness and desire to connect and collaborate exhibits a need for similar studies on an international level, particularly in countries where blindness may be more prevalent, such as Asia and sub-Saharan Africa (Steinmetz et al., 2021). Whereas blindness is a low incidence disability (Hayden & Prince, 2023), certain challenges are presented in finding a large number of participants who are willing and able to participate in any given study. However, with an estimated 45 million blind people worldwide (Taylor, 2019), I believe future efforts are warranted in exploring the NOS views of blind and low vision populations to ensure that equitable and inclusive opportunities are provided for visually impaired people to engage in the sciences, both as students and as professionals.

Conclusion

In conclusion, NOS is a crucial component for comprehending the science curriculum and assisting students in making informed decisions pertaining to the scientific world around them (Akerson et al., 2014). Although the students who participated in this study should not be viewed as all-encompassing of the blind community, they were able to demonstrate how blind and low vision students can actively engage in the science curriculum and fully participate when provided with adapted learning materials that are tactile in nature. In addition, the students found science to be fun and were able to articulate ways in which they could provide valuable insight and different perspectives from that of someone who is sighted. With that said, it is concerning that blind and low vision individuals tend to avoid STEM-related educational and occupational opportunities (Supalo et al., 2014). As higher levels of educational achievement tend to ameliorate the increased levels of unemployment that blind individuals often face (Bell & Mino, 2013), it is imperative that blind and low vision students be provided with the appropriate tools to access the curriculum and succeed in the classroom.

While information pertaining to blind and low vision students' understandings of NOS concepts appears to be absent from previous research, and more work has yet to be done, results of this study showed that online explicit-reflective NOS instruction was found to have a positive impact on visually impaired students' conceptions of NOS ideas. Although blind and low vision students are faced with a lack of incidental learning, explicit-reflective instruction paired with tactile NOS activities and accessible classroom materials can help bridge this gap. In addition, assisting blind and low vision students in making connections based upon past experiences and familiarities can help them make sense of scientific subject matter. As blind and low vision students see themselves as capable contributors with valuable insight, it is imperative that they be provided with inclusive and equitable opportunities to understand NOS concepts and be encouraged to contribute to the fields of science in meaningful ways.

REFERENCES

Abels, S. (2015). Implementing inquiry-based science education to foster emotional engagement of special-needs students. In M. Kahveci & M. Orgill (Eds.), *Affective Dimensions in Chemistry Education* (pp. 107-131). Berlin: Springer.

Akerson, V. L., & Abd-El-Khalick, F. S. (2005). "How should I know what scientists do?—I am just a kid": Fourth-grade students' conceptions of nature of science. *Journal of Elementary Science Education, 17*(1), 1-11. https://doi.org/10.1007/BF03174669

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295–317. https://doi.org/10.1002/(SICI)1098-2736(200004)37:4<295::AID-TEA2>3.0.CO;2-2

Akerson, V. L., Buck, G. A., Donnelly, L. A., Nargund-Joshi, V., & Weiland, I. S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology, 20*, 537-549. https://doi.org/10.1007/s10956-011-9312-5

Akerson, V. L. & Carter, I. S. (Eds.). (2022). *Teaching nature of science across contexts and grade levels: Explorations through action research and self study.* ISTES Organization.

Akerson, V. L., Carter, I., Pongsanon, K., & Nargund-Joshi, V. (2019a). Teaching and learning nature of science in elementary classrooms: Research-based strategies for practical implementation. *Science & Education, 28*, 391-411. https://doi.org/10.1007/s11191-019-00045-1

Akerson, V., & Donnelly, L. A. (2010). Teaching Nature of Science to K-2 Students: What understandings can they attain? *International Journal of Science Education*, *32*(1), 97-124. https://doi.org/10.1080/09500690902717283

Akerson, V. L., Elcan Kaynak, N., & Avsar Erumit, B. (2019b). Development of third graders' identities as "persons who understand nature of science" through a gravity unit. *International Journal of Research in Education and Science*, *5*(2), 450-456. https://files.eric.ed.gov/fulltext/EJ1203845.pdf

Akerson, V., Nargund-Joshi, V., Weiland, I., Pongsanon, K., & Avsar, B. (2014). What third-grade students of differing ability levels learn about nature of science after a year of instruction. *International Journal of Science Education*, *36*(2), 244-276. https://dx.doi.org/10.1080/09500693.2012.761365

Akerson, V. L., & Volrich, M. L. (2006). Teaching nature of science explicitly in a first-grade internship setting. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *43*(4), 377-394. https://doi.org/10.1002/tea.20132

Alase, A. (2017). The interpretative phenomenological analysis (IPA): A guide to a good qualitative research approach. *International Journal of Education and Literacy Studies*, *5*(2), 9-19.

Alice Cogswell and Anne Sullivan Macy Act, S. 2945, 118th Cong. (2023-2024). https://www.congress.gov/bill/118th-congress/senate-bill/2945

Allman, C. (2009). *Making tests accessible for students with visual impairments: A guide for test publishers, test developers, and state assessment personnel.* (4th ed.). Louisville, KY: American Printing House for the Blind, Inc.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Americans with Disabilities Act of 1990, 42 U.S.C. §§ 12101 *et seq.* (1990).

Andersson, K., & Gullberg, A. (2014). What is science in preschool and what do teachers have to know to empower children?. *Cultural Studies of Science Education*, *9*(2), 275-296. https://doi.org/10.1007/s11422-012-9439-6

Ariyaratne, T. (2023). *Comparing chemists' views of the nature of science (NOS) with their levels of research expertise* (Publication No. 30531018) [Doctoral Dissertation, Indiana University Bloomington]. ProQuest Dissertations and Theses Global.

