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EXPLORING AMERICAN INDIAN STUDENTS' PERCEPTIONS, ATTITUDES, AND MISCONCEPTIONS OF SCIENTISTS AND THE NATURE OF SCIENCE

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EXPLORING AMERICAN INDIAN STUDENTS' ATTITUDES, PERCEPTIONS, AND MISCONCEPTIONS OF SCIENTISTS AND THE NATURE OF SCIENCE

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DEDICATION

This work is dedicated to my family, especially my parents Elton Riley and Carolyn Joyce Crofford.

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ABSTRACT

The purpose of this study is to describe and analyze the perceptions, attitudes, and misconceptions (PAM) that high school American Indian (AI) students possess about scientists and the nature of science. AI is the least represented group in science, technology, engineering, and mathematics (STEM) majors and careers, both proportionally and aggregately. The results of this study may be used as a baseline or "snap shot" to gauge the effectiveness of the current and future initiatives addressing the underrepresentation of AI and other minorities in science, mathematics, engineering, and health care and computer professions.

Views on Science-Technology-Society (VOSTS), Draw-A-Scientist Test Checklist (DAST-C), and Views of Nature of Science Questionnaire (VNOS) instruments are used to characterize the perceptions, attitudes, and misconceptions of 133 high school students from a school district in a midwestern state. Based on the analysis of quantitative data, there is no significant difference in students' DAST scores between genders and among different school grades. The analysis shows a significant effect of school grade on students' naive views on science-technology-society. Also, it shows that those students' views on science-technology-society became less naïve and more informed as they progressed through grades. However, results show that *merit position score* and *informed position score* were independent of school grade. The results also reveal that there is no significant relationship between school grade and any of the VOSTS positions, which implies that school grade did impact naive position, merit position and informed position of AI students.

CHAPTER 1: INTRODUCTION

Background

The director of the education department of a large American Indian (AI) nation recently related to me an informal and unpublished study carried out by a former superintendent of a school located within the tribal boundaries. The school was a small and rural dependent district comprised of pre-kindergarten through eighth-grade with a student population of almost 100% AI. Over several years, the superintendent surveyed fourth-graders on what they wanted to be when they grew up. Their answers ranged across the spectrum of vocations, from teachers and professional athletes to firefighters and doctors. When the students were asked the same question four years later as eighth-graders, their responses were mostly limited to one of the two: chicken pullers at the nearby food processing facility or line workers at the pie and cake factory in the same town.

This revelation was startling and disconcerting to me, considering the fact that AI college attendance rates are low and drop-out rates are high, especially in science, technology, engineering, and mathematics (STEM) majors (Demmert, 2001). This prompted an investigation of the role of science education in addressing AI college attendance and retention since AI is considered the least represented group in STEM majors and careers, both in sheer numbers as well as proportionally (Demmert, 2001).

Adequate science education, including development of critical thinking skills, for students before entering higher education is a crucial foundation of America's technological and intellectual strength, which arises from its talented workforce prepared as STEM majors (Babco, 2003). A possible approach for addressing the documented educational deficit among AI students is exemplified by the Native Science Connections Research Project (NSCRP) at Northern Arizona University in Flagstaff. The NSCRP project attempts to integrate relevant cultural knowledge and language into an inquiry-based science curriculum, and has demonstrated some initial success (Gilbert, 2008). My personal experience after attending a summer science institute at the state's flagship institution was that my students (mostly AI) responded well to inquiry-based science instruction. This was further supported by Aikenhead (1977) and Marek (2008 & 2009).

According to Prince and Felder (2006), learning cycles are instructional models wherein students "work through sequences of activities that involve complementary thinking and problem-solving approaches" (p. 126). The learning cycle consists of three phases: exploration, concept development, and application (Marek, 2008 & 2009). In the exploration phase, the student is engaged in an introductory activity about a concept where the student can collect good data, which provides them with a practical base for the next phase (Chiaverina, 2002). The phenomenon introduced in the exploratory phase is further explained in the concept development phase, wherein basic principles, terminology, and mathematical reasoning are introduced (Atkins & Karplus, 1962). For the application phase, students apply what they have learned from the preceding phases to relevant real world applications (Chiaverina, 2002).

Inquiry-based science instruction focuses on critical thinking and problem solving while emphasizing the need to evaluate teacher strategies to ensure that they align with the learning styles of particular students (Tomlinson, 2004). Greater student enthusiasm for science occurred among my third through eighth-grade classes, along with increased student comprehension, especially during the concept development and expansion/application phases of the learning cycles. Increased comprehension is particularly noteworthy when relating a concept to something from the students' real-world environment and interests, while emphasizing the organization of the concept amongst their prior knowledge and applying the concept in a different context.

Anecdotal observations of increased comprehension led, in part, to the school adopting the Carolina Biological Company's Science and Technology for Children (STC) program. Science instruction, and specifically inquiry-based science instruction, began to occur more often at the school. The faculty was encouraged to modify and adapt the STC curriculum program kits to reflect more of a true learning cycle teaching approach. This school has received national awards and recognition, in particular for the superintendent's "psychomotor" activity-based teaching and learning approach for its AI students (Southwest Educational Development Laboratory, 1995). Although research indicated that all students tend to learn better with an inquiry-based approach to science education (Lee, Greene, Odom, Schechter, & Slatta, 2004; Marzano, 2003; National Research Council, 1996; National Science Teachers Association [NSTA], 2004), this study was prompted, at least partially, by the question of whether AI students are somehow uniquely suited for science instruction via learning cycles.

Several years ago, the Cherokee Nation (CN) government recognized the deficit in CN students pursuing STEM majors and careers, and took steps in initiating programs to address the problem (Lemont, 2001). Among these were the CN science fair, STEM summer camps, robotics workshops, scholarships, and an emphasis on science and mathematics in schools with large AI populations.

Today, there is a growing push nationwide for similar programs. Examples include the Significant Opportunities in Atmospheric Research and Science (SOARS) Program at the National Center for Atmospheric Research and the South Dakota Space Grant Consortium. Professional organizations such as the National Indian Education Association (NIEA) and the AI Science and Engineering Society (AISES) are currently initiating several STEM programs as well.

Research presented in this dissertation investigates AI students' perceptions, attitudes and misconceptions (PAM) about science and scientists. Such research constitutes an important step in addressing the documented educational deficits among the population in question.

The research took place at a school district in a midwestern state. According to the governing tribe's official web site, the research site is an AI boarding school, and originated in 1871 when the tribe's National Council passed an act setting up an orphan asylum to take care of the many children left without parents due to the Civil War. In 1914, the tribe's National Council authorized the sale and conveyance of the property, including 40 acres of land and all the buildings, to the United States Department of Interior for $5,000. In 1925, the name of the institution was changed to honor the individual who developed the tribe's first syllabary, or written language. From a school with one building and 40 acres of land, it grew into a modern institution, covering more than 90 acres and a dozen major buildings and other facilities situated on a beautiful campus. In November 1985, the tribe resumed the operation of the school from the Bureau of Indian Affairs.

It now operates through a grant and is regionally and state accredited for grades 7 to 12. The student population consists of 300 students representing 42 tribes, and their ages range from 10 to 18. The student population with the exception of two students is entirely AI and mostly Cherokee. Required for admittance are grade point average of 2.25 on a 4.0 scale, superior references from previously attended schools, good past attendance rates, and proficient state test scores. Graduation requirements exceed those of the state, with 27 credits needed as opposed to 23 for the state. Some of the required credits include Cherokee Language, Native American History, and Leadership. According to the superintendent, more than ninety percent of this school's graduates at least attempted some post-secondary education or training.

The science teachers whose classes provided the students for this study ranged in teaching experience from 15 to 30+ years. Most are also coaches and only teach a single block of science each day. Very little inquiry-based or culturally relevant instruction takes place according to the teachers and administration. There is an emphasis on life science courses and not many students enroll in physics or chemistry. Students have not participated in science fairs recently, but the school's AISES chapter and robotics program are both very active.

Problem Statement and Research Question

The central circumstance underpinning this study is the paucity of AI attainment of STEM degrees in higher education (Babco, 2003). In addition, underrepresentation is compounded by a lack of research on the perceptions, attitudes, and misconceptions of AI high school students about scientists and the nature of science. Without understanding how AI high school students think about science and scientists, teachers cannot optimally instruct these students. It is also difficult to gauge the impact of science education-related initiatives. Since America relies on a strong and highly educated technical workforce, the attainment of STEM degrees within the AI population is ultimately important to the progress of the American economy in general and AI in particular.

The central research question of this study is: *What are the perceptions, attitudes, and misconceptions of AI high school students regarding scientists and the nature of science?* Similar studies have been performed previously with other ethnic nationalities (Dogan & Abd-El-Khalick, 2008; Ebenezer & Zoller, 1993; Seiler, 2001). To the best of the researcher's knowledge, no research has been done specifically on AI students' perceptions of scientists and the nature of science. Statistical and qualitative analysis of student responses to selected components of three chosen survey instruments are used to measure a wide range of the students' PAM of scientists and the nature of science.

CHAPTER 2: LITERATURE REVIEW

In this chapter, inquiry-based education and its utility in science education are presented, followed by an overview of AI learning trends and styles. Inquiry-based education is discussed because the site school of this study has been deficient in this type of instruction, according to the administration and teachers. The next section includes existing literature on AI in higher education and the AI trends in STEM education and degree attainment.

AI learning must reflect and respect the cultural perspective and heritage of the AI society and culture. Traditional AI viewpoints of the world and environment are mutualistic and holistic, emphasizing the interconnectedness of the universe and all its living and non-living components (Cajete, 1999). Therefore, Cajete noted, "Presenting educational material from a holistic perspective is an essential and natural strategy for teaching Indian people" (p. 142).

