

# **Effectiveness of inquiry based and teacher directed instruction in an Alabama elementary school**

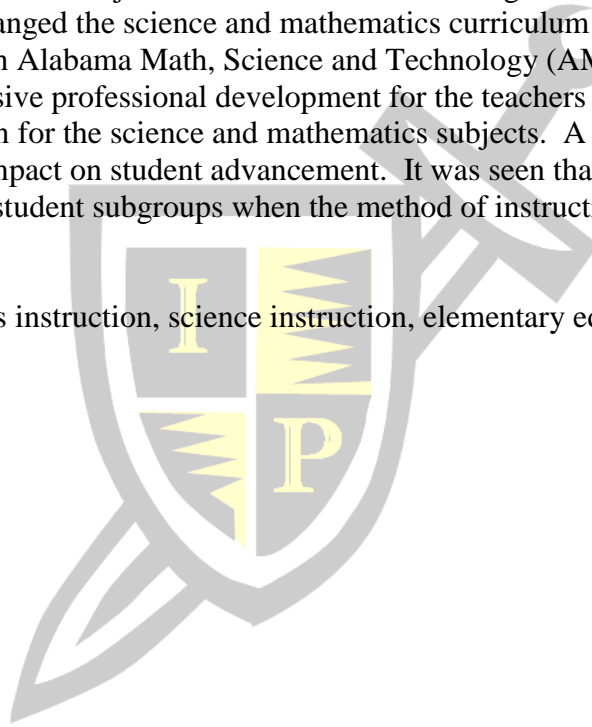
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## **ABSTRACT**

This research analyzed the teacher-directed instruction against the effectiveness of inquiry-based instruction at a subject school in Alabama for 5<sup>th</sup> grade science and mathematics. The Alabama school changed the science and mathematics curriculum for a period of 3 years and in the process became an Alabama Math, Science and Technology (AMSTI) school. During the process there was extensive professional development for the teachers and their efforts to apply inquiry-based instruction for the science and mathematics subjects. A statistical analysis was done to determine the impact on student advancement. It was seen that there was a significant improvement for many student subgroups when the method of instruction followed inquiry-based techniques.

Keywords: mathematics instruction, science instruction, elementary education



## INTRODUCTION

Today there is more of a global society and students in American schools today will enter extreme competitiveness among the talented graduates for the best careers (Cornish, 2004). There is continuing research studies seeking to find the one best way to give American students the appropriate education during this era of great change (Kirby, Berends, & Naftel, 2003), some fears have not yet permitted some innovative teaching methodologies to become as widespread as possible (Emery, 2007). The Alabama Mathematics, Science, and Technology Initiative (AMSTI; 2009) is a method that seeks to provide schools with in-depth expert development, inquiry-based learning modules, and the appropriate necessary supplies to implement these new learning experiences.

This study investigated the effectiveness of inquiry based instruction in improving the mathematics and science achievement of fifth graders in a rural elementary school in south Alabama as measured by standardized achievement scores. Standardized achievement test scores in mathematics and science over a 6-year time period were analyzed in order to compare the group percentile rank of fifth graders in mathematics and science when teacher-directed instruction was utilized with the group percentile rank of fifth graders in science and mathematics education following the application of inquiry based classroom instruction.

The actions of inquiry include questioning, observations of current ideals, gathering data, and creating explanations (National Research Council, 1996). Dewey (1938) posed that inquiry based instruction occurs when an “educator is responsible for a knowledge of individuals and for a knowledge of subject-matter that will enable activities to be selected in which all participate and are the chief carrier of control.” The work of Dewey and his colleague Vygotsky were central to comprehending the structure of inquiry based instruction. As a result, writings of these two pioneers are often applied over the course of this study.

Recently, there have been reviews of the American Education pedagogical shifts. Sherman (2009) adhered that a progressive movement in education is paramount to the potential success of American students in the future. His research outlined two levels of inquiry based instruction that is distinct in American classrooms in recent times: differentiation and open education. Differentiation permits the desires of the students to affect how given content is encountered while open education permits the daily classroom instruction to be controlled by the students’ desires. Sherman reported that open education was attempted and abandoned. Also, the researchers postulated differentiation, which is the most current technique related to inquiry based instruction, may not continue to be an effective component of modern classrooms unless there is a wide support for the use of inquiry based instruction.

The traditional method of instruction (teacher directed) where teachers present organized and specific bodies of knowledge to the students is in contrast to this progressive model of knowledge (and subsequent learning) presentation. When teacher directed instruction methods are utilized, Dewey (1938) said, “books, especially textbooks, are the chief representatives of the ... wisdom of the past, while teachers are the organs through which pupils are brought into effective connection with the material” (p. 18). A recent study by Olsen and Sexton (2009) found that a contributing and significant element to the extension for the classic of teachers guiding students to knowledge is societal validity. Specifically, the architectures that accommodate public schools’ fiscal support and then proceed to oversee the progress that the institutions are making expect and sometimes call for the familiar design of teacher directed instruction without any given consideration for potentially effective other pedagogical methods.

## BACKGROUND

Within the framework of the formal American educational system, there is a close reliance that is revealed on teachers as dispensers of the body of knowledge to their students. Also, this is a formidable pattern for the educational institutions to replace (Hickey, Moore, & Pellegrino, 2001). Upon the productive demonstration for inquiry based science and mathematics instruction at regional level of schools, this academic work may boost the student accomplishment outcomes by accumulating support for research proven inquiry based education in science and mathematics. This academic work presents significant direction in the available standardized testing data. As well, it presents positive teacher perceptions of inquiry based education methods over time. This will allow educational administrators to support their teachers in a confident manner during their transitional efforts toward inquiry based instruction.