Avramidis, E., & Kalyva, E. (2007). The influence of teaching experience and professional development on Greek teachers' attitudes towards inclusion. *European Journal of Special Needs Education*, *22*(4), 367-389. https://doi.org/10.1080/08856250701649989

Avramidis, E., & Norwich, B. (2002). Teachers' attitudes towards integration/inclusion: A review of the literature. *European Journal of Special Needs Education*, *17*(2), 129-147. https://doi.org/10.1080/08856250210129056

Ayala-Villamil, L. A., & García-Martínez, Á. (2020). VNOS: A historical review of an instrument on the nature of science. *Interdisciplinary Journal of Environmental and Science Education*, *17*(2), e2238. https://doi.org/10.21601/ijese/9340

Beck-Winchatz, B. & Riccobono, M. A. (2008). Advancing participation of blind students in science, technology, engineering, and math. *Advances in Space Research*, *42*(11), 1855-1858. https://doi.org/10.1016/j.asr.2007.05.080

Beede, D. N., Julian, T. A., Langdon, D., McKittrick, G., Khan, B., & Doms, M. E. (2011). Women in STEM: A gender gap to innovation. *Economics and Statistics Administration*

Issue Brief, (04-11).

Bell, E. C., & Mino, N. M. (2013). Blind and visually impaired adult rehabilitation and employment survey: Final results. *Journal of blindness Innovation and Research*, *3*(1), 1-35.

New International Version Bible. (2011). Biblica, Inc.

Bjønness, B., & Johansen, G. (2014). Bridging the gap between teaching and research on science inquiry: Reflections based on two action research projects. *Action Researcher in Education*, *5*(1), 6-35.

Bloom, M., Binns, I. C., & Koehler, C. (2015). Multifaceted NOS instruction: Contextualizing nature of science with documentary films. *International Journal of Environmental and Science Education*, *10*(3), 405-428.

Boza-Chua, A., Gabriel-Gonzales, K., & Andrade-Arenas, L. (2021). Inclusive education: implementation of a mobile application for blind students. *International Journal of Advanced Computer Science and Applications*, *12*(11), 785-795.

Braaten, M., & Sheth, M. (2017). Tensions teaching science for equity: Lessons learned from the case of Ms. Dawson. *Science Education*, *101*(1), 134-164. https://doi.org/10.1002/sce.21254

Broderick, A., & Lalvani, P. (2017). Dysconscious ableism: Toward a liberatory praxis in teacher education. *International Journal of Inclusive Education*, *21*(9), 894-905. https://doi.org/10.1080/13603116.2017.1296034

Bualar, T. (2018). Barriers to inclusive higher education in Thailand: Voices of blind students. *Asia Pacific Education Review*, *19*, 469-477. https://doi.org/10.1007/s12564-017-9512-7

Bugingo, B. B., Yadav, L. L., Mugisha, I. S., and Mashood, K. K. (2022). Improving teachers' and students' views on nature of science through active instructional approaches: A review of the literature. *Science and Education*. https://doi.org/10.1007/s11191-022-00382-8

Carlson, J. A. (2010). Avoiding traps in member checking. *Qualitative Report*, *15*(5), 1102-1113.

Case, B. J., Zucker, S., & Jeffries, J. L. (2005). *Harcourt assessment report: A primer on assessing the visually impaired.* Harcourt Assessment, Inc. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=32c3d07868348d43be6d40ddf8df3c28889046d5

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology*, *12*(3), 297-298. https://doi.org/10.1080/17439760.2016.1262613

Cofré, H., Cuevas, E., & Becerra, B. (2017). The relationship between biology teachers' understanding of the nature of science and the understanding and acceptance of the theory of evolution. *International Journal of Science Education*, *39*(16), 2243-2260. https://doi.org/10.1080/09500693.2017.1373410

Cook, K. L., & Buck, G. A. (2013). Pre-service teachers' understanding of the nature of science through socio-scientific inquiry. *The Electronic Journal for Research in Science & Mathematics Education*, *17*(1). https://files.eric.ed.gov/fulltext/EJ1188474.pdf

Crockett, J. B., & Yell, M. L. (2017). *IEPs, least restrictive environment, and placement.* In E. Shaver & J. Decker (Eds.), A Guide to Special Education Law. (pp. 65-98). Cleveland, OH: Education Law Association.

Decker, J., & Brady, K. (2015). Increasing school employees' special education legal literacy. *Journal of School Public Relations*, *36*(3), 231-259. https://doi.org/10.3138/jspr.36.3.231

Decker, J. R., Ober, P. D., & Schimmel, D. M. (2019). The attitudinal and behavioral impact of school law courses. *Journal of Research on Leadership Education, 14*(2), 160-185. https://doi.org/10.1177/1942775117742647

Decker, J. R., & Shaver, E. A. (2017). *Introduction: Special education legal literacy.* In E. Shaver & J. Decker (Eds.), A Guide to Special Education Law. (pp. 1-8). Cleveland, OH: Education Law Association.