Inquiry-Based Education

There are a variety of viewpoints concerning what constitutes inquiry-based education. Lee et al. (2001) defined *inquiry-based education* as "learning in terms of four student commitments-critical thinking, independent inquiry, responsibility for one's own learning, and intellectual growth and maturity" (p. 63). Marzano (2003) believed that science education for middle and high school students is better when using inquiry-based techniques. The National Science Education Standards (NRC, 1996) defined and recommended scientific inquiry as

> The diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and

> understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (p. 23)

The standards in the state in which this study was conducted are process-oriented and inquiry-based standards. These provide the foundation for all elementary and secondary school instruction in the state. Inquiry requires, and at the same time, develops critical thinking and problem solving skills. It may contribute to the implementation of a program of instruction that ensures "what a student learns, how he/she learns it, and how the student demonstrates what he/she has learned is a match for that student's readiness level, interests, and preferred mode of learning" (Tomlinson, 2004, p. 188).

The central purpose of American education, as stated in 1961 by National Education Association's (NEA) Educational Policies Commission (EPC), is for students to be able to think critically. Furthermore, NSTA (2004) recommended that,

> all K–16 teachers embrace scientific inquiry and the NSTA is committed to helping educators make it the centerpiece of the science classroom. The use of scientific inquiry will help ensure that students develop a deep understanding of science and scientific inquiry. (n.p.)

Existing research indicated a growing belief in the superiority of inquiry-based techniques over more conventional, rote-based practices. Steinberg (2007) stated that,

> Too much of today's science education focuses on making students memorize bits of information that will be outdated within a few years. There is too little emphasis on how to think like a scientist. And there is no substitute for hands-on (inquiry) research experience. (p. 13)

Marzano (2003) agreed that teachers need to "provide students with tasks and activities that are inherently engaging" (p. 149). Inquiry-based education targets the specific learning styles of students and provides engaging and educational activities that integrate with students' unique educational perspectives.

Research shows that inquiry-based science instruction utilizing the *learning cycle* approach is particularly effective for teaching and learning (Marek, 2008). Learning cycles are grounded primarily in Piagetian theory of cognitive development, along with aspects of social constructivism and meaningful-learning theory. The underlying theory base supporting the use of learning cycles as an effective teaching approach consists of the nature of science as inquiry, critical thinking, national and state standards for science education, and the nature of the learner and learning as described by Piaget (Marek, 2009). Individuals such as Robert Karplus, John "Jack" Renner, and Anton Lawson, among others, had also made significant contributions to the historical development and evolution of learning cycles since the late 1950s.

A commonly used type of learning cycle consists of three stages: exploration, concept development, and concept application/extension (Marek, 2008 & 2009). In the exploration phase, students gather and record meaningful data with the guidance of the instructor. This is what Piaget referred to as *Assimilation*. In the critical second phase, students are put through divergent, scaffolded, and meaningful questioning by the teacher to help each student utilize all of the data to mentally construct the target science concept. This corresponds to Piagetian *Accommodation*. In the third phase, the concept is placed and prioritized among the students' prior learning and applied in different contexts through a variety of activities (Karplus, 1977). Piaget referred to this step as *Organization*. The learning cycle teaching and learning approach is currently recognized as the most effective way to structure inquiry-based science, as well as develop the all-important critical thinking skills (NSTA, 2004).

Educators quickly discover that students have different backgrounds and life circumstances, and that these differences can be profound regarding the contrast between mainstream students and minorities, such as AI. *Differentiation* is an important concept in inquiry-based pedagogy. It refers to the tailoring of teaching techniques to the educational needs of students. A program of differentiation is a systematic way of meeting the needs of all students (Tomlinson, 2004). The learning community is not only concerned with meeting the needs of learners at different levels but also different learning styles. According to Willis and Mann (2000), differentiated instruction is intended "to deliver instruction in ways that meet the needs of auditory, visual, and kinesthetic learners. And they, (teachers), are trying to tap into students' personal interests. In short, these teachers are differentiating instruction" (pp. 1-2).

Through the use of differentiated instruction programs and inquiry-based instructional approaches, teachers can be better prepared to meet the needs of the learners in a diverse learning community. "Educators commonly see one of their major roles as helping students to acquire broader and deeper understandings of the physical and social world around them" (Kuhn, 2005). Kuhn also stated that, "Becoming educated, then, means achieving the skills and values that confer an unlimited capacity and inclination to learn and to know" (p. 109), giving strength to the effectiveness and purpose of inquiry instruction and learning. In fact, subject areas other than science are more effectively taught through inquiry. O'Brien (2006) stated,

> Inquiry is given even more credibility by supporting the standards and being part of those published by *The National Center for History in the Schools.* The standards were published in 1994 and revised in 1996. The first five standards, deal with historical thinking and required students to develop inquiry skills such as the ability to engage in chronological thinking, to interpret primary source

> material, to pose historical questions within the appropriated context, and to construct historical narrative-all hallmarks of inquiry learning. (pp. 11-12)

Research by the above-mentioned authors confirms that inquiry-based education is an effective mode of teaching science, particularly to groups of students with learning techniques and perspectives of science that may differ from those of the mainstream. The science education literature is replete with studies showing inquiry-based instruction and in particular learning cycles to be more effective than other teaching practices.

AI Learning

Although students tend to learn better using an inquiry-based teaching approach, it is important for this research to determine if AI students are particularly suited for socially based, constructivist/transactional teaching and learning (Lee et al., 2004; Marzano, 2003). Traditionally, AI children learn about the world around them by actively exploring it on their own, as well as through passing on of knowledge by oral story-telling and direct experience instruction and practice (Cajete, 1999). *Traditional Ecological Knowledge* (TEK) has been recognized as a sub-culture within the larger culture of science itself, and its intersection with classic Western science may be used to promote AI learning instead of hindering it (Snively & Corsiglia, 2000).

The Cherokee Nation's Long Man Project is an example of Western modern science being taught concurrently with traditional Native science to enhance students' interest and understanding (Faddis, 2008). The Long Man Project is part of a Cherokee Nation STEM summer camp program. According to Faddis (2008), the program introduces high school students to tribal thinking process, including the use of "metaphor (stories), emulation, and spirituality along with other tribal practices in scientific endeavors" (p. 2). At the same time, the project emphasizes that students utilize their particular cultural identities while learning to apply native science alongside modern Western science (Faddis, 2008).

Snively and Corsiglia (2000) presented a notion of *indigenous science*, which refers to “both the science knowledge of long-resident, usually oral culture peoples, as well as the science knowledge of all peoples who, as participants in culture, are affected by the worldview and relativist interests of their home communities” (p. 6). The term *native science* is more of an American term, while *indigenous science* is its global and mostly synonymous counterpart. The concept of indigenous or native science is useful when thinking about AI learning. Although there is a growing body of literature surrounding TEK, Snively and Corsiglia (2000) suggested that Western modern science has been taught at the expense of indigenous science. It was also observed that the “universalist gatekeeper” of Western modern science “can be seen as increasingly problematic and even counterproductive” (p. 6). Therefore, teaching AI students and not acknowledging their particular learning styles, traditional culture, community, social and political mores, and language may be a disadvantage to their science education. Gilbert (2008) found that indigenous students taught this way may unintentionally inhibit their desire to learn science, avoid science professions, and even question their own cultural identity. Cajete (2000) stated,

> Native science is a metaphor for a wide range of tribal processes of perceiving, thinking, acting, and 'coming to know' that have evolved through human experience with the natural world. Native science is born of a lived and storied participation with the natural landscape. To gain a sense of Native science one must participate with the natural world. To understand the foundations of Native science one must become open to the roles of sensation, perception, imagination, emotion, symbols, and spirit as well as that of concept, logic, and rational empiricism. (p. 2)

A complement to this point of view is that indigenous science knowledge, instead of being consumed by the standard account of Western modern science, is better off as a different kind of knowledge that can be valued for its own merits and can play a vital role in the science education of AI students (Cobern & Loving, 2001). Within this perspective, a possible goal for educational leadership and researchers would be to work toward developing and instituting inquiry-based instructional programs, especially in science, in the educational departments of schools within AI tribal boundaries. Research shows that inquiry-based professional development may enhance teachers' understanding of Piagetian models of intelligence and increase their use of appropriate constructivist approaches, such as the learning cycle, in the classroom (Marek, Cowan, & Cavallo, 1994; Marek, Eubanks, & Gallaher, 1990).

Gerber, Marek and Cavallo (2001) have discovered in their research that encouraging more informal learning opportunities, including visits to museums and other field trips, chess, speech, and science fairs, is important for all students' achievement. Likewise, emphasizing AI culture and language at home and in school should be the priorities for teachers of AI children (Matthew & Smith, 1994). Students need to actively construct their own knowledge with the teacher's guidance, engage in varied activities in and out of school, and be encouraged to maintain their native identity (Gilliland, 1995). That is, they need to realize that they can "*be Cherokee*," for instance, and yet also be successful in school and professionally, in the larger world outside their usually rural home environments (Nelson-Barber & Estrin, 1995). Establishing a baseline of AI students' PAM about STEM classes and professions could be beneficial in knowing how to effectively teach and encourage participation and success in science, technology, engineering, and math. There is a small but growing body of literature that supports the notion that incorporating and maintaining AI culture and language greatly enhances students' overall academic performance and likelihood to seek and complete post-secondary work (Aikenhead & Jegede, 1999; Cajete, 2000; Deloria, 2000; Gilliland, 1995).

AIs and Higher Education

According to the National Center for Education Statistics (2005), there is a significant gap in the academic achievement levels of AI students as compared to the achievement levels of all American students. As of 1997, AI attrition rates in institutions of higher education range between 75% and 93% (Brown & Kurpius, 1997). According to Larimore and McClellan (2005), in secondary education, 40% of AI students drop out before attaining their high school diploma. Minorities overall suffer from lower rates of academic achievement than Caucasians, and AI have particularly high rates of student attrition.

Larimore and McClellan (2005) suggested using multiple theoretical lenses or perspectives in evaluating AI students and their learning experiences in order to enhance a small but growing body of knowledge about effective teaching strategies for AI. Issues of financial means to higher education also present barriers to AI students, who are often at the bottom of the socio-economic ladder (Brown & Kurpius, 1997). Increases in the availability and accessibility of higher education opportunities for AI are critical for improving AI academic achievement and retention rates.