Vygotsky's (1962) work on learning beside the work of Dewey (1938) is a significant portion of the theoretical constructs for this work. Fundamental to both AMSTI and the constructivist learning theory, there is an assumption of the role of facilitator toward student learning knowledge on the part of educational instructors. AMSTI (2009) presents the teachers with the favorable circumstances to facilitate student development of significant understanding through ongoing technical support, professional development and classroom supplies. Adding to the constructivist learning theory and inquiry based learning while contributing to the literature on the subject, an extensive study produced by Le, Lockwood, Stecher, Hamilton, and Martinez (2009) found that progressive educational reforms in science and mathematics consistently led to advances in achievement depth designed to evaluate students' processing and problem solving abilities.

An elementary school serving 1,210 students in rural south Alabama, from kindergarten through fifth grade, began utilizing mathematics and science units devoted to inquiry-based learning after years of relying on teacher-directed instruction in these subject areas. This study explored the effectiveness of the implementation of AMSTI over three subsequent school years and identified existing trends in student data before the AMSTI was implemented. It is important to demonstrate the effectiveness of inquiry-based instruction in mathematics and science as measured by student achievement on standardized assessments if teacher, administrator, and parent support for the initiative is to continue.

For the purposes of this study, the researchers statistically analyzed the aggregate mathematics and science standardized testing data of the fifth-grade students to observe trends in the data during the 3 years before AMSTI implementation and the 3 years following AMSTI implementation. Fifth grade will be targeted for the purposes of this study due to the emphasis on the group's positive performance on standardized testing instruments before the students are placed at the middle school for the following instructional year.

Fifth-grade students in the study school performed less well compared to same-age peers across the national norming group in nearly every area during the 2003-2004 school year. As evidenced in Table 1, the only subgroup of students performing above the 50th national percentile were Caucasians in mathematics and science (Alabama Department of Education, 2009). Of particular concern were the percentile rank score in mathematics of African Americans and the science percentile rank scores of students living in poverty. Each of these student groups performed only slightly above the 30th percentile rank compared to the national norming group. Teacher-directed instruction was implemented during this school year. This calls into question

the effectiveness of teacher directed instruction with African Americans students and students living in poverty in the fields of science and mathematics.

An analysis of fifth-grade students in the study school indicated performance below same-age peers across the national norming group was still apparent during the 2004-2005 school year. African American students and students living in poverty were continuing to perform significantly below the 50th percentile in both mathematics and science (Alabama Department of Education, 2009). The percentile rank scores in science of these two student subgroups were especially concerning. Again, these student groups scored only slightly higher than the 30th percentile compared to the national norming group.

Teacher-directed instruction was implemented during this school year. Particularly, concerning science instruction, concerns arose concerning the effectiveness of teacher-directed instruction with the African American students and students living in poverty.

Performance below same-age peers across the national norming group continued to be evident during the 2005-2006 school year. African American students and students living in poverty were continuing to perform below the 50th percentile (Alabama Department of Education, 2009). In fact, these student groups once again performed only slightly better than the 30th percentile compared to the national norming group. Also of note, when considering the percentile rank scores of all fifth-grade students in mathematics and science, percentile rank scores in both mathematics and science were only slightly above the 50th percentile compared to the national norming group. Teacher-directed instruction was implemented during this school year. Following this school year, the fifth-grade teachers underwent extensive professional development required of all schools interested in participating with AMSTI. As a result, mathematics and science instruction for the following academic years was more inquiry-based in nature.

Performance below same-age peers across the national norming group appeared to dwindle for the study group during the 2006-2007 school year. The only area of continuing concern involves two subgroups of students in science. African American students and students living in poverty continued to perform near the 30th percentile rank compared to the national norming group. In fact, percentile rank scores in science continued at relatively low levels for females, African Americans, and students living in poverty. These student groups are not mutually exclusive. For example, a female African American student living in poverty who struggles in science would have her standardized achievement score factored into the group percentile rank for all students, African American students, female students, and students living in poverty. It is important, then, to target student instruction to meet the needs of struggling students at risk for poor performance on standardized testing instruments. Inquiry-based instruction was implemented for the first time during this school year.

Performance, when compared to same-age peers across the national norming group during the 2007-2008 school year scores for fifth-grade students in the subject school, showed promising gains. The only area of ongoing concern continues to involve two subgroups of students in science: African American students and students living in poverty. Of interest, there is a single group performing near the 30th percentile compared to the national norming group. Although efforts must continue to increase the science achievement of students living in poverty, it is encouraging that scores are increasing. Inquiry-based instruction was again implemented during this school year. The question remains whether or not inquiry-based instruction will satisfactorily increase the achievement of student groups consistently performing below the 50th percentile at the subject school compared to the national norming group.

## LITERATURE REVIEW

### Teacher-directed instruction

According to Heal, Hanley, and Layer (2009), “Direct instruction is characterized by relatively simple and precise materials tailored to specific learning objectives, planned (and sometimes scripted) prompting procedures, provision of high-quality reinforcement for responding, and multiple trials conducted during brief teaching periods” (p. 124). Some examples of direct instructional strategies would include student completion of worksheets, lectures that are led by teachers, and computer programs that allow skills to be repeated to facilitate the learning process (Thompson, 2006). In the past, this instruction has been part of the majority of experiences for student learning in the United States while attempting to get the utmost student achievement. The underlying framework of teacher directed instruction is that teachers have been utilizing this teaching technique all through our history to create learning by the students (Alsup, 2005). More recently, student achievement goals have been defined through the NCLB Act (2001) with content mastery that has been memorized to affect the outcomes of direct instruction.

The greatest affects and commonly preferred directed instruction was found by Heal et al. (2009) for preschool students. This is in direct contrast to early elementary and preschool environments which often are composed of some type of play that is structured. It has been found that teacher directed learning procedures create significant benefits for preschool children and that is it often enjoyed by the students.

In recent legislation it has been suggested by the response to intervention (RTI) that there is a link amongst teacher directed and the 2001 NCLB Act as a method to bridge any gaps in the effectiveness of student learning (Coddling, Hilt-Panahon, Panahon, & Benson, 2009). Public schools are charged with methodically analyzing the data for student examination and should also a priori define strategies that differ in intensity to address the actual needs of the students. As such, RTI is then relevant to the performance of students at their specific grade level standards as well as insufficiencies the any core related areas. There needs to be a series of evidence based learning procedures for the students that are offered in some type of tiered succession.