De Coster, K., & Loots, G. (2004). Somewhere in between touch and vision: In search of a meaningful art education for blind individuals. *International Journal of Art & Design Education*, *23*(3), 326-334. https://doi.org/10.1111/j.1476-8070.2004.00411.x

Devetak, I., Glažar, S. A., & Vogrinc, J. (2010). The role of qualitative research in science education. *Eurasia Journal of Mathematics, Science and Technology Education*, *6*(1), 77-84. https://doi.org/10.12973/ejmste/75229

Dinnesen, M. S., & Kroeger, S. D. (2018). Toward Active Partnership: Notice of Procedural Safeguards Designed for Parent Use. *Journal of Disability Policy Studies, 29*(1), 54-64. https://doi.org/10.1177/1044207317751674

Donohue, D. K., & Bornman, J. (2015). South African teachers' attitudes toward the inclusion of learners with different abilities in mainstream classrooms. *International Journal of Disability, Development and Education*, *62*(1), 42-59. https://doi.org/10.1080/1034912X.2014.985638

Dragoo, K. E. (2020). *The Individuals with Disabilities Education Act: A comparison of state eligibility criteria.* Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R46566/4

Dunn, D. S., & Andrews, E. E. (2015). Person-first and identity-first language: Developing psychologists' cultural competence using disability language. *American*

Psychologist, *70*(3), 255. https://psycnet.apa.org/doi/10.1037/a0038636

Dymond, S. K., Renzaglia, A., Rosenstein, A., Chun, E. J., Banks, R. A., Niswander, V., & Gilson, C. L. (2006). Using a participatory action research approach to create a universally designed inclusive high school science course: A case study. *Research and Practice for Persons with Severe Disabilities*, *31*(4), 293-308. https://doi.org/10.1177/154079690603100403

Elkhart Community Schools. (2016). Special education: Eligibility, code po2461.07. BoardDocs. https://go.boarddocs.com/in/elkh/Board.nsf/Public#

Elkhart Community Schools. (2016). Animals on school corporation property, code po8390. BoardDocs. https://go.boarddocs.com/in/elkh/Board.nsf/Public#

Elliott, J. (1994). Research on teachers' knowledge and action research. *Educational Action Research*, *2*(1), 133-137.

Eloff, I., & Kgwete, L. K. (2007). South African teachers' voices on support in inclusive education. *Childhood Education*, *83*(6), 351-355. https://doi.org/10.1080/00094056.2007.10522949

Estes, M. B. (2003). Zero reject and school choice: Students with disabilities in Texas’ charter schools. *Leadership and Policy in Schools*, *2*(3), 213-235. https://doi.org/10.1076/lpos.2.3.213.16532

Every Student Succeeds Act (ESSA), 20 U.S.C. § 6301 (2015).

Faldet, A. C., & Nes, K. (2021). Valuing vulnerable children’s voices in educational research. *International Journal of Inclusive Education*, *28*(5), 657–672. https://doi.org/10.1080/13603116.2021.1956602

Farnsworth, C. R., & Luckner, J. L. (2008). The impact of assistive technology on curriculum accommodation for a braille-reading student. *RE: view*, *39*(4), 171.

Fensham, P. J. (1985). Science for all: A reflective essay. *Journal of Curriculum Studies*, *17*(4), 415-435.

Girnus, A. C. (2018, September 5). *Lack of resources for blind youth can lead to gaps that last a lifetime*. Nevada Current. https://www.nevadacurrent.com/2018/09/05/lack-of- resources-for-blind-youth-can-lead-to-gaps-that-last-a-lifetime/

Harrison-Bernard, L. M., Augustus-Wallace, A. C., Souza-Smith, F. M., Tsien, F., Casey, G. P., & Gunaldo, T. P. (2020). Knowledge gains in a professional development workshop on diversity, equity, inclusion, and implicit bias in academia. *Advances in Physiology Education*, *44*(3), 286-294. https://doi.org/10.1152/advan.00164.2019

Hay, J. F., Smit, J., & Paulsen, M. (2001). Teacher preparedness for inclusive education. *South African Journal of Education*, *21*(4), 213-218. file:///C:/Users/User/Downloads/24905-Article%20Text-31563-1-10-20060630.pdf

Hayden, H. E., & Prince, A. M. (2023). Disrupting ableism: Strengths-based representations of disability in children’s picture books. *Journal of Early Childhood Literacy*, *23*(2), 236-261. https://doi.org/10.1177/1468798420981751

Heale, R., & Forbes, D. (2013). Understanding triangulation in research. *Evidence-based nursing*, *16*(4), 98-98. https://doi.org/10.1136/eb-2013-101494

Hehir, T. (2002). Eliminating ableism in education. *Harvard educational review*, *72*(1), 1-33. https://doi.org/10.17763/haer.72.1.03866528702g2105

Hehir, T. (2007). Confronting ableism. *Educational Leadership*, *64*(5), 8-14. https://www.learntechlib.org/p/99685/

Hess, F. M., & Meeks, O. (2010). *School boards circa 2010: Governance in the accountability* *era.* Thomas B. Fordham Institute.

Ìdin, S., & Dönmez, I. (2017). The views of Turkish science teachers about gender equity within science education. *Science Education International*, *28*(2). https://doi.org/10.33828/sei.v28.i2.4

Indiana Code §§ 20-35-9-1 *et seq.* (2023).

Indiana State Board of Education, Title 511, Ind. Admin. Code 7-41-2 (2020).

Individuals with Disabilities Education Act, 20 U.S.C. §§ 1400 *et seq.*, 34 C.F.R. §§ 300 *et seq.* (2004).

Johnston, M. F., & Akerson, V. L. (2022). Nature of Science in an NGSS Chemistry Classroom. In V. L. Akerson & I. S. Carter (Eds.), *Teaching nature of science across contexts and grade levels: Explorations through action research and self study.* (pp. 25-68). ISTES Organization.