Pavel (1992) identified AI as among the groups least likely to enroll in a public four-year institution, and the least likely to graduate from those institutions. In addition, Larimore and McClellan (2005) noted that the post-secondary retention rate may be as low as 15%. These researchers highlighted the need for research to focus on pre-higher education levels of AI academic achievement. It was found that levels of academic achievement were typically lower for AI students than their peers, and researchers have postulated that conflicts in learning and teaching styles may be partly responsible for this disparity of academic achievement (Brown & Kurpius, 1997). Clearly, these studies suggested a significant problem of AI education that needs to be addressed immediately.

AI Students and STEM Education

Babco (2003) stated that AI students must have an adequate science education, including development of critical thinking skills, before entering higher education. As stated before, AI are earning degrees in science and engineering (S&E) at startling low rates; for the year 2000, only 2,782 (0.7% of S&E degrees) of AI earned S&E bachelor's degrees, 340 (0.4%) earned S&E master's degrees, and 88 (0.3%) earned doctoral degrees. In addition, the AI that are attaining degrees as S&E majors tend to graduate in the social sciences and psychology, as opposed to the disciplines encompassed under the STEM umbrella. In addition, Babco noted that AI attainment of STEM degrees has not kept pace with the growth of the AI population in the past 30 years.

In a qualitative study of AI college student perceptions of higher education, AI students found counseling and guidance in the high school important to prepare them for the transition to higher education (Hoover & Jacobs, 1992). On the other hand, students noted that academic resources and instruction were adequate in college (Hoover & Jacobs, 1992). This suggested that problems of low rates of attainment of STEM degrees by AI students may have more to do with preparation before entering college than with the resources available to AI students once they are enrolled in college.

However, Wright (1990) suggested that guidance and counseling for AI students in college is just as important as it is for AI students in high school. Wright reported that AI students desired counseling in college to help them develop their confidence and steer them into specializations and career fields. May and Chubin (2003) noted that in America, the job sectors that are growing fastest are based in science, engineering, and technology, and in order for AI students to keep pace in the economy, more will need to attain STEM degrees. May and Chubin (2003) also highlighted the need for financial assistance, academic intervention programs, and pre-college preparation to increase undergraduate STEM education among AI. Researchers in the field of STEM education who have studied an AI population have routinely found that additional strategies are necessary to improve STEM education both in high school and in college.

Summary

A review of the literature suggests that AI students are suffering from low levels of academic achievement and graduation from high schools and institutions of higher education. Furthermore, it is noted that within AI education, STEM majors are disproportionately low as compared to other minorities and Caucasians in this country. Inquiry-based education has been advanced as a theoretical perspective that aligns the teaching styles of instructors with learning styles of students. In addition, indigenous science education may serve AI students better than science education based exclusively in a Western modern perspective. Because AI often originates from life circumstances that are significantly different from those of most students in mainstream education, particular interventions, such as inquiry-based activities, may be required to ensure that AI students are experiencing science education that is comparable across all cultures in our country.

CHAPTER 3: RESEARCH METHODS

The purpose of this exploratory study was to describe and analyze the perceptions, attitudes, and misconceptions (PAM) that high school AI students possessed with regard to scientists and the nature of science. AI students who took part in the study had rarely participated in an inquiry-based science education program, especially one that included instruction through learning cycles.

In order to gauge the effectiveness of any type of STEM initiative over time, this research required a baseline of data that would indicate where students in the affected schools were prior to implementation of inquiry-based and informal learning. Information on the students' academic perceptions before and after the implementation of a learning initiative was needed to ascertain if inquiry-based education influences students' learning. Therefore, the goal was to measure the PAM of high school AI students toward scientists and the nature of science. The following survey instruments were used: (a) selected portions of the Views on Science-Technology-Society (VOSTS), (b) the Draw-A-Scientist Test (DAST-C), and (c) the Views of Nature of Science Questionnaire (VNOS). The parts which were considered useful in the study of Dogan & Abd-El-Khalick (2008) were retained in this dissertation. The aspects of NOS relating to these components, it should be noted, had been emphasized in national science education reform documents and were considered accessible by pre-college students according to these authors.

A sample of 133 AI high school students answered the modified surveys. It was expected that more of the older students had experienced some of the STEM initiatives currently underway, and data were compared by the grade level, level of tradition, gender, and the PAM of the students. Pearson's correlation analysis, ANOVA, Chi-square, and an independent samples *t*-test were used to test the relationship between the perceptions, attitudes, and misconceptions of AI high school students with various demographic factors. The tests provided findings about demographic factors' influence on student perceptions, attitudes, and misconceptions regarding scientists and the nature of science. The Pearson's correlation analysis determined the magnitude of the relationship between variables. ANOVA computed the influence of demographic factors to student perceptions, attitudes and misconceptions. Chi-square test was used to analyze the variations between responses. The t-test was used to determine if there was a significant difference between the outcomes of two groups of respondents. A characterization of students' attitudes about science and scientists and a comparison of responses by gender were established. The remainder of this chapter presents the research design, population, sampling plan, sample size, instrumentation, data collection, and methods of data analysis.

Research Design and Appropriateness

A quantitative comparative and qualitative design was used to compare a group of participants with one another and to determine if there were significant differences or correlations in their responses on the VOSTS, DAST-C, and VNOS instruments (Cozby, 2001). The comparison made in this study was among the ninth-grade students' survey results through the twelfth-grade students' survey results to see if any significant patterns emerged between datasets. Students were given the following survey instruments to complete: selected portions of VOSTS relating to the nature of the scientific endeavor, the entire DAST-C and VNOS. Each instrument included aspects of scientific models, hypotheses, theories, laws, and methods. In order to compare grade level and gender, an independent samples *t*-test and ANOVA were used. The results of the three instruments were analyzed and explained to gain some context to the current PAM of AI students toward scientists and the nature of science. The instruments were administered by the researcher in the students' science classes over a period of three weeks. Written responses were clarified by interviewing approximately 10% of the students.

The proposed research used a quantitative correlational research design to identify relationships between two sets of variables. According to Bickman and Rog (2009), research designs served as "the architectural blueprint of a research project, linking design, data collection, and analysis activities to research questions" (p. 11). Quantitative descriptive research designs illustrated a phenomenon as it naturally occurs, as opposed to an experimental design where effects of intervention were studied (Bickman & Rog). In descriptive correlational studies, the researcher measured the relationship between two or more variables using correlational statistical tests (Creswell, 2005).

Qualitative research was used in order to garner an understanding of a paradigm. In qualitative research, little was known about the problem or variables prior to study (Creswell, 2005). A small number of research subjects were typically involved in qualitative research. Data were in textual format and text analysis was used to describe information and stratify it into themes (Creswell, 2005).

In quantitative research, an analysis of the relationship between variables is conducted in order to reveal a relationship. After selecting a topic and specifying an issue that requires clarification, a quantitative researcher collects data from a specified population and statistically analyzes that data. The explanation of the relationship between variables leads to the description of trends in quantitative research (Creswell, 2005).

Descriptive research could be used to summarize the relationship between two or more variables (Bickman & Rog, 2009). The use of descriptive correlational research was justified for the proposed study because numerical data were collected from a sample representing the PAM of students on scientists and the nature of science for the purpose of determining whether an association existed between various demographic factors and the PAM of AI high school students on scientists and the nature of science. Bickman and Rog (2009) suggested that “a descriptive approach is appropriate when the researcher is attempting to answer ‘what is’ or ‘what was’ questions” (p. 16).

For the proposed research, quantitative analysis was more appropriate because the relationship between the perceptions on scientists and nature of science and the various demographic factors within the mid-western AI high school students was explored. Qualitative analysis was used in the study to support and validate the quantitative findings. For an in-depth description on VNOS-B and its validity, administration, and analysis, see Lederman et al. (2002).

Population and Sample

The general population for the study was AI students who were enrolled in science courses at a boarding school in a midwestern state. The sample population for this study was 133 AI high school students. A non-probability sampling plan was used for this study, and was based on a purposeful sampling plan (Urdan, 2005). The purpose of this study was to sample only AI students, and assess their PAMs.

A power analysis, which allowed the researcher to determine the number of participants to constitute a sufficiently large sample, was conducted in order to ensure that the results found in the sample of the study were valid and generalized toward the target population. There were three items that contribute to calculating the required sample size for the study.

1. The first item was the power of the study. The power referred to the probability of correctly rejecting a false null hypothesis (Keuhl, 2000).
2. The second item used to calculate the sample size of the study was the desired effect size. The effect size was defined as being the strength of the relationship between the predictor and outcome variables (Cohen, 1988).
3. The third and final item was level of significance. The level of significance for this study was set at 5%.

The effect size of d = .60 was used with a level of significance of 5%, and a power of 80%, which produced the minimum sample size required for this study equal to 90. This calculation was also based on using an independent sample *t*-test. The sample size and power calculation for this study was produced in G*Power.

Instrumentation

Three instruments were used to collect data: (a) the Views on Science-Technology-Society (Aikenhead & Ryan, 1992), (b) the Draw-A-Scientist Test (Chambers, 1983; Finson, Beaver, & Cramond,1995), and (c) the Views of Nature of Science Questionnaire (Lederman et al., 2002). By assigning numerical or categorical values to the responses provided on the VOSTS, DAST-C, and VNOS instruments, it was possible to assess the relationships and differences using quantitative methods (i.e., by comparing the different numerical responses with one another using several statistical techniques). The validity and reliability of these instruments were established in the cited literature.

The DAST-C (Appendix A) included a brief written response and was administered in two parts. In the first stage, each student was given a piece of paper with the following instructions: “Draw a picture of a scientist at work.” Below the space for drawing, students were asked to explain what the scientist is doing. DAST-C had an interrater reliability ranging from .94 to .98. No validity was present in the literature for this instrument. The DAST-C was scored using the criteria in the paper by Finson and collaborators (1995) using a checklist to measure the level of positive stereotypes of scientists held by the participants. The scores obtained were thus measures of positive stereotypy towards scientists in the samples.