There are specific parts of the school day are in three tiers of RTI and there is participation by the students and participation is required in a least one tier if not all of them. The students who are qualified at or even above the grade of mastery which is set by the school district are presented Tier 1 methods of instruction. This is whole group and is mostly teacher directed lessons. Any students with deficiencies receive Tier 2 lessons this is mostly smaller groups of students and drill and repetition type instruction. Lastly, the students who have the most significant needs in a subject receive all of the RTI tiers of instruction including Tier 1, Tier 2 and Tier 3. The third tier is usually a distinct, layered opportunity that is teacher directed and is particularly directed toward the weaknesses and strengths of the smaller student groups.

RTI directs, for math instruction, mostly computational issues and provides strategies for tiered interventions while varying from individualized delivery methods to whole class methods which include repetition using flash cards, drilling of the targeted skills and lessons that are scripted for teacher directed methods.



Codding et al. (2009) in an analysis of RTI math strategies that are currently being employed found “explicit instructional components such as drill, repetition, segmentation, strategy cues and active instruction represented the most variance associated with high effect sizes” (p. 281). The greatest affect of instructional strategies were found to be teacher directed while directing the generalized math education within a whole class setting. As this has been more commonly prescribed, the methodologies that were presented as teacher directed to students were designated in the more complex tiers and were arranged to close the gaps in student achievement. It is reported by the researchers that success is more widespread with teacher directed presentation for providing the math framework as it is perceived to be essential for creating the math conceptual framework.

### **Inquiry based instruction**

Due to the student-centered premise behind inquiry-based instruction, Hazari, North, and Moreland (2009) differentiate inquiry-based instruction from teacher-directed instruction by focusing on the unique role of the student “learners construct personal interpretation of knowledge based on their previous experience and application of knowledge in a relevant context” (p. 189). It was stated by Thompson (2006) that constructivist learning, inquiry based activities involve the use of “manipulatives or hands-on materials” (p. 53) “incorporating inquiry, discovery, and problem-solving approaches . . . [and] applying math and science concepts to real-world context” (p. 54). Moreover, inquiry based methods for learning associates the activities in the classroom to distinct careers and involves the original data analysis. It also inspires both collaboration and communications by the students (Thompson, 2006). Thompson found support for the idea that there is effectiveness for inquiry based presentations for improving the achievement of the students as well as the satisfaction of the instructors when development occasions that are appropriate are made available. In a wide variety of perspectives and in a broad number of methods in the seventy years since Dewey (1938) hedged education as a progressive movement, there is still a strong predisposition toward using teacher directed methods of instruction. With respect to the instruction of math which was considered previously, although many believe memorization of basic operations and computational facts must be accomplished using teacher directed methods (Codding et al., 2009), proponents of inquiry based methods suggest that there needs to be some sort of declaration of real world math concepts before any elementary skill sets are committed to memory (Thompson, 2006).

Dewey (1938) gave the following framework which is predicated on the academic basis of inquiry based education with regard to his defined progressive movement of academics: It is a defined rule of the recent institution that the initiation of learning should be created based on experience that students already have learned. This experience combined with the aptitudes already developed during its engagement should provide the initial mark for the learning in the future (p. 74).

Dewey moved on to state that the presentation of instructors giving students a thetical set of information comes from an era that predicated the past and future would not be dissimilar. Also, when the movement of progressive education began about 70 years ago, change was thought to be unavoidable. This review covers the suggestions, theories and ideals of both Dewey and Vygotsky (1962) and their writings will be sufficiently examined. These writings are imminently critical to a comprehension of the educational framework called inquiry based education.

There are questions pertaining to inquiry-based instruction that was presented by Dewey (1938) and is of primary concern to proponents of this methodology. It is, “What does freedom mean and what are the conditions under which it is capable of realization?” (p. 22). There was a pilot analysis created by Papanikolaou and Grigoriadou (2009) of an educational science adept at presenting guidance to learners as they openly select individualized learning routes in the process of creating a unique educational result. They outlined a differentiation between the existing media and this new media that focuses on the design of educational procedures and materials as well as the outcome objects that are targeted, and methods of assessment that conclude whether or not students have retained the appropriate levels while the constructivist approach centers on in context learning organized about certain assignments (p. 194).

During the process of this study, the researchers found that non-passive presence which was requested through the use of the inquiry based model for guided questions the learners elected to participate in both an effective and motivated manner. This was concluded using professional examinations of the available educational medium along with student experimentation with a reasonable sample size of 19 students.

In his work, Dewey (1938) predicated an instructor’s part in an inquiry based educational environment as an exquisite designer. This person is charged with renewing the associations between the prior experiences of the students with the given subject area and offer new connections to learners who are then able to create more skills, connections, and factual evidence. During the process of comparing teachers in the two educational methods (inquiry based vs. teacher directed) Dewey (1938) acclaimed that there is much more lead time for planning for inquiry based methods because they must assuredly give exposure the continually build on the previous experiences of the students.

Marshall (2010) started with the supporting proposition, “our habits of mind, innate curiosity, and ways of thinking and acting are shaped and developed through immersion in experience and repeated practice” (p. 48). Here, the investigators supposed that the method in which students were presented with learning material was equivalently paramount to the absorption of the content that is learned. In turn, more compelling instructors should have a purpose to create unique educational sessions as was suggested by Marshall and attempt to create an environment that is conducive to an ever developing global culture as was defined by Cornish (2004).

Of importance to note, Dewey’s intentions (1938) on all participations were not to be viewed as a complete presentation of education nor did he view that learning experiences would need to be equivalent. His views were that an instructor’s lead in an inquiry based model of instruction would be that of a guide for learning experiences. Instructors in an inquiry based model should be accountable for aiding learners to avoid experiences that could possibly reduce their abilities to perform in ever changing and increasingly difficult positions while giving direction toward enlightenment of concept development through normal curiosity. Dewey (1938) gave ownership to instructors with understanding “how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up experiences that are worthwhile” (p. 40).