Kinsella, E. A. (2006, May). Hermeneutics and critical hermeneutics: Exploring possibilities within the art of interpretation. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 7, No. 3). https://doi.org/10.17169/fqs-7.3.145

Klimentyeva, V., Klimentyev, D., Pashneva, S., Umerenkova, A., & Fedorova, D. (2021). Impact of inclusive education on improving the quality of life of totally blind students. *SHS Web of Conferences*, *98*, 1-6. https://doi.org/10.1051/shsconf/20219802013

Koenig, A. J., & Holbrook, M. C. (2000). Ensuring high-quality instruction for students in braille literacy programs. *Journal of Visual Impairment & Blindness*, *94*(11), 677-694. https://doi.org/10.1177/0145482X0009401102

Lalvani, P., & Broderick, A. A. (2013). Institutionalized ableism and the misguided “Disability Awareness Day”: Transformative pedagogies for teacher education. *Equity & Excellence* *in Education*, *46*(4), 468-483. https://doi.org/10.1080/10665684.2013.838484

Laudonia, I., Mamlok-Naaman, R., Abels, S., & Eilks, I. (2018). Action research in science education–An analytical review of the literature. *Educational Action Research*, *26*(3), 480-495. https://doi.org/10.1080/09650792.2017.1358198

Lederman, N. G. (1992). Students’ and teachers’ conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, *29*(4), 331-359. https://doi.org/10.1002/tea.3660290404

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(8), 916-929. https://doi.org/10.1002/(SICI)1098-2736(199910)36:8<916::AID-TEA2>3.0CO;2-A

Lederman, N. G. (2006, June). Research on nature of science: Reflections on the past, anticipations of the future. In *Asia-Pacific forum on science learning and teaching* (Vol. 7, No. 1, pp. 1-11). The Education University of Hong Kong, Department of Science and Environmental Studies.

Lederman, N. G. (2010). Nature of science: Past, present, and future. In S. K. Abell and N. G. Lederman (Eds.), *Handbook of research on science education*. (pp. 831-880). Mahweh, NJ: Erlbaum.

Lederman, N. G. (2013). Nature of science: Past, present, and future. In *Handbook of research on science education* (pp. 831-879). Routledge.

Lederman, N., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. F. McComas (Ed.), *The Nature of*

Science in Science Education: Rationales and Strategies (pp. 83-126). Dordrecht: Springer Netherlands.

Lederman, J. S., & Khishfe, R. (2002). Views of nature of science, Form D. *Unpublished paper. Illinois Institute of Technology, Chicago, IL.*

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science, and Technology, 1*(3), 138-147. https://files.eric.ed.gov/fulltext/ED543992.pdf

Lee, S. Y. & Mesfin, F. B. (2017). Blindness. In: StatPearls. StatPearls Publishing, Treasure Island, FL.

Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues*, *2*(4), 34-46.

Libarkin, J. C., & Kurdziel, J. P. (2002). Research methodologies in science education: The qualitative-quantitative debate. *Journal of Geoscience Education, 50*(1), 78-86.

Librea-Carden, M. R., & Mulvey, B. K. (2023). The potential of nature of science (NOS) in special education (SPED): Preservice teachers' conceptions, plans, and identified NOS implications for SPED. *Research in Science Education*, 1-22. https://doi.org/10.1007/s11165-023-10125-6

Librea-Carden, M. R., Mulvey, B. K., Borgerding, L. A., Wiley, A. L., & Ferdous, T. (2021). 'Science is accessible for everyone': preservice special education teachers' nature of science perceptions and instructional practices. *International Journal of Science Education*, *43*(6), 949-968. https://doi.org/10.1080/09500693.2021.1893857

Lintangsari, A. P., & Emaliana, I. (2020). Inclusive education services for the blind: Values, roles, and challenges of university EFL teachers. *International Journal of Evaluation and*

Research in Education, *9*(2), 439-447. https://doi.org/10.11591/ijere.v9i2.20436

MacFarlane, K., & Woolfson, L. M. (2013). Teacher attitudes and behavior toward the inclusion of children with social, emotional and behavioral difficulties in mainstream schools: An application of the theory of planned behavior. *Teaching and Teacher Education*, *29*, 46-52. https://doi.org/10.1016/j.tate.2012.08.006

Mamlok-Naaman, R., & Eilks, I. (2012). Different types of action research to promote chemistry teachers' professional development- A joined theoretical reflection on two cases from Israel and Germany. *International Journal of Science and Mathematics Education*, *10*, 581-610. https://doi.org/10.1007/s10763-011-9306-z

Mandelbrojt, J. (1994). Art and science: Similarities, differences and interactions. *Leonardo, 27*(3), 179-180.

McCarthy, M. M., Eckes, S., & Decker, J. R. (2019). *Legal rights of school leaders, teachers, and students*. Pearson.

McGee Banks, C. A., & Banks, J. A. (1995). Equity pedagogy: An essential component of multicultural education. *Theory Into Practice*, *34*(3), 152-158. https://doi.org/10.1080/00405849509543674

McGinnis, J.R., & Kahn, S. (2014). Special needs and talents in science learning (pp. 223-245). In N. Lederman & S. Abell (Eds). *Handbook of research on science education*, *2.* Oxford England: Routledge Publishers, Taylor and Francis Group.