The VOSTS survey (Appendix B), a tool that could help describe how students view the social nature of science and how science, was conducted. 9 of the 14 items chosen by Dogan and Abd-El-Khalik in their 2008 study were used in this study. The nature of science (NOS) aspects targeted by these 9 items included the theory-driven nature of scientific observations; tentative nature of scientific knowledge; relationship between scientific constructs (models and classification schemes) and reality; the epistemological status of different types of scientific knowledge (hypotheses, theories, and laws) and their coherence across various scientific disciplines; nature of, and relationship between, scientific theories and laws; myth of a universal and/or stepwise “Scientific Method;” the nonlinearity of scientific investigations; and the role of probabilistic reasoning in the development of scientific knowledge. These aspects of

NOS, it should be noted, had been emphasized in national science education reform documents and were considered accessible by pre-college students according to Dogan and Abd-El-Khalik (2008). VOSTS reliability is given as .84, however the validity of the process and the final instrument lies in the trust which subsequent researchers place in the comparison of the original students' responses to the final choices included in the instrument. 9 of the 14 VOSTS items were used (items 2, 9, 12, 13, and 14 were excluded) because these had the best match with the nature of science intended to be studied in the present research.

Each VOSTS response was categorized as representing a "naive" position (N), an "informed" position (I), or a position that "has merit" (M). The scoring of responses as naïve, informed, or has merit was performed as per criteria outlined in the work of Dogan and Abd-El-Khalick (2008). These positions (naïve, informed, has merit) were utilized as ordinal measures of VOSTS in data analysis. Overall, as per the National Institute for Science Education (n.d.), the more than 100 questions on the original VOSTS instrument asked students about:

1. what science and technology are;
2. how society influences science and technology;
3. how science and technology influences society;
4. how science as taught in school influences society;
5. what characterizes scientists;
6. how scientific knowledge comes about; and
7. the nature of scientific knowledge.

The VNOS (Appendix C), a conceptual diagnostic test, had three versions, all of which were open-ended. The most frequently used versions were the VNOS–B (7 items) and the VNOS–C (10 items). VNOS-B was chosen for this study, and the results were coded and quantified. No reliability or validity is found in the literature because this is an open-ended or qualitative instrument. Each instrument elucidates students' views about several aspects of "nature of science" (NOS). These NOS aspects, according to the National Institute for Science Education (n.d.), included:

1. Empirical NOS: Science is based, at least partially, on observations of the natural world.
2. Tentative NOS: Scientific knowledge is subject to change and never absolute or certain.
3. Inferential NOS: The crucial distinction between scientific claims (e.g., inferences) and evidence on which such claims are based (e.g., observations).
4. Creative NOS: The generation of scientific knowledge involves human imagination and creativity.
5. Theory-laden NOS: Scientific knowledge and investigation are influenced by scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations.
6. Social and cultural NOS: Science as a human enterprise is practiced within, affects, and is affected by, a larger social and cultural milieu.
7. Myth of the "Scientific Method": The lack of a universal step-wise method that guarantees the generation of valid knowledge.

8. Theories and Laws: Recognizing the nature of, and distinction between scientific theories and laws (e.g., lack of a hierarchical relationship between theories and laws).

Data Collection

Data were collected within one month during spring 2009. Each participant in the study received a unique identification number to maintain anonymity and confidentiality. There were absolutely no risks, discomfort, or inconvenience of any type for the study's participants, and benefits included, but are not limited to, helping to understand and improve science education and STEM degree attainment for AI students.

Research Questions and Hypotheses

The purpose of the proposed quantitative study is to examine student attitudes, perceptions and misconceptions regarding scientists and the nature of science. The following research questions establish the direction of the proposed research:

1. Do students' pictures of a scientist (DAST) vary significantly among high school grade levels, gender and traditions of AI students?
2. Do students' views on science-technology society (VOSTS) vary significantly among high school grade levels, gender and traditions of AI students?
3. Do students' views on the Nature of Science Questionnaire (VNOS) vary significantly among high school grade levels, gender and traditions of AI students?

The proposed research questions yield the following hypotheses:

H_1: Students' pictures of a scientist (DAST) vary significantly across high school grade levels, gender and traditions among AI students.

H_0: Students' pictures of a scientist (DAST) do not vary significantly across high school grade levels, gender and traditions among AI students.

H_2: Students' views on science-technology society (VOSTS) vary significantly across high school grade levels, gender and traditions among AI students.

H_0: Students' views on science-technology society (VOSTS) vary significantly across high school grade levels, gender and traditions among AI students.

H_3: Students' views on Nature of Science Questionnaire (VNOS) vary significantly across high school grade levels, gender and traditions among AI students.

H_0: Students' views on Nature of Science Questionnaire (VNOS) vary significantly across high school grade levels, gender and traditions among AI students.

Data Analysis

Data collected with the three survey instruments were analyzed using a Pearson correlation analysis, ANOVA, Chi-square test and independent samples t-test. The purpose of the independent samples *t*-test and ANOVA were to determine whether there was a statistically significant difference in measurements taken from two or more independent groups of students with respect to an average value for some dependent variable (Moore & McCabe, 2006). Pearson's correlation allowed the identification of relationships among variables, while chi-square test analyzed the variation of the responses

CHAPTER 4: RESULTS

This chapter includes the results of the analysis of the PAM that high school AI students possess regarding scientists and the nature of science. The analyses relate students' academic perceptions to student grade levels to ascertain if inquiry based education influenced the learning of students. The results are discussed vis-à-vis the following research questions.

1. Do students' pictures of a scientist (DAST) vary significantly among high school grade levels of AI students?
2. Do students' views on science-technology society (VOSTS) vary significantly among high school grade levels of AI students?

The methods of analysis conducted to answer these questions were independent samples *t*-test, analysis of variance (ANOVA), chi-square test and Pearson's correlation. The first two methods were applied to examine if there is a statistically significant difference in the scores on DAST-C between two or more groups of students (based on grade level). Pearson's correlation was used to assess the degree of association between test scores and grade levels. Chi-square test was used to analyze the variation in the frequency of students' VOSTS across school grades In addition, qualitative analysis was used to explore the responses to seven questions presented in open-ended format on the survey instrument VNOS.

Before addressing the research questions, a description of the data is in order to get preliminary indication of a possible relationship between the outcome variable students' PAM and the independent variables school grade level, gender, and tradition.

Table 1 is the summary statistics of DAST scores by school grade, gender, and tradition. There are four observed school grades, namely, 9^{th} to 12^{th} grade. Figure 1 illustrates the DAST scores in bar graphs. The scores on DAST ranged from 4.89 for twelve graders to 5.85 for ninth graders. Based on the median scores indicated below, the 10^{th} and 12^{th} graders have a central tendency of getting a score of 5, while the 9^{th} and 11^{th} graders tend to get a score of 6. This suggests the older students presented a slightly more "stereotypical" version of scientists in their drawings.

Table 1: Drawing Score by grade, gender, and tradition

Grade	N	Mean	Std. Deviation	Skewness	Median
9	42	5.86	2.031	.754	6.00
10	42	5.24	1.923	.076	5.00
11	30	5.53	1.717	.268	6.00
12	19	4.89	1.761	-1.051	5.00
Total	133	5.45	1.901	.278	5.00
Gender					
F	81	5.31	1.928	.289	5.00
M	52	5.67	1.855	.310	6.00
Total	133	5.45	1.901	.278	5.00
Cherokee					
No	72	5.71	2.045	.245	5.50
yes	61	5.15	1.682	.108	5.00
Total	133	5.45	1.901	.278	5.00

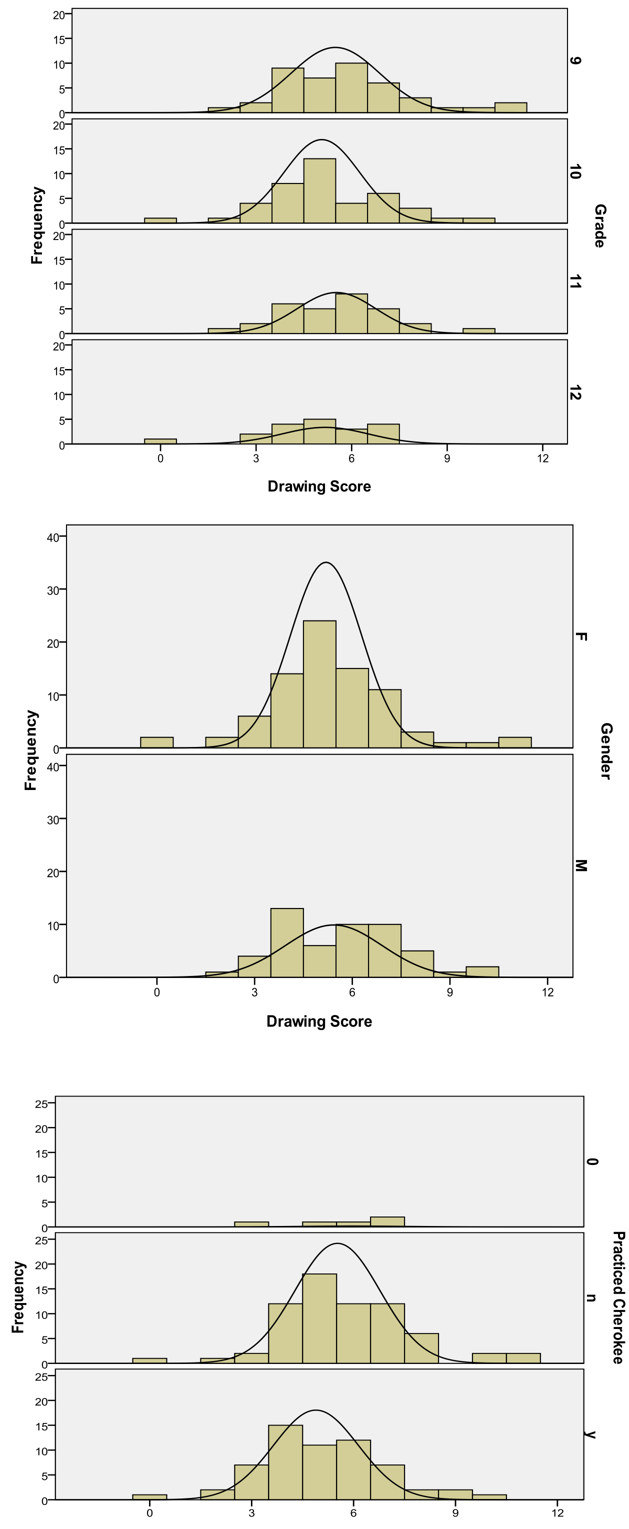

Figure 1: Histograms for Drawing Scores per Grade, Gender and Tradition

It is also shown in Table 1 that male participants appear to have higher score on DAST than female participants in terms of both mean and median scores. Students who practice more Native tradition have lower mean and median DAST scores.