Initially, the concepts of instructors as designers and the teachers who bring out and direct curiosity remain to be important parts of education that is inquiry based. It was found by Kazempour (2009) that inquiry based instructor development opportunities would be a significant contributor as a factor during the process of implementing inquiry based education in the classrooms of today. His study looked at the changing of the perceptions of a high school

teacher's necessity and abilities toward the implementation of inquiry based education that came from the professional development presented through a series of summer workshops. Along with these development opportunities, the instructor was found to have greater certainty in his capability to design for education that was inquiry based and also direct the students along their learning path.

On the topic of knowledge retention, Dewey (1938) guided that isolated learning of facts within a traditional teacher directed environment while practicing in a poor method can create a situation where learners are not able to perform as well on standardized tests than if the students had received no instruction at all. He found that it is possible to harm learners with isolated learning routines even though children have native capabilities to reason.

Additionally, Dewey asserted that content learned and skills acquired in this manner will not be efficiently conveyed from the practice environment to any other environment. Coinciding with this type of logic, it would follow that instructors would be surprised by any student's lack of success on the standardized tests that are given. As Oliver-Hoyo (2011) states "What works in one environment at a particular institution or within a specific discipline might not work at another so the need to provide alternative options is of primary importance" (p. 9). This circumstance appears to illustrate yet another level of support for the use of inquiry based teaching to advance scores of student accomplishment for application beside other teaching methods, because the very character of inquiry based teaching and learning is the conduction of experiences along a sequence of learning events.

Dewey (1938) said that if "the two principles of continuity and interaction as criteria of the value of experience are so intimately connected that it is not easy to tell just what special educational problem to take up first" (p. 51), it is likely better to comprehend learning and education in a social framework where the two assemblies exist side by side. Dewey associated the establishment which underlies inquiry based learning to a society that is democratic in nature. Also, he continued on to as if given readers can ponder a preferred desire for democracy (i.e., inquiry based learning and the associated techniques) over a dictatorial method (i.e., teacher directed learning). Dewey did accept that inquiry based learning has a much lower relation to coursework of study and arrangement of learning goals than teacher directed learning. As such, this is a continuing reason for concern for administrators in the educational sector who are aiming to obtain sufficient progress from one year to the next.

Further, as Hattie (2009) demonstrates through extensive meta-analysis of the impact on student achievement brought about by various instructional and environmental factors, a variety of instructional strategies including but not limited to inquiry-based instruction may be necessary to maximize student achievement. Ortlieb and Lu (2011) offer further support for the importance of inquiry-based instruction in their study of pre-service teachers. Teachers who are encouraged to employ the inquiry-based teaching model demonstrate greater, more sustained commitment to aiding students' development of critical thinking strategies. The implementation of well designed, conceptually based instructional units for inquiry supervised by educators with a strong foundation in multiple instructional delivery models is supported by the literature. AMSTI offers inquiry-based instructional frameworks designed to meet course of study objectives and increase students' critical thinking while allowing for the implementation of multiple instructional strategies.

Schiller (2009) underscored the significance of social teamwork to the attainment of success of knowledge retention and learning. His study concluded that learners who were participating in a team-based in an inquiry based learning environment had high inclinations to



attend to the given task of knowledge learning and retained information at the applicable stage of comprehension. His study pertained to math at a high level with students from a university environment but the suggestion contained the applicability to a team based and inquiry based environment to K through grade 12 math material.

Vygotsky (1962) proposed that direct teaching of concepts is impossible and would not be fruitful. He said that an instructor who attempts to accomplish this mostly never succeeds at anything but empty terminology with meaningless repeating of terminology by the learner. He compared it to a simulation of a learning environment covering the appropriate abstractions but actually housing a void (p. 83).

Vygotsky (1962) was in unison with the underlying principles of Piaget and Dewey but he made an important differentiation. He acquiesced that given thought methods of young people came out of their own background experiences and these methods are significantly dissimilar compared with the learning methods of adults. He also stated that young people use both extemporaneous and non-extemporaneous methods and that these methods are mostly codependent.

Hernandez-Ramos and De La Paz (2009) compiled an analysis which compared inquiry based instruction with teacher directed instruction in a group of over 700 learners in a given middle school and a similar number of learners in a geographically close middle school with similar educator credentials and student demographics. During this study, they found support for higher efficacy for learning that was student oriented. They found that learners that had inquiry based material presentation achieved better results as contrasted with students in controlled group in both internal motivation and overall material knowledge. Also, they reported the students had increased critical thinking abilities within the content area.

It may be declared that it is necessary to form the intellection of comprehending and retaining science education to be an exclusive relationship of life experiences along with organized experiences in an educational environment structured to facilitate learners to construct on their learned conceptual comprehensions in significant methods to obtain a complete understanding of given scientific concepts. Along with Vygotsky's (1962) hypothesis which makes use of teacher directed science education is like teaching learners to assume a comprehension of science while never accumulating a comprehension at all. The benefit of inquiry based education gives instructors a vehicle to supply educational activities that are structured to involve learners in genuine learning in both science and mathematics.

Vygotsky (1962) explored three concepts for budding youth intellect. The first concept he discussed was the idea from Piaget that youth have the ability to experience, respond to and comprehend information gained from given activities at an individualistic depth well before rational thinking is possible. This strengthened the notion from Vygotsky that presenting ideas to learners verbally before any inquiry is allowed can be viewed as fruitless. The second concept used by Vygotsky made use of a supposition by Stern that youth have a mysterious exhibition of comprehension processes that seems to lead to a casual experience which may serve as a catalyst for an important inquiry based educational experience. Lastly, Vygotsky expressed both the faults and benefits of ideas from both Stern and Piaget prior to presenting the structured framework for inquiry based education. Vygotsky further stated, "Our investigation shows that the development of the psychological foundations for instruction in basic subjects does not precede instruction but unfolds in a continuous interaction with the contributions of instruction" (p. 101).