Mead, J.F. (2017). *Fundmentals of federal disability law.* In E. Shaver & J. Decker (Eds.), A Guide to Special Education Law. (pp. 17-28). Cleveland, OH: Education Law Association.

Miyauchi, H. (2020). A systematic review on inclusive education of students with visual impairment. *Education Sciences*, *10*(11), 346. https://doi.org/10.3390/educsci10110346

Morales, M. P. E. (2016). Participatory action research (PAR) cum action research (AR) in teacher professional development: A literature review. *International Journal of Research in Education and Science*, *2*(1), 156-165.

Mushoriwa, T. (2001). A study of the attitudes of primary school teachers in Harare towards the inclusion of blind children in regular classes. *British Journal of Special Education, 28*(3): 142-147. https://doi.org/10.1111/1467-8527.00214

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

National Science Teaching Association (NSTA). (2023, April 7). *Position statement: Nature of science.* https://www.nsta.org/nstas-official-positions/nature-science

Nelson, N. C., & Stamper, T. N. (2022). Assessing personal conceptions of nature of science: A self-study of nature of science instruction in a college-level biology course. In V. L. Akerson & I. S. Carter (Eds.), *Teaching nature of science across contexts and grade levels: Explorations through action research and self study.* (pp. 305-322). ISTES Organization.

Next Generation Science Standards: For States by States. (2013, April). *Appendix H-Understanding the scientific enterprise: The nature of science in the Next Generation Science Standards.* https://www.nextgenscience.org/sites/default/files/resource/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Scienc e%20Standards%204.15.13.pdf

Norman, C. L. (2023). *Child Find: Improving the Referral Process between Physicians and the Local Education Agency* [Doctoral dissertation, University of Dayton].

O'Leary, E. S., Shapiro, C., Toma, S., Sayson, H. W., Levis-Fitzgerald, M., Johnson, T., & Sork, V. L. (2020). Creating inclusive classrooms by engaging STEM faculty in culturally responsive teaching workshops. *International Journal of STEM education*, *7*(1), 1-15. https://doi.org/10.1186/s40594-020-00230-7

Olson, J. K. (2018). The inclusion of the nature of science in nine recent international science education standards documents. *Science & Education, 27*, 637-660. https://doi.org/10.1007/s11191-018-9993-8

Payan v. L.A. Cmty. Coll. Dist., Case No.: 2:17-cv-01697-SVW-SK (C.D. Cal. May. 21, 2019)

Penn Harris Madison School Corporation. (2022). Nondiscrimination and access to equal educational opportunity, code po2260. BoardDocs. https://go.boarddocs.com/in/phm/Board.nsf/Public#

Petitioner v. Seminole County School District, Case No.: 18-1717E (State of Florida Division of Administrative Hearings 2018). https://www.fldoe.org/core/fileparse.php/10992/urlt/18-1717.pdf

Presley, I., & D'Andrea, F. M. (2008). *Assistive technology for students who are blind or visually impaired: A guide to assessment*. American Foundation for the Blind.

Pruitt, S. L. (2014). The next generation science standards: The features and challenges. *Journal of Science Teacher Education*, *25*(2), 145-156. https://doi.org/10.1007/s10972-014-9385-0

Qin, D. (2016). Positionality. *The Wiley Blackwell encyclopedia of gender and sexuality studies*, 1-2. https://doi.org/10.1002/9781118663219.wbegss619

Quigley, C., Pongsanon, K., & Akerson, V. L. (2011). If we teach them, they can learn: Young students views of nature of science during an informal science education program. Journal of Science Teacher Education, 22(2), 129-149. https://doi.org/10.1007/s10972-010-9201-4

Rivera, L. A., & Tilcsik, A. (2023). Not in My Schoolyard: Disability Discrimination in Educational Access. *American Sociological Review, 88*(2), 284-321. https://doi.org/10.1177/00031224221150433

Roy Payan, et al. v. LACCD, 11 F.4th 729 (9th Cir. 2021).

Schimmel, D., Eckes, S., & Militello, M. (2017). *Principals avoiding lawsuits: How teachers can be partners in practicing preventive law*. Rowman & Littlefield.

Schussler, E. E., Bautista, N. U., Link-Pérez, M. A., Solomon, N. G., & Steinly, B. A. (2013). Instruction matters for nature of science understanding in college biology laboratories. *BioScience*, *63*(5), 380-389. https://doi.org/10.1525/bio.2013.63.5.11

Schwartz, R. S., & Lederman, N. G. (2002). “It's the nature of the beast”: The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *39*(3), 205-236. https://doi.org/10.1002/tea.10021

Section 504 of the Rehabilitation Act of 1973, as amended, 29 U.S.C. § 794 (1973).

Sharma, S., & Hamilton, C. (2019). Understanding ableism: A teaching and learning tool for early childhood education practitioners. *Early Childhood Folio*, *23*(2), 9-13.

Sharma, U., & Sokal, L. (2015). The impact of a teacher education course on pre-service teachers' beliefs about inclusion: an international comparison. *Journal of Research in Special Educational Needs*, *15*(4), 276-284. https://doi.org/10.1111/1471-3802.12043

Shaver, E. A. (2017). *Qualifying for special education and related services under IDEA.* In E. Shaver & J. Decker (Eds.), A Guide to Special Education Law. (pp. 47-64). Cleveland, OH: Education Law Association.