VOSTS by Grade, Gender, and Tradition

Table 2 is a presentation of the percentage distribution of VOSTS positions (Naive, Merit, and Informed) by school grade, gender, and tradition for each VOSTS items. The distribution of VOSTS positions appears to vary across the school grades and across VOSTS items. Here, the percentage distribution of VOSTS positions varies across gender and VOSTS items and across tradition and VOSTS items. However, there appears no clear pattern common to all VOSTS items. This suggests a population homogeneous enough to not register significant differences in their PAM of VOSTS for the most part but we have effectively characterized the group as a whole.

Table 2: Position on VOSTS items by school grade, gender, and tradition (row percentage distribution)

		Vosts_item1_position (90111)			Vosts_item3_position (90311)		Vosts_item4_position (90411)		Vosts_item5_position (90511)		Vosts_item6_position (90521)		Vosts_item7_position (90541)			Vosts_item8_position (90621)			Vosts_item10_position (90711)			Vosts_item11_position (91011)	
		N	M	I	N	I	N	I	N	I	N	I	N	M	I	N	M	I	N	M	I	N	I
Grade	9	14	50	36	29	71	26	74	86	14	81	19	57	19	24	32	49	20	27	5	68	81	19
	10	33	38	29	21	79	26	74	90	10	74	26	57	5	38	38	50	12	38		62	69	31
	11	17	47	37	33	67	13	87	83	17	73	27	73	7	20	31	52	17	39	4	57	70	30
	12	16	37	47	5	95	26	74	79	21	68	32	42	26	32	21	63	16	16	16	68	63	37
Total		**21**	**44**	**35**	**24**	**76**	**23**	**77**	**86**	**14**	**75**	**25**	**59**	**13**	**29**	**32**	**52**	**16**	**32**	**5**	**64**	**72**	**28**
Gender	F	25	44	31	17	83	21	79	85	15	75	25	58	15	27	32	49	19	28	6	65	72	28
	M	15	42	42	35	65	27	73	87	13	75	25	60	10	31	33	56	12	37	2	61	73	27
Total		**21**	**44**	**35**	**24**	**76**	**23**	**77**	**86**	**14**	**75**	**25**	**59**	**13**	**29**	**32**	**52**	**16**	**32**	**5**	**64**	**72**	**28**
Cherokee	N	22	49	29	23	77	28	72	89	11	78	22	63	14	24	38	46	15	31	1	68	74	26
	Y	20	38	43	26	74	18	82	82	18	72	28	54	11	34	25	58	17	33	9	59	70	30
Total		**21**	**44**	**35**	**24**	**76**	**23**	**77**	**86**	**14**	**75**	**25**	**59**	**13**	**29**	**32**	**52**	**16**	**32**	**5**	**64**	**72**	**28**

Legend: N=naive, M=merit, I=informed.

Do students' pictures of a scientist (DAST) vary significantly between school grades of high school AI students?

A one-way analysis of variance of DAST score on school grade was done.[1] Four school grades were observed: 9^{th} to 12^{th} grade. A one way ANOVA test was administered to see if there is a significant effect of school grade on Student DAST scores. The null hypothesis was that there is no significant effect. The result is given in Table 3.

Table 3: A one-way ANOVA of DAST Score on school grade

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.914	3	4.971	1.388	.249
Within Groups	462.018	129	3.582		
Total	476.932	132			

Note dependent variable: DAST score, independent variable: school grade

There is no significant effect of the school grade so the null hypothesis cannot be rejected. This result suggests that student score on DAST is independent of their school grades.[2]

Do students' pictures of a scientist (DAST) vary significantly among gender groups of AI high school students?

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[1] The test can also be carried out using independent sample t-test, but a one way ANOVA would do better because the observed school grades are more than two. Multiple comparisons of scores are easier with ANOVA than with independent sample t-test.
[2] There is no point in conducting POST HOC tests to compare the DAST scores between each pair of grades since the overall result is insignificant.

To answer this question, an independent samples t-test was conducted.[3] The null hypothesis is that there is no significant difference in mean scores on DAST between male and female participants. Table 4 shows that the null hypothesis could not be rejected, meaning there is no significant variation in mean DAST scores between male or female participants.

Table 4: Independent Samples t-test Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Drawing_Score	Equal variances assumed	.439	.509	-1.080	131	.282	-.36443	.33756
	Equal variances not assumed			-1.089	111.942	.279	-.36443	.33471

Do students' pictures of a scientist (DAST) vary significantly among levels of tradition of AI high school students?

[3] There are only two gender groups, so this is easier handled with independent sample t-test than with ANOVA, although ANOVA would not give different result.

To answer this question, an independent samples t-test was conducted.[4] The null hypothesis is that there is no significant difference in mean DAST scores between those who practiced Native traditions and those who did not. Table 5 shows that the null hypothesis cannot be rejected, meaning there is no significant variation in mean DAST scores between those who practice Cherokee traditions and those who do not.

Table 5: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Drawing_Score	Equal variances assumed	2.265	.135	-1.708	131	.090	-.561	.328
	Equal variances not assumed			-1.735	130.895	.085	-.561	.323

Table 6 presents the analysis of variance results of DAST scores on grade, gender, and tradition variables together. The table also shows if there was an interaction effect,

[4] There are only two gender groups, so this is easier handled with independent sample t-test than with ANOVA, although ANOVA would not give different result.

i.e., all possible interactions between grade, gender, and Native tradition. Table 7 confirms the results in Tables 3 to 5, where it was shown that there is no significant effect of the grade, gender, and tradition variables on DAST score.

Table 6: Analysis of Variance, Dependent Variable: Drawing Score (Tests of Between-Subjects Effects)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	113.738(a)	36	3.159	.819	.747
Intercept	1411.705	1	1411.705	365.786	*.000*
Grade	9.393	3	3.131	.811	.491
Gender	1.165	1	1.165	.302	.584
Cherokee	5.858	1	5.858	1.518	.221
Grade * gender	7.345	3	2.448	.634	.595
Grade * Cherokee	5.174	3	1.725	.447	.720
Gender_new * Cherokee	9.688	1	9.688	2.510	.116
Grade * gender_new * Cherokee	6.380	2	3.190	.827	.441
Error	362.781	94	3.859		
Total	4379.000	131			
Corrected Total	476.519	130			

a R Squared = .239 (Adjusted R Squared = -.053)

Correlation Analysis

As an alternative test to ANOVA and independent-samples t-test, Pearson's correlation analysis was also conducted to examine if there was a significant association between DAST score and each of the grade, gender, and tradition variables. A correlation analysis showed the direction of relationship between drawing scores and each of the variables grade, gender, and tradition variables. The gender variable was redefined to take a value of 1 if male, and zero otherwise. The test results are presented in Table 7.

Table 7: Pearson's correlations

		Drawing Score
Grade	Pearson Correlation	-.137
	Sig. (2-tailed)	.116
	N	133
Gender new	Pearson Correlation	.094
	Sig. (2-tailed)	.282
	N	133
Cherokee	Pearson Correlation	-.148
	Sig. (2-tailed)	.090
	N	133

** Correlation is significant at the 0.01 level (2-tailed).

In Table 7, no significant correlation was detected between DAST score and school grade, gender, and tradition variables. This confirmed the results in Tables 3 to 7.

Do students' views on science-technology society (VOSTS) vary significantly across school grades?

A Chi-square test was run since both the dependent and independent variables in this case were categorical variables. Each VOSTS response was categorized as representing a "naive" position (N), an "informed" position (I), or a position that "has merit" (M). Has school grade any affect on whether students' VOSTS position is naive, merit based, or informed? The cross tabulation of the VOSTS positions by grade is given in Table 2. Table 9 presents the chi-square test results in order to assess the research question.

As seen in Table 8, there is no significant relationship between school grade and any of the VOSTS positions. For each chi-square test, three alternative p-values were given. None of these values was smaller or equal to the acceptable level of significance, which is 0.05.

Table 8: Chi-square test

Pearson Chi-Square	Value	df	Asymp. Sig. (2-sided)
Grade * Vosts_item1_position	6.735	6	.346
Grade * Vosts_item3_position	5.822	3	.121
Grade * Vosts_item4_position	2.156	3	.541
Grade * Vosts_item5_position	1.627	3	.653
Grade * Vosts_item6_position	1.313	3	.726
Grade * Vosts_item7_position	11.524	6	.073
Grade * Vosts_item8_position	2.560	6	.862
Grade * Vosts_item10_position	10.450	6	.107
Grade * Vosts_item11_position	2.656	3	.448

As an alternative to the chi-square test, a one-way ANOVA of VOSTS position scores on school grade and gender was conducted. To generate the VOSTS position scores, a dummy variable was generated for each position in every VOSTS items. The position dummy values were then summed up over like positions over VOSTS items to give a total score for each VOSTS position. These results in three score variables referred to, hereafter, as *naive_score, merit_score*, and *informed_score.* A one-way analysis of variance was then conducted to test if these scores vary significantly across school grade. The result for the grade effect is given in Table 9.

Table 9: A one-way ANOVA of VOSTS position scores on school grade

		Sum of Squares	df	Mean Square	F	Sig.
naive_score	Between Groups	17.060	3	5.687	3.272	.023
	Within Groups	224.173	129	1.738		
	Total	241.233	132			
merit_score	Between Groups	3.720	3	1.240	1.594	.194
	Within Groups	100.355	129	.778		
	Total	104.075	132			
informed_score	Between Groups	8.807	3	2.936	1.441	.234
	Within Groups	262.863	129	2.038		
	Total	271.669	132			

The results in Table 10 show that the null hypothesis that *naïve_score* is independent of school grade. It is rejected with a level of significance of 0.05, meaning the naivete of students' views on science-technology society depends on their school grade. However, the results did not show which grades were responsible for the significant results. The Benferroni test was then conducted to identify the grades which were causing the significant variation in *naïve score.* The result is given in Table 10.