## RESEARCH QUESTIONS

### Research Question 1

How does the group percentile rank for students receiving inquiry-based mathematics instruction differ from the group percentile rank for students receiving teacher-directed mathematics instruction in terms of Stanford Achievement Test, 10th Edition (SAT-10), mathematics subtest scores for fifth graders at the subject elementary school? The researchers assessed the merit of AMSTI compared to teacher-directed learning in mathematics (Stufflebeam, 2002) by exploring statistical trends and differences in the group percentile ranks in mathematics on the SAT-10 for fifth graders at the study school for 3 years before AMSTI implementation and 3 years after AMSTI implementation. It was the supposition that the trend of standardized achievement scores in mathematics will support earlier independent findings of the success of AMSTI in improving student test scores (Ricks, 2008).

Finney (2010) conducted a group randomized control trial of 40 Alabama schools to compare the effectiveness of AMSTI inquiry-based instructional practices with teacher-directed practices longitudinally. The study further supports the effectiveness of AMSTI inquiry-based instructional units in increasing students' standardized test scores in mathematics and science over time. This will further indicate the continued applicability of the educational theories of Dewey (1938) and Vygotsky (1962) to modern mathematics instruction.

### Research Question 2

How does the group percentile rank for students receiving inquiry-based science instruction differ from the group percentile rank for students receiving teacher-directed science instruction in terms of SAT-10 science subtest scores for fifth graders at subject elementary school? The merit of AMSTI was assessed compared to teacher-directed learning in science (Stufflebeam, 2002) by exploring statistical trends and differences in the group percentile ranks in science on the SAT-10 for fifth graders at the study school for 3 years before AMSTI implementation and 3 years after AMSTI implementation. It was the supposition that the trend of standardized achievement scores in science will support earlier independent findings of the success of AMSTI in improving student test scores (Finney, 2010; Ricks, 2008). This will further indicate the continued applicability of the educational theories of Dewey (1938) and Vygotsky (1962) to modern science instruction.

## RESULTS

### Research Question 1

How does the group percentile rank for students receiving inquiry-based mathematics instruction differ from the group percentile rank for students receiving teacher-directed mathematics instruction in terms of SAT-10, mathematics subtest scores for fifth graders at the subject elementary school?

The research employed a factorial analysis of the group percentile rank. The statistical analysis was applied to mathematics data from the SAT-10 for fifth graders attending the target school for the 2002-2003, 2003-2004, and 2004-2005 school terms during which teacher directed

instruction was employed as compared to the 2005-2006, 2006-2007, and 2007-2008 school terms during which inquiry based instruction was employed. Some statistically significant changes in student achievement were revealed. The total student population performance with teacher directed instruction and inquiry based instruction was analyzed as was the performance of the student subgroups of male and female, black and white, and poverty and non-poverty when considering the years of teacher directed instruction as compared to inquiry based instruction. Although the total student population group percentile rank standardized scores were greater when inquiry based instruction was employed, the difference was not statistically significant ( $t = -1.50$ ,  $p = .136$ ).

The potential difference in mathematics achievement of females and males was also explored for the six years considered. Statistically significant results were found when analyzing the effectiveness of teacher directed instruction as compared to inquiry based instruction for the student subgroups of females and males ( $t = 2.08$ ,  $p = 0.071$ ). The use of inquiry based instruction was found to have a positive effect on student achievement for both females and males. This is shown in figure 1 below. For the individual groups of females and males, both were found to be statistically significant as well. Female students earned higher achievement test results during the three years of inquiry-based mathematics instruction. Figure 2 depicts the impact of inquiry based instruction on the performance of fifth grade females.

The difference in student performance of males as impacted by the implementation of inquiry-based instruction is seen in Figure 3. Not only did male students perform better on a standardized mathematics achievement test following inquiry based instruction, but the variance in performance of male students decreased when inquiry based instruction was employed.

The combination of differences between the performance of black and white students and those between teacher directed and inquiry based instruction explain much of the variation in the data ( $R^2(\text{adj}) = 76.8\%$ ). For this combination of data, the student subgroups of black and white are a significant variable ( $t = -5.89$ ,  $p = 0.000$ ) while the instructional delivery method, teacher directed or inquiry based, is also a significant factor ( $t = 2.06$ ,  $p = 0.074$ ). Figure 4 depicts the interactions of these data sets.

The study further found that there is both a desirable increase in student mathematics performance when inquiry based instruction is employed and also a desirable decrease in variation of performance ( $F = 212.33$ ,  $p = .009$ ) among white students with the use of inquiry based instruction.

For students living in poverty, inquiry based learning was found to have a positive, statistically significant impact on student achievement ( $t = -2.70$ ,  $p = 0.037$ ). The variance of scores for students designated as living in poverty was not found to be different when teacher-directed instructional years and inquiry-based instructional years were considered. This was observed with both an F-test and Levene's test to account for either normal or non-normal data.

Further analyses of the SAT-10 mathematics achievement data illustrate student subgroups with no statistically significant differences attributable to the use of teacher direction instruction as contrasted with inquiry based instruction. No significant difference was found for white students with respect to the different teaching methods but, as described above, there was a significant difference for black students. In addition, no significant difference was found for non-poverty students when inquiry based learning was employed.

## Research Question 2

How does the group percentile rank for students receiving inquiry-based science instruction differ from the group percentile rank for students receiving teacher-directed science instruction in terms of SAT-10 science subtest scores for fifth graders at subject elementary school?

Again, the research employed a factorial analysis of the group percentile rank. The statistical analysis was applied to science achievement data from the SAT-10 for fifth graders attending the target school for the 2002-2003, 2003-2004, and 2004-2005 school terms during which teacher directed instruction was employed as compared to the 2005-2006, and 2006-2007 school terms during which inquiry based instruction was employed. Some statistically significant changes in student achievement were revealed. The total student population performance with teacher directed instruction and inquiry based instruction was analyzed as was the performance of the student subgroups of male and female, black and white, and poverty and non-poverty when considering the years of teacher directed instruction as compared to inquiry based instruction.