Shea, M. V., & Sandoval, J. (2020). Using historical and political understanding to design for equity in science education. *Science Education*, *104*(1), 27-49. https://doi.org/10.1002/sce.21555

Smith, G. M. (2000). Secondary teachers' perceptions toward inclusion of students with severe disabilities. *NASSP Bulletin*, *84*(613), 54-60. https://doi.org/10.1177/019263650008461309

Spektor-Levy, O., & Yifrach, M. (2019). If science teachers are positively inclined toward inclusive education, why is it so difficult?. *Research in Science Education*, *49*(3), 737-766. https://doi.org/10.1007/s11165-017-9636-0

Steinmetz, J. D., Bourne, R. R., Briant, P. S., Flaxman, S. R., Taylor, H. R., Jonas, J. B., ... & Morse, A. R. F. (2021). Causes of blindness and vision impairment in 2020 and trends over 30 years, and prevalence of avoidable blindness in relation to VISION 2020: the Right to Sight: an analysis for the Global Burden of Disease Study. *The Lancet Global Health*, *9*(2), e144-e160.

Stratton, S. J. (2021). Population research: Convenience sampling strategies. *Prehospital and Disaster Medicine*, *36*(4), 373-374. https://doi.org/10.1017/S1049023X21000649

Supalo, C. A., Isaacson, M. D., & Lombardi, M. V. (2014). Making hands-on science learning accessible for students who are blind or have low vision. *Journal of Chemical Education*, *91*(2), 195-199. https://doi.org/10.1021/ed3000765

Taylor, A. (2012). Addressing ableism in schooling and society? The capabilities approach and students with disabilities. *Philosophy of Education Archive*, 113-121.

Taylor, H. R. (2019). Global blindness: The progress we are making and still need to make. *The Asia-Pacific Journal of Ophthalmology, 8*(6), 424-428.

Tom, S. L., Mpekoa, N., & Swart, J. (2018, March). Factors that affect the provision of visually impaired learners in higher education. In *2018 Conference on Information Communications Technology and Society (ICTAS)* (pp. 1-5). IEEE.

Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, *17*(7), 783-805. https://doi.org/10.1016/S0742-051X(01)00036-1

Umpstead, R., Decker, J. R., Brady, K. P., Schimmel, D., & Militello, M. (2015). *How to prevent special education litigation: Eight legal lesson plans*. Teachers College Press.

Unianu, E. M. (2012). Teachers' attitudes towards inclusive education. *Procedia-Social and Behavioral Sciences*, *33*, 900-904. https://doi.org/10.1016/j.sbspro.2012.01.252

Vaz, S., Wilson, N., Falkmer, M., Sim, A., Scott, M., Cordier, R., & Falkmer, T. (2015). Factors associated with primary school teachers' attitudes towards the inclusion of students with disabilities. *PloS One*, *10*(8), e0137002. https://doi.org/10.1371/journal.pone.0137002

Wahbeh, N., & Abd-El-Khalick, F. (2014). Revisiting the translation of nature of science understandings into instructional practice: Teachers' nature of science pedagogical content knowledge. *International Journal of Science Education*, *36*(3), 425-466. https://www.tandfonline.com/doi/full/10.1080/09500693.2013.786852

Walls, L. (2012). Third grade African American students' views of the nature of science. *Journal of Research in Science Teaching*, *49*(1), 1-37. https://doi.org/10.1002/tea.20450

Wertheim, C., & Leyser, Y. (2002). Efficacy beliefs, background variables, and differentiated instruction of Israeli prospective teachers. *The Journal of Educational Research*, *96*(1), 54-63. https://doi.org/10.1080/00220670209598791

Wilcox-McBride, K. (2017, December 14). *Lack of district resources makes it harder for visually impaired students.* The Southerner. https://www.shsoutherner.net/features/2017/12/14/lack-of-district-resources-makes-it-harder-for-visually-impaired-students/

Willings, C. (2020, April 9). *Teacher of students with visual impairments.* Teaching Students with Visual Impairments, LLC. https://www.teachingvisuallyimpaired.com/teacher-of-students-with-visualimpairments.html#:~:text=A%20Teacher%20of%20Students%20with,needs%20of%20students%20who%20are

U.S. Const. art. VI, § 2

APPENDIX A

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE (VNOS-FORM D)

1. What is science?
2. How is science different from other subjects?
3. Scientists are always trying to learn about our world. Do you think what scientists know might change in the future?
4. How do scientists know that dinosaurs really existed? How certain are scientists about the way dinosaurs looked?
5. A long time ago all the dinosaurs died. Scientists have different ideas about how and why they died. If scientists all have the same facts about dinosaurs, why do you think they disagree about this?
6. TV weather people show pictures of how they think the weather will be for the next day. They use lots of scientific facts to help them make these pictures. How certain do you think the weather people are about these pictures? Why?
7. Do you think scientists use their imaginations when they do their work? **Yes/No** If **No**, explain why? If **Yes**, then when do you think they use their imaginations?

APPENDIX B

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE (VNOS-FORM D+)

1. What is science?
2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other subjects/disciplines (art, history, philosophy, etc.)?
3. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.
4. (a) How do scientists know that dinosaurs really existed? Explain your answer.

   (b) How certain are scientists about the way dinosaurs looked? Explain your answer.

   (c) Scientists agree that about 65 million years ago that dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

   (d) If a scientists wants to persuade other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer.
5. In order to predict the weather, weather person collect different types of information. Often they produce computer models of different weather patterns.
   (a) Do you think weather persons are certain (sure) about the computer models of the weather patterns?
   (b) Why or why not?
6. The model inside of the earth shows that the Earth is made up of several layers called the crust, upper mantle, mantle, outer core and the inner core. Does the model of the layers of the Earth *exactly* represent how the inside of the Earth looks? Explain your answer.

7. Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imaginations and creativity when they do these investigations/experiments?
   (a) If **NO**, explain why.
   (b) If **YES**, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.
8. Is there a difference between scientific theory and scientific law? Illustrate your example with an answer.
9. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.
10. Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

APPENDIX C

EXIT SLIP

Lesson: ____1 ____2 ____3 ____4 ____5____6

1. What was the clearest scientific concept that you learned during this lesson?

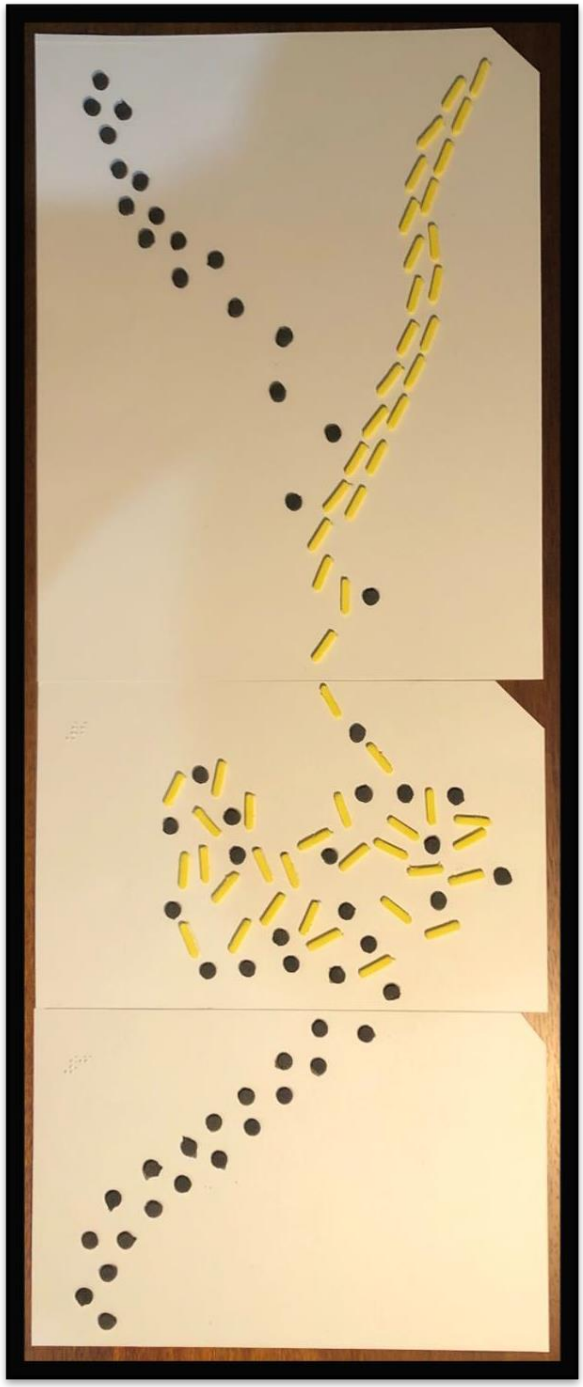
2. What scientific concept do you feel was least clear, or needed further discussion during this lesson?