Table 10: Comparison of *naive_score* across grade groups

(I) Grade	(J) Grade	Mean Difference (I-J)	Std. Error	Sig.
9	10	-.167	.288	1.000
	11	.010	.315	1.000
	12	.941	.364	.066
10	9	.167	.288	1.000
	11	.176	.315	1.000
	12	1.108(*)	.364	.017
11	9	-.010	.315	1.000
	10	-.176	.315	1.000
	12	.932	.387	.104
12	9	-.941	.364	.066
	10	-1.108(*)	.364	.017
	11	-.932	.387	.104

* The mean difference is significant at the .05 level.

Table 10 shows that 10^{th} graders have a significantly higher mean *naive_score* than 12^{th} graders. There is no significant difference in the mean *naive_score* between other grades. 10^{th} and 12th graders are, therefore, responsible for the overall significant relationship between *naive_score* and school grade, as shown in Table 10. The null hypotheses that *merit_score* and *informed_score* are independent of school grade could not be rejected (Table 9). This means that merit based and informed views do not depend on school grade.

Table 11 presents the results for the one-way ANOVA of VOSTS position scores on gender. The results show no significant effect of gender on VOSTS positions.

Table 11: A one-way ANOVA of VOSTS position scores on gender

		Sum of Squares	Df	Mean Square	F	Sig.
naive_score	Between Groups	2.160	1	2.160	1.184	.279
	Within Groups	239.073	131	1.825		
	Total	241.233	132			
merit_score	Between Groups	.050	1	.050	.063	.803
	Within Groups	104.025	131	.794		
	Total	104.075	132			
informed_score	Between Groups	2.373	1	2.373	1.154	.285
	Within Groups	269.296	131	2.056		
	Total	271.669	132			

Table 12 presents the results for the one-way ANOVA of VOSTS position scores on tradition. The results show a weak significant (p=.057) effect of tradition VOSTS positions. Participants who did not practice their native language at home were less naïve in their views on science-technology society.

Table 12: A one-way ANOVA of VOSTS position scores on tradition

		Sum of Squares	Df	Mean Square	F	Sig.
naive_score	Between Groups	6.597	1	6.597	3.683	.057
	Within Groups	234.636	131	1.791		
	Total	241.233	132			
merit_score	Between Groups	.084	1	.084	.105	.746
	Within Groups	103.992	131	.794		
	Total	104.075	132			
informed_score	Between Groups	4.252	1	4.252	2.083	.151
	Within Groups	267.417	131	2.041		
	Total	271.669	132			

Tables 13 through 15 present analysis of variance of VOSTS position scores on the grade, gender, and tradition variables together. The tables also tested if there was an interaction effect, i.e., on all possible interactions between grade, gender, and tradition. In Table 13, the dependent variable is *Naïve_Score*. The result shows that there is a significant relationship between the dependent variable and the independent variables. *Naïve_score* depends significantly on grade. These results are consistent with the results in Tables 9 through 12. The table also reports significant effects of the interaction between grade and gender, and the interaction between age and tradition with *Naïve_score.*

Table 13: Two way ANOVA: Dependent Variable: naive_score

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	*115.282(a)*	*36*	*3.202*	*2.490*	*.000*
Intercept	1013.153	1	1013.153	787.721	.000
Grade	29.999	3	10.000	7.775	.000
Gender_new	1.843	1	1.843	1.433	.234
Cherokee	*9.245*	*1*	*9.245*	*7.188*	*.009*
*Grade * gender_new*	*10.430*	*3*	*3.477*	*2.703*	*.050*
Grade * Cherokee	8.369	3	2.790	2.169	.097
gender_new * Cherokee	.625	1	.625	.486	.487
Grade * gender_new * Cherokee	.749	2	.374	.291	.748
Error	120.901	94	1.286		
Total	2596.000	131			
Corrected Total	236.183	130			

a R Squared = .488 (Adjusted R Squared = .292)

In Table 14, the dependent variable is *merit_score.* The results show that there is no significant relationship between the dependent variable and the independent variables. This result is consistent with the corresponding results in tables 9 through 12.

Table 14: Dependent Variable: merit_score (Tests of Between-Subjects Effects)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.

Corrected Model	30.734(a)	36	.854	1.134	.310
Intercept	60.631	1	60.631	80.507	.000
Grade	6.290	3	2.097	2.784	.045
Gender_new	.291	1	.291	.386	.536
Cherokee	.845	1	.845	1.122	.292
Grade * gender_new	1.705	3	.568	.755	.522
Grade * Cherokee	1.400	3	.467	.620	.604
Gender_new * Cherokee	1.024	1	1.024	1.360	.247
Grade * gender_new * Cherokee	3.544	2	1.772	2.353	.101
Error	70.793	94	.753		
Total	271.000	131			
Corrected Total	101.527	130			

a R Squared = .303 (Adjusted R Squared = .036)

In table 15, the dependent variable is *informed_score.* The results showed that there is a significant relationship between the dependent variable and the independent variables. The variables grade and tradition have a significant effect on *informed_score.* These results are not consistent with the corresponding results in tables 9 through 12. The table also reports a significant effect of the interaction between grade and gender (1=male, 0=female) on informed choice.

Table 15: Dependent Variable: informed_score (Tests of Between-Subjects Effects)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	107.146(a)	36	2.976	1.854	.009

Intercept	611.779	1	611.779	381.056	.000
Grade	*14.912*	*3*	*4.971*	*3.096*	*.031*
gender_new	.919	1	.919	.572	.451
Cherokee	*14.545*	*1*	*14.545*	*9.059*	*.003*
*Grade * gender*	*15.865*	*3*	*5.288*	*3.294*	*.024*
Grade * Cherokee	2.819	3	.940	.585	.626
gender_new * Cherokee	2.826	1	2.826	1.760	.188
Grade * gender_new * Cherokee	7.335	2	3.668	2.284	.107
Error	150.915	94	1.605		
Total	1930.000	131			
Corrected Total	258.061	130			

a R Squared = .415 (Adjusted R Squared = .191)

Correlation Analysis

As an alternative to ANOVA, a Pearson's correlation analysis is conducted to examine if the newly generated VOSTS position score variables were correlated with school grade and gender. Correlation also indicates the direction of the relationship between the VOSTS position scores and the variables grade, gender, and tradition. The result is given in Table 16. The results in Table 16 show a significant negative correlation between *naïve_score* and grade. This suggests that students' VOSTS position becomes less naive as they advance in school grade.

Table 16: Pearson's Correlations between VOSTS positions

	Grade	gender	Cherokee

naive_score	Pearson Correlation	-.182(*)	.095	-.165
	Sig. (2-tailed)	.036	.279	.057
	N	133	133	133
merit_score	Pearson Correlation	.048	-.022	.028
	Sig. (2-tailed)	.582	.803	.746
	N	133	133	133
informed_score	Pearson Correlation	.148	-.093	.125
	Sig. (2-tailed)	.089	.285	.151
	N	133	133	133

** Correlation is significant at the 0.01 level (2-tailed);* Correlation is significant at the 0.05 level (2-tailed).

Qualitative Analysis

Seven questions included on the survey were in the form of open-ended questions.

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.
2. What does an atom look like? How certain are scientists about the nature of the atom? What specific evidence do you think scientists use to determine what an atom looks like?
3. Is there a difference between scientific theory and a scientific law? Give an example to illustrate your answer.
4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain your answer and provide examples if appropriate.
6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.
7. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

In order to examine the answers to these questions, qualitative analysis was used to code the answers given by students into common invariant constituents (categories or themes). Tables 17-23 illustrate the common invariant constituents or themes and frequencies of responses among students surveyed.

Table 17: VNOS-B Question 1

Q1: After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
Yes, theories change, no explanation	87	47
Yes, things change every day or over time/new discoveries made/knowledge changes	28	15
Yes, different for everyone, not everyone gets same results/right until proven wrong/people think differently	21	11
No, theories cannot change	20	11
Yes, theories are not for sure things, are opinion/what we think, not actually true	9	5
Don't know	9	5
Yes, if experiment changes, then the theory could too. Opinions change with experiment/testing of hypotheses.	7	4
Need to search for answers don't know, we learn from it	4	2

Note: all other responses received only a single response

Table 18: VNOS-B Question 2

Q2: What does an atom look like? How certain are scientists about the nature of the atom? What specific evidence do you think scientists use to determine what an atom looks like?

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
They use microscopes	38	25
Don't Know	37	24
Scientists are certain what it looks like	24	16
Looks like a small dot, circle, or ball/small & round	19	13
Very small	11	7
Don't think scientists know what looks like; it changes every day; that's why they study it	10	7
They aren't certain, just guessing	7	5
A ball with protons, neutrons, electrons floating around it/ball with rings	6	4

Note: all other responses received < 3 responses.

Table 19: VNOS-B Question 3

Q3: Is there a difference between scientific theory and a scientific law? Give an example to illustrate your answer.

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
Yes, law is how it is, theory is how they think; theory is a guess, law has been proven; theory is an idea or opinion, law is fact	48	42
No, no difference	19	17
Don't know, not sure	16	14
Yes, difference (no explanation, or only a single response of the particular explanation)	27	23
Yes, theory turns into law, theory has to come true to become law.	5	4

Table 20: VNOS-B Question 4

Q4: How are science and art similar? How are they different?

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
Both create new things, are creative, use imagination; both can be invented; both experiment with things	26	20
Don't Know	23	18
Both draw things; use illustrations; are colorful	14	11
Art is drawing things	9	7
Science is making theories, hypotheses, conclusions	9	7
In science, you figure stuff out (the scientific world), discover things	8	6
Don't see how are similar/not similar	7	5
Science is more academic, has math, is logical, technical, more complex	7	5
Different subjects/ideas/purpose	6	5
Basically the same/similar	5	4
One uses brushes, one a laboratory	4	3
Art can do anything you want/ express yourself in any way	4	3
Both discover things/explore	3	2
Both you have to think about what to do/use your brain	3	2

Science is boring/complex and art is fun	3	2

Note: all other responses received < 3 responses.