For the total student population in fifth grade science achievement, no statistically significant difference was noted. However, the use of inquiry based science instruction did have a statistically significant, positive impact on the achievement of black students ( $t = -1.27$ ,  $p = 0.147$ ). There was no difference in variances discovered for the black students. This underscores the statistical significance of the data demonstrating the positive impact of inquiry-based instruction for this student subgroup.

A statistically significant, positive difference was also noted for male students when inquiry based science instruction was employed ( $t = -1.11$ ,  $p = 0.173$ ). Again, there were no differences discovered for the variances of the two methods for the male groups.

Students living in poverty were also positively impacted by inquiry based science instruction ( $t = -2.60$ ,  $p = 0.40$ ). The test for equal variances among the SAT-10 data for students living in poverty is again satisfactorily passed to a level of 90% confidence.

It was also noted a non-statistically significant impact of inquiry based science instruction for several student subgroups. Inquiry based instruction did not impact the science achievement of white students, female students, or non-poverty students to the level necessary to reach statistical significance.

## CONCLUSIONS

For mathematics achievement, the common significant effect found in each factorial experiment was teaching method. For the target school, inquiry based mathematics instruction as provided by AMSTI is effective in increasing student mathematics achievement as measured by the SAT-10 for certain student subgroups, particularly black students. This study further supports the findings of Finney (2010) and Ricks (2008) by demonstrating significant, positive impacts on student achievement of AMSTI, inquiry based instruction.

For science achievement, the common significant effect found in each factorial experiment was teaching method. For the target school, inquiry based science instruction as provided by AMSTI is effective in increasing student science achievement as measured by the SAT-10 for certain student subgroups, particularly black students, female students, and students living in poverty. By increasing the science achievement of traditionally underperforming student subgroups in the area of science, inquiry based instruction cements an important place in the total school plan to obtain AYP under NCLB (2001).

Through a thorough analysis of standardized achievement data during instructional periods with teacher directed mathematics and science instruction as well as instructional periods within an inquiry based science and math learning environment, it may be concluded that AMSTI is effective in increasing student achievement in mathematics, particularly among black students. Further, students living in poverty may be expected to greatly increase their science achievement through the use of inquiry based science instruction. These are important conclusions to reach for the target school, since NCLB requires adequate yearly progress of these student subgroups. Additionally, black students and those living in poverty have historically been at risk student populations (Alsup, 2005).

**TABLES AND FIGURES**

Table 1  
*Stanford Achievement Test, 10th Edition, Percentile Ranks for Fifth-Grade Students in the 2003-2004 School Year*

Group	Subtest	Percentile rank score
All students	Mathematics	41
All students	Science	47
Females	Mathematics	42
Females	Science	47
Males	Mathematics	41
Males	Science	47
African Americans	Mathematics	34
African Americans	Science	37
Caucasians	Mathematics	55
Caucasians	Science	63
Students living in poverty	Mathematics	29
Students living in poverty	Science	35



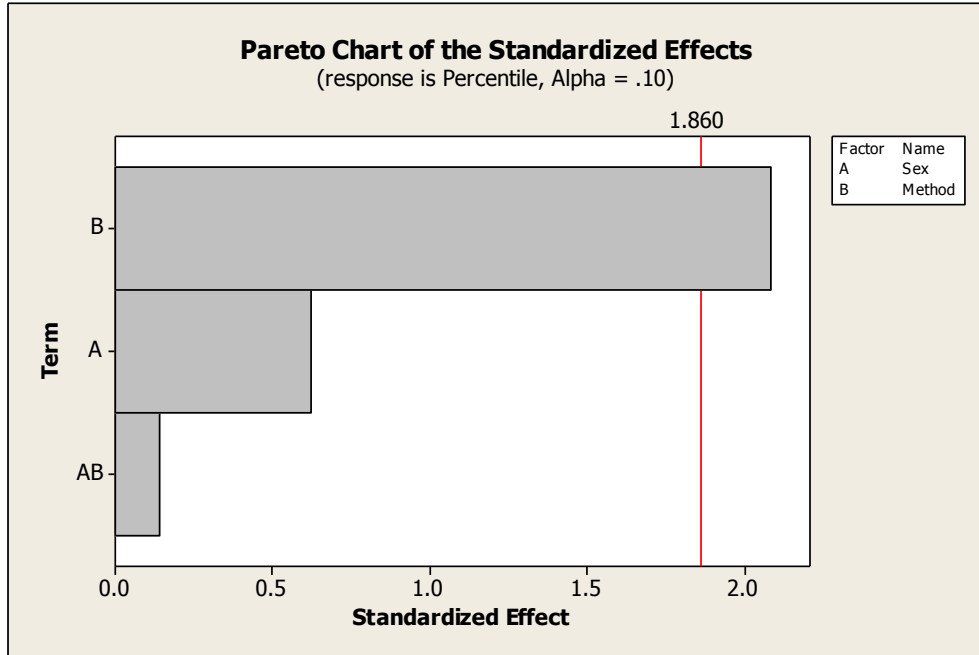
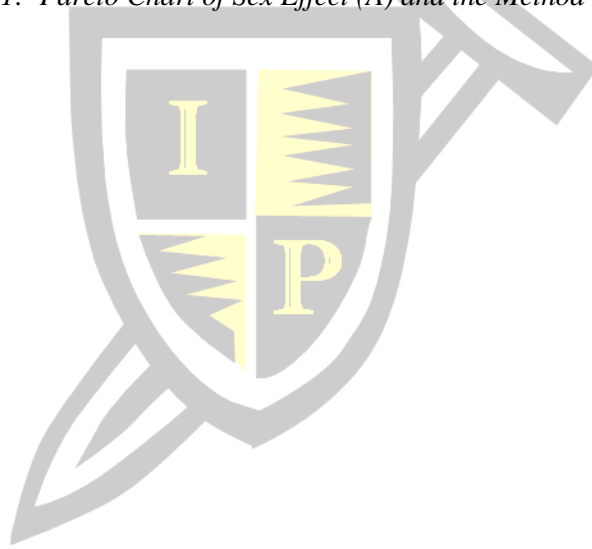


Figure 1: Pareto Chart of Sex Effect (A) and the Method Effect (B).