3. How do you feel the instructor could make this lesson better for visually impaired students?

4. Please make any other suggestion(s) that you feel would improve this lesson for blind and low-vision students.

APPENDIX D

***TRICKY TRACKS!* – ADAPTED**

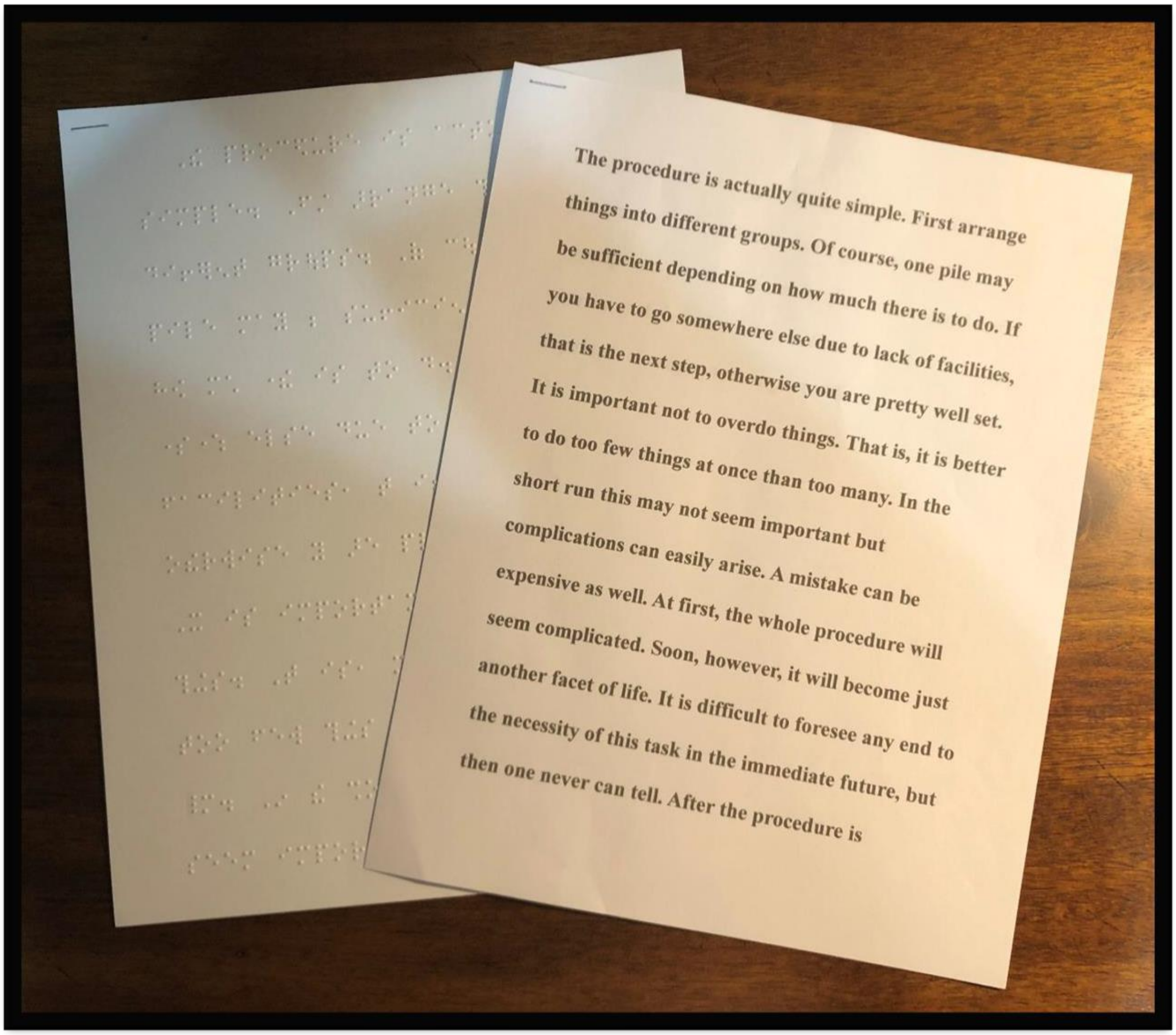


APPENDIX E

REAL FOSSILS, REAL SCIENCE – ADAPTED

APPENDIX F

THAT'S PART OF LIFE! – ADAPTED



APPENDIX G

YOUNG? OLD? – ADAPTED

APPENDIX H

THE TUBE

APPENDIX I

***THE CUBE ACTIVITY* – ADAPTED**

TINA N. STAMPER

ACADEMIC CURRICULUM VITAE

Ed.D. Program
Department of Curriculum & Instruction
Indiana University- Bloomington

201 N. Rose Avenue
Bloomington, Indiana 47405
tnstampe@iu.edu

EDUCATION:

01/2025	**Doctor of Education: Curriculum & Instruction – Science Education** Doctoral Minor: Education Law Indiana University, Bloomington, IN
07/2023	**Graduate Certificate: Education Law** Indiana University, Bloomington, IN
04/2006	**Master of Science: Biology** Grand Valley State University, Allendale, MI
05/2001	**Bachelor of Science: Biology** Minor: Chemistry University of Findlay, Findlay, OH

ACADEMIC APPOINTMENTS:

INDIANA WESLEYAN UNIVERSITY: Central Indiana Campuses; National & Global

2012 – Present	***Science Faculty***	College of Adult & Professional Studies (CAPS)
2019	***Subject Matter Expert, Anatomy***	School of Health Sciences

HONORS & AWARDS:

2005	***Outstanding Biology Student:*** Grand Valley State University
2004 - 2006	***Full Academic Scholarship with Stipend:*** Grand Valley State University
2000	***Katherine Ballard Reed Memorial Scholarship:*** University of Findlay
1999 – 2001	***Tau Omega Pi Honorary Academic Fraternity:*** University of Findlay
1999 – 2001	***Honor's Program:*** University of Findlay

SELECTED PUBLICATIONS:

EDITOR REVIEWED BOOK CHAPTERS

Nelson, N. C., & **Stamper, T. N.** (2022). Assessing personal conceptions of nature of science: A self-study of nature of science instruction in a college-level biology course. In V. L. Akerson & I. S. Carter (Eds.), *Teaching nature of science across contexts and grade levels: Explorations through action research and self study*. (pp. 305-322). ISTES Organization.

Stamper, T. N., & Nelson, N. C. (2022). An action research study: How do values and faith affect students' views on the nature of science? In V. L. Akerson & I. S. Carter (Eds.), *Teaching nature of science across contexts and grade levels: Explorations through action research and self study*. (pp. 99-127). ISTES Organization.

RECENT PRESENTATIONS AT PROFESSIONAL MEETINGS:

INTER/NATIONAL MEETINGS

Stamper, T. N. (Upcoming: 2025, March 23-26). *Ensuring equitable opportunities to improve how blind students conceptualize the nature of science.* [Paper presentation]. NARST 98th Annual International Conference, Washington, D.C., United States.

Stamper, T. N., & Nelson, N. C. (2023, April 18-21). *Effectively teaching nature of science in a way that coexists with religious principles.* [Poster presentation]. NARST 96th Annual International Conference, Chicago, Illinois, United States.

Stamper, T. N., & Nelson, N. C. (2023, January 3-6). *An action research study: How do values and faith affect students' views on the nature of science?* [Poster presentation]. 2023 Hawaii International Conference on Education, Honolulu, Hawaii, United States.

LOCAL MEETINGS

Stamper, T. N. (2023, March 3). *Blind students and equity within the science classroom.* [Poster presentation]. Curriculum & Instruction Graduate Research Symposium (GRaS), Indiana University, Bloomington, Indiana, United States.