Table 21: VNOS-B Question 5

Q5: Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain you answer and provide examples if appropriate.

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
I don't Know	17	20
Yes, in order to think how something works, have to imagine and when find something wonder what it's for/experimenting, investigating, and discovering/ only way to figure out answer to problem	17	20
Yes (no explanation)	13	15
Yes, creativity & imagination are part of what a scientist is	6	7
No, use facts	6	7
Yes, use it through the whole process/during they have to keep thinking	6	7
Yes, because of originality, because they thought of it to begin with	4	5
Possibly/think they do, maybe would help	4	5
Yes, can make them better	4	5
Yes, have to / can't just go by book / would be more difficult without	4	5
Yes, use creativity & imagination when trying something new/test things in a new or different way.	3	4

Note: all other responses received < 3 responses. Total yes score=68, no=9

Table 22: VNOS-B Question 6

Q6: Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
Yes, opinion is what you think and knowledge is what is true/is fact; knowledge is what you know, opinion is a guess; knowledge is based on facts, opinions you think based on knowledge	54	55
No, not different/basically the same; all theories and laws are opinion	22	22
I don’t know	11	11
Yes (no explanation)	8	8
Scientific knowledge comes from discoveries, opinion is based on fact	3	3

Note: all other responses received a single response.

Table 23: VNOS-B Question 7

Q7: Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

Invariant Constituent	# of participants to offer this response	% of participants to offer this response
Because scientist see things (data) differently and form different opinions; different interpretations; they have different theories, hypotheses, viewpoints, opinions, ideas; they think differently	45	56
I don't know	20	25
Scientist make different observations, notice different things, make different discoveries	5	6
Do different experiments/ do something different	4	5
There is no proof to give the right answer; no one knows	3	4
Some may calculate wrong, use data wrong / errors	3	4

Note: all other responses received <3 responses.

Regarding the first question on whether a theory can ever change, the majority of the students (63%) responded that theories indeed change, though offered no explanation for their answer. In contrast, 14% of students did not believe theories could change. Of the respondents who offered an explanation for their response, the central theme was that theories change because things change over time, knowledge changes, and new discoveries are made (20%). In addition, students believed that theories change because people think differently and not everyone gets the same results (15%).

The second question asked about what an atom looks like and how certain scientists are about the nature of an atom. Central to this question were the responses that scientists use microscopes (27%), and that the student respondents did not know (26.6%). Students felt more strongly that scientists were certain what an atom looks like (17%) and the students most frequently described an atom to be a small dot, circle, or round ball (14%).

The students were asked if they thought there was a difference between scientific theory and law. The highest frequency of responses included that there was a difference in that law is fact/proven and theory is an opinion or idea (35%). Fourteen percent of respondents thought that there was no difference, and 11.5% did not know. Twenty-seven students (19%) also believed that there is a difference between the two, but offered no explanation for their response.

The central themes to the fourth question, whether art and science are similar and how, include that both art and science create new things, are creative, use imagination, and experiment with things and can be invented (19%). Twenty-three students (16.5%) did not know the answer. Other responses that were slightly more common included that both draw things and use illustrations (are colorful) (10%), that art is drawing (6.5%), and that science is making theories, hypotheses, and conclusions (6.5%). Only 7 students (5%) believed that the two were not similar.

Question five asked whether the students believed scientists use creativity and imagination. The two highest frequency responses for this question included a response of I don't know (12%) and that scientists do use creativity and imagination in order to think of how something works and wonder what it is for, for experimenting, investigating, and discovering, and as the only way to figure out a problem (12%). Thirteen additional students believed that scientists use creativity and imagination, but offered no explanation for their response (9%), while another 4% believe that creativity and imagination are part of what a scientist is and 4% believe they use it throughout the whole process. A total of six students (4%) responded that scientists do not use creativity and imagination, noting that they use facts.

In regard to whether there is a difference between scientific knowledge and opinion, student responses demonstrated clear themes. The majority of respondents agreed that scientific knowledge is fact or based on fact/what you know while opinion is a guess/what you think (39%). However, 16% believed that they are not different, and that they are basically the same. Eight percent of respondents did not know.

The last question revealed beliefs of students on how different scientists can have different conclusions given the same information. Similar to results of question four, this question revealed a clear theme. The highest frequency response included that different conclusions are possible because scientists see things (data) differently and have different opinions, interpretations, viewpoints, ideas, theories, and hypotheses (i.e., they think differently) (32%). Fourteen percent of respondents did not know, and all other frequencies were relatively low.

Summary

The purpose of this chapter was to analyze and summarize the data related to the PAM of AI high school students in relation to scientists and the nature of science. The analysis found no significant effect of school grade and gender on students' DAST. The analysis showed significant effect of school grade on students' naive views on science-technology society. The analysis also showed that students' views on science-technology society gets less naïve and more informed as they advance in grade.

CHAPTER 5: CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

Many AI students tend to drop or avoid high school math and science courses, which are not specifically required for graduation, resulting in a lack of the necessary preparation to pursue scientific or technical careers. AI students are the least represented group in STEM majors and careers, both in numbers as well as proportionally (Demmert, 2001). In addition, under-representation is compounded by the gap in the literature regarding the science education of AI students and its connections to achievement in higher education and STEM majors. This gap highlights the need for studies to examine the perceptions, attitudes, and misconceptions of AI high school students about scientists and the nature of science.

Establishing a PAM baseline is imperative to introducing teaching initiatives in schools, particularly the learning cycle approach that research has shown to be the most effective way to structure inquiry- based science and also honing an essential element in science learning-- critical thinking abilities (NSTA, 2004). Teachers must be aware of the PAM to customize teaching approaches and styles that respond to the AI's educational perspective. AI students' PAM can gauge their participation and success in STEM, along with grades, college entrance and retention rates, and other factors.

Conclusions

The current quantitative comparative and qualitative study sought to measure AI students' perceptions, attitudes, and misconceptions of scientists and the nature of science. The study also explored the impact student school grades, gender and tradition had on the PAM that high school AI students possessed regarding scientists and the nature of science.

Research Questions

Research Question 1. Do students' pictures of a scientist (DAST) vary significantly among high school grade levels of AI students?

The students' mental image of a scientist was measured using a Draw-A-Scientist Test (DAST). The school grade level of students was considered as an independent variable. The results showed that the null hypothesis, wherein there is no significant effect of the school grade, could not be rejected. This suggests that students' scores on DAST are independent of their school grades. An independent samples t-test was conducted to evaluate if a student's picture of a scientist (DAST) varied significantly between gender groups of AI high school students. The result showed that there is no significant variation in mean DAST scores between male and female participants. An independent samples t-test was also conducted to test if a student's picture of a scientist (DAST) varied significantly between traditions of AI high school students. The results indicated that there is no significant variation in mean DAST scores between those who practice native languages and those who do not. Overall, the results of the statistical analysis show that students' DAST are not influenced by their gender, grade level, or their level of tradition, contrasting past research on the topic area.

Research Question 2. Do students' views on science-technology society (VOSTS) vary significantly between high school grade levels of AI students?

The VOSTS survey was to describe how students viewed the social nature of science and how science is conducted. Each VOSTS response was categorized as representing a “naive” position (N), an “informed” position (I), or a position that “has merit” (M).

To address this question, a chi-square test was conducted to assess if the VOSTS positions were associated with school grade. The results revealed that there is no significant relationship between school grade and any of the VOSTS positions. In addition, a one-way ANOVA of VOSTS position scores with school grade, and gender was conducted. The results showed that the null hypothesis, wherein *naive position score* was independent of school grade, was rejected which implies that the naivete of students’ views on science-technology society depends on their school grade level. The Bonferroni test conducted thereafter indicated that 10^{th} graders had significantly higher mean *naive position score* than 12^{th} graders. There was no significant difference in the mean *naive position score* between other grades. The results also showed that *merit position score* and *informed position score* were independent of school grade which implies that merit based and informed views do not depend on school grade. The results generated by ANOVA on VOSTS position scores on gender showed that there is no significant effect of students’ gender on any of the students VOSTS position scores. The results generated by ANOVA on VOSTS position scores on tradition showed a weak significant ($p=.057$) effect of tradition on naive position score. Participants who did not practice native languages were less naïve in their views on science-technology society. A Pearson’s correlation analysis was also conducted to examine if the VOSTS position scores are correlated with school grade, and gender. The results showed a significant negative correlation coefficient between *naïve position score* and grade.

In answer to the research question, school grade and AI's practice of the native language seem to be factors in shaping students' ideas about the social nature of science and how it is conducted. Students' VOSTS position gets less naive as they advance in school grade. Participants who did not practice native languages were less naïve in their views on science-technology society.

Research Question 3. Do students' views on the Nature of Science Questionnaire (VNOS) vary significantly between high school grade levels of AI students?

The VNOS, a conceptual diagnostic test (version B) includes seven open ended questions to elucidate students' views about several aspects of "nature of science" (NOS). Themes and patterns emerged from analyzing responses to the survey questions. Students' VNOS do not vary significantly because the frequency of answers to most questions was low. Only one question had a response with a frequency exceeding half of the sample population that completed the survey.

Previous studies identify a number of factors influencing attitudes towards scientists and science in general. These are broadly defined as gender, personality, structural variables and curriculum variables. Of all these, the most significant is gender for, as Gardner (1995) commented, 'sex is probably the most significant variable related towards students' attitude to science. What is clear from literature on this subject is that girls' attitudes to science are significantly less positive than boys (Breakwell and Beardsell 1992; Jones, 2000). Other studies examine the relationship between socio-economic class and attitudes towards science. Breakwell (1996) reported that involvement on extra-curricular activities is not significantly correlated to students' attitudes toward science. Educators discover that students have different backgrounds and life circumstances, and that these differences can be profound in regard to the contrast between mainstream students and minorities, such as AI (Gardner, 1995). A program of differentiation is a systematic way of meeting the needs of all students (Tomlinson, 2004).