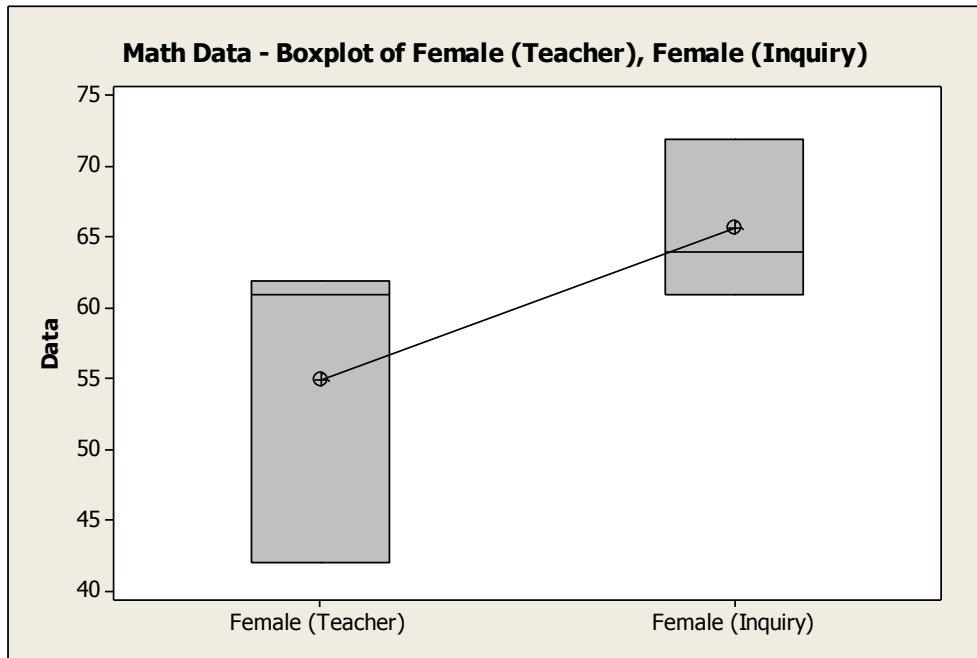


Figure 2: Box Plot of Method Effect on Female Students

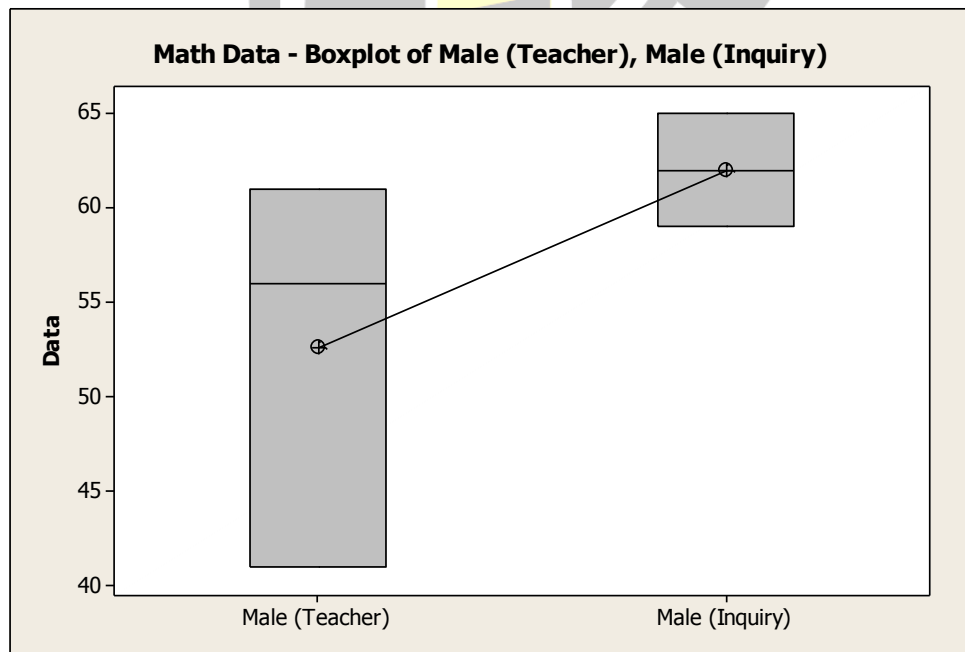


Figure 3: Box Plot of Method Effect on Male Students

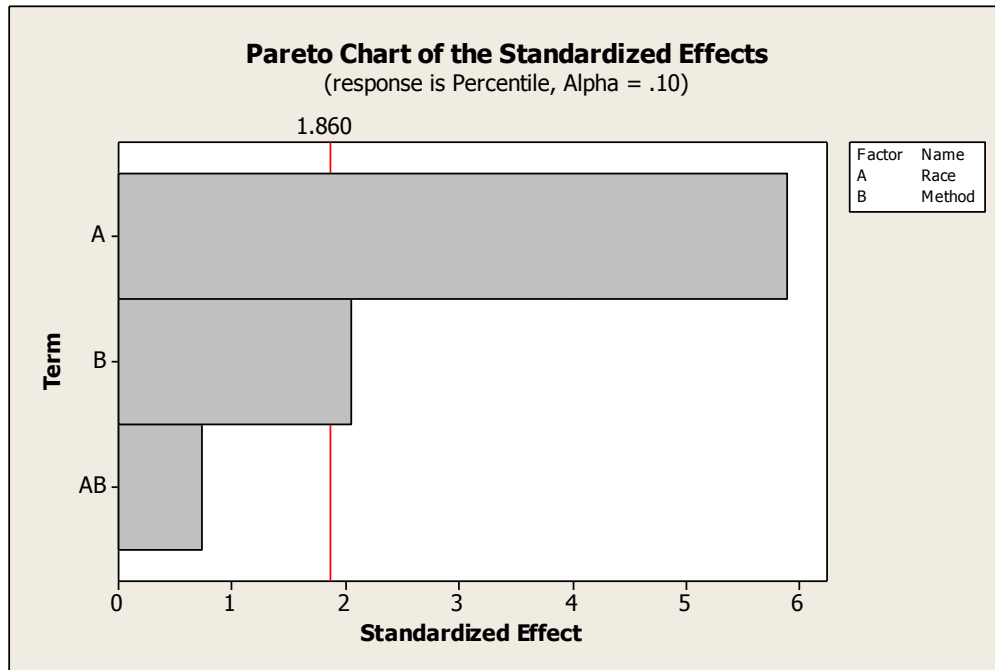


Figure 4: Pareto Chart of Race Effect (A) and the Method Effect (B).

## REFERENCES

- Alabama Department of Education. (2009). *Accountability reporting*. Retrieved from <http://www.alsde.edu>
- Alabama Math, Science, and Technology Initiative. (2009). *Welcome to AMSTI*. Retrieved from <http://www.amsti.org>
- Alsup, J. (2005). A comparison of constructivist and traditional instruction in mathematics. *Educational Research Quarterly*, 28(4), 3-17.
- Codding, R. S., Hilt-Panahon, A., Panahon, C. J., & Benson, J. L. (2009). Addressing mathematics computations problems: A review of simple and moderate intensity interventions. *Education and Treatment of Children*, 32, 279-312.
- Cornish, E. (2004). *Futuring: The exploration of the future*. Bethesda, MD: World Future Society.
- Dewey, J. (1938). *Experience and education*. New York, NY: Collier Books.
- Emery, K. (2007). Corporate control of public school goals: High stakes testing in its historical perspective. *Teacher Education Quarterly*, 34(2), 25-43.
- Finney, P. (2010). *The effectiveness of the Alabama, math, science, and technology initiative (AMSTI)*. Retrieved from <http://ies.ed.gov/ncee/edlabs/projects/project.asp?projectID=69>
- Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Rutledge.
- Hazari, S., North, A., & Moreland, D. (2009). Investigating pedagogical value of wiki technology. *Journal of Information Systems Education*, 20, 187-198.

- Heal, N. A., Hanley, G. P., & Layer, S. A. (2009). An evaluation of the relative efficacy of and children's preferences for teaching strategies that differ in amount of teacher directedness. *Journal of Applied Behavior Analysis*, *42*, 123-143.
- Hernandez-Ramos, P., & De La Paz, S. (2009). Learning history in middle school by designing multimedia in a project-based learning in a project-based learning experience. *Journal of Research on Technology in Education*, *42*, 151-173.
- Hickey, D. T., Moore, A. L., & Pellegrino, J. W. (2001). The motivational and academic consequences of elementary mathematics environments: Do constructivist innovations and reforms make a difference. *American Educational Research Journal*, *38*, 611-652.
- Kazempour, M. (2009). Impact of inquiry-based professional development on core conceptions and teaching practices: A case study. *Science Educator*, *18*(2), 56-68.
- Kirby, S. N., Berends, M., & Naftel, S. (2003). *Implementation in a longitudinal sample of new American schools: Four years into scale-up*. Retrieved from [http://www.rand.org/pubs/monograph\\_reports/MR1413/](http://www.rand.org/pubs/monograph_reports/MR1413/)
- Le, V. N., Lockwood, J. R., Stecher, B. M., Hamilton, L. S., & Martinez, J. F. (2009). A longitudinal investigation of the relationship between teachers' self-reports of reform-oriented instruction and mathematics and science achievement. *Educational Evaluation and Policy Analysis*, *31*, 200-220. doi:10.3102/0162373709336238
- Marshall, S. P. (2010, January). Re-imagining specialized STEM academies: igniting and nurturing decidedly different minds, by design. *Roeper Review*, *32*, 48-60. doi:10.1080/02783190903386884
- National Research Council. (1996). *National science education standards: Observe interact, change, learn*. Washington, DC: National Academy Press.
- No Child Left Behind Act, (2001), 20 U.S.C. § 6319.
- Oliver-Hoyo, M. T. (2011). Lessons learned from the implementation and assessment of student-centered methodologies. *Journal of Technology and Science Education*, *1*(1), 2-12.
- Olsen, B., & Sexton, D. (2009). Threat rigidity, school reform, and how teachers view their work inside current educational policy contexts. *American Educational Research Journal*, *46*, 9-44. doi:10.3102/0002831208320573
- Ortlieb, E. T., & Lu, L. (2011). Improving teacher education through inquiry-based learning. *International Education Studies*, *4*(3), 41-46. doi: 10.5539/ies.v4n3p41
- Papanikolaou, K., & Grigoriadou, M. (2009) Combining adaptive hypermedia with project and case-based learning. *Journal of Educational Multimedia and Hypermedia*, *18*, 191-220.
- Ricks, S. (2008). *External evaluation results for AMSTI*. Retrieved from <http://www.amsti.org>.
- Schiller, S. Z. (2009). Practicing learner-centered teaching: Pedagogical design and assessment of a second life project. *Journal of Information Systems Education*, *20*, 369-381.
- Sherman, S. (2009). Haven't we seen this before: Sustaining a vision in teacher education for progressive teaching practice. *Teacher Education Quarterly*, *36*(4), 41-60.
- Stufflebeam, D. L. (2002). *CIPP evaluation model checklist: A tool for applying the fifth installment of the CIPP model to assess long-term enterprises*. Retrieved from <http://www.wmich.edu/evalctr/checklists/cippchecklist.htm>
- Thompson, C. J. (2