Based on the analysis of the data of this study, themes emerged concerning the belief and perception of AI students on the nature of science and scientists. Though the data present positive results in this regard, as the majority of the students possess beliefs and perceptions about science that would be productive to science learning and can be considered informed. A sizable number of such students are unable to defend their viewpoints in meaningful terms. Moreover, a significant number of students still possess discouraging and misled viewpoints and perceptions about science. These results imply a great potential for inquiry-based instructional approaches to positively impact students' PAM.

The results of the current research reveal that there is no significant effect of school grade level, gender, or tradition on students' DAST. Significant effects of school grade on students' naive views on science-technology-society exist. The analysis also reveals that students' views on science-technology society become less naïve and more informed as they advance in grade level. The findings of the current study do not support previous conclusions that gender is a significant factor in influencing attitudes toward science in general.

Limitations

This study is limited in several ways because of the nature of the study. One major limitation is the sampling frame. Sampling from only one school has the potential to be a limiting factor, as well as the potential homogeneous makeup of the sample and the inability to generalize the findings. Selecting participants from a specific pool of students creates a homogeneous sample for views and perceptions of AI students.

Researcher bias is also a limitation for the qualitative survey instrument because the researcher serves as an instrument in the study for data collection and analysis. The findings of the study could be biased because of the influence on the interpretation of the survey responses. In addition, a pilot study was not conducted prior to the survey to evaluate the validity and reliability of the survey instrument, and check how well the participants understand the survey questions.

Implications of the Study

AI students are the least represented group in STEM majors and careers, both in sheer numbers as well as proportionally. The increasing attention to this phenomenon is driven by recognition that all is not well with science education, particularly for minorities. Science has increasing significance in contemporary life, both at a personal and a societal level. However, there is a large gap in the literature with regard to science education of AI students and its connections to achievement in higher education and STEM majors. The current study sought to measure AI students' perceptions, attitudes, and misconceptions of scientists and the nature of science. The study also evaluated the impact of school grades, gender, and level of traditional practices on the PAM the AI students possessed regarding scientists and the nature of science. The author and researcher suggests that a combination of the approaches to STEM instruction discussed in the literature review, specifically formal and informal inquiry-based and culturally relevant instruction, would best serve the student population in question and produce measurable and positive changes in their PAMs of scientists and the nature of science. It may also positively impact the students' critical thinking and problem solving skills, as well as instill the knowledge and confidence that may propel them into STEM related majors and careers.

Recommendations for Future Research

This survey study focused on one AI school, which limits the generalization of the study findings and implications. It is recommended that future studies should have larger representative sample size for the purpose of increasing the validity of the findings. Sampling participants from multiple schools will improve the present design's restriction of range. Additional studies could also take into consideration the teacher factor, socio-economic status, and highest education level of students' family. Differences in evaluating PAM AI students had toward scientists and the nature of science may be derived from such studies.

Summary

This survey based comparative study employed quantitative and qualitative approaches to measure the perceptions, attitudes, and misconceptions of AI students toward scientists and the nature of science. The study also explored the impact of school grade level, gender, and tradition on PAM toward scientists and science within an AI tribal school. Based on the analysis of quantitative data, there was no significant difference in students' DAST scores between genders and among different school grades levels. The analysis showed a significant effect of school grade on students' naive views on science-technology society and those students' views on science-technology society get less naïve and more informed as they advance in grade. This study represents just one piece of the puzzle we attempt to solve as we continue the push for social justice, equity, self-determination, and self-sufficiency for American Indians and other minorities.

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Appendix A

DAST-C

Number________________Grade/Age_______________Gender___________________

On the line below, list the language(s) spoken in your home, in order, beginning with the most used and followed by the least used.

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Draw a scientist at work in the space below.

Explain what the scientist is doing.

List examples of where, when, and how you learn science.

Appendix B

Selected VOSTS Items

Number________________Grade/Age_______________Gender___________________

Please circle one choice per question.

90111—Scientific observations made by competent scientists will usually be different if the
scientists believe different theories.

Your position, basically:
(M) A. Yes, because scientists will experiment in different ways and will notice different things.
(I) B. Yes, because scientists will think differently and this will alter their observations.
(N) C. Scientific observations will not differ very much even though scientists believe different
theories. If the scientists are indeed competent their observations will be similar.
(N) D. No, because observations are as exact as possible. This is how science has been able to
advance.
(N) E. No, observations are exactly what we see and nothing more; they are the facts.

90311—When scientists classify something (e.g., a plant according to its species, an element
according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong.

Your position, basically:
(N) A. Classifications match the way nature really is, because scientists have proven them over many years of work.
(N) B. Classifications match the way nature really is, because scientists use observable characteristics when they classify.
(I) C. Scientists classify nature in the most simple and logical way, but their way is not necessarily the only way.
(I) D. There are many ways to classify nature, but agreeing on one universal system allows scientists
to avoid confusion in their work.

(I) E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.
(I) F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is so diverse. Thus, scientists could correctly use more than one classification scheme.

90411—Even when scientific investigations are done correctly, the knowledge that scientists
discover from those investigations may change in the future.

Your position, basically:
Scientific knowledge changes:
(I) A. because new scientists disprove the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigation.
(I) B. because the old knowledge is reinterpreted in light of new discoveries. Scientific facts can
change.
(N) C. Scientific knowledge APPEARS to change because the interpretation or the application of
the old facts can change. Correctly done experiments yield unchangeable facts.
(N) D. Scientific knowledge APPEARS to change because new knowledge is added on to old
knowledge; the old knowledge doesn't change.

90511—Scientific ideas develop from hypotheses to theories, and finally, if they are good enough, to being scientific laws.

Your position, basically:
Hypotheses can lead to theories, which can lead to laws:
(N) A. because a hypothesis is tested by experiments, if it proves correct, it becomes a theory. After a theory has been proven true many times by different people and has been around for a long time, it becomes a law.
(N) B. because a hypothesis is tested by experiments, if there is supporting evidence, it's a theory. After a theory has been tested many times and seems to be essentially correct, it's good enough to become a law.
(N) C. because it is a logical way for scientific ideas to develop.

(N) D. Theories cannot become laws because they both are different types of ideas. Theories are
based on scientific ideas, which are less than 100% certain, and so theories cannot be proven true. Laws, however, are based on facts only and are 100% sure.
(I) E. Theories cannot become laws because they both are different types of ideas. Laws describe
things in general. Theories explain these laws. However, with supporting evidence, hypotheses may become theories (explanations) or laws (descriptions).

90521—When developing new theories or laws, scientists need to make certain assumptions about nature (e.g., matter is made up of atoms). These assumptions must be true in order for science to progress properly.

Your position, basically:
Assumptions MUST be true in order for science to progress:
(N) A. because correct assumptions are needed for correct theories and laws. Otherwise, scientists would waste a lot of time and effort using wrong theories and laws.
(N) B. otherwise society would have serious problems, such as inadequate technology and
dangerous chemicals.
(N) C. because scientists do research to prove their assumptions true before going on with their
work.
(N) D. It depends. Sometimes science needs true assumptions in order to progress. But sometimes history has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.
(I) E. It doesn't matter. Scientists have to make assumptions, true or not, to get started on a project. History has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.
(N) F. Scientists do not make assumptions. They research an idea to find out if the idea is true. They do not assume it is true.

90541—Good scientific theories explain observations well. But good theories are also simple
rather than complex.

Your position, basically:

(N) A. Good theories are simple. The best language to use in science is simple, short, direct
language.
(N) B. It depends on how deeply you want to get into the explanation. A good theory can explain
something either in a simple way or in a complex way.
(I) C. It depends on the theory. Some good theories are simple, some are complex.
(N) D. Good theories can be complex, but they must be able to be translated into simple language if they are going to be used.
(M) E. Theories are usually complex. Some things cannot be simplified if a lot of details are
involved.
(M) F. Most good theories are complex. If the world was simpler, theories could be simpler.

90621—The best scientists are those who follow the steps of the scientific method.

Your position, basically:
(N) A. The scientific method ensures valid, clear, logical, and accurate results. Thus, most scientists will follow the steps of the scientific method.
(N) B. The scientific method should work well for most scientists; based on what we learned in
school.
(M) C. The scientific method is useful in many instances, but it does not ensure results. Thus, the
best scientists will also use originality and creativity.
(I) D. The best scientists are those who use any method that might get favorable results (including
the method of imagination and creativity).
(M) E. Many scientific discoveries were made by accident, and not by sticking to the scientific
method.

90711—Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what probably might happen. They cannot tell what will happen for certain.

Your position basically:
Predictions are NEVER certain:
(I) A. because there is always room for error and unforeseen events that will affect a result. No one can predict the future for certain.
(I) B. because accurate knowledge changes as new discoveries are made, and therefore predictions will always change.
(N) C. because a prediction is not a statement of fact. It is an educated guess.
(M) D. because scientists never have all the facts. Some data are always missing.
(N) E. It depends. Predictions are certain, only as long as there is accurate knowledge and enough information.

91011—For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists discover scientific LAWS. Others think that scientists invent them. What do you think?

Your position, basically:
Scientists discover scientific laws:
(N) A. because the laws are out there in nature and scientists just have to find them.
(N) B. because laws are based on experimental facts.
(N) C. but scientists invent the methods to find those laws.
(N) D. Some scientists may stumble onto a law by chance, thus discovering it. But other scientists may invent the law from facts they already know.
(I) E. Scientists invent laws, because scientists interpret the experimental facts that they discover.
Scientists do not invent what nature does, but they do invent the laws that describe what nature does.

Appendix C

Number________________Grade/Age_______________Gender___________________

Please write your responses in the space below.

VNOS – Form B
1. After scientists have developed a theory (e.g. atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples. 2. What does an atom look like? How certain are scientists about the nature of the atom? What specific evidence do you think scientists use to determine what an atom looks like? 3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer. 4. How are science and art similar? How are they different? 5. Scientists perform experiments/investigations when trying to solve problems. Other than the planning and design of these experiments/investigations, do scientists use their creativity and imagination during and after data collection? Please explain you answer and provide examples if appropriate. 6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer. 7. Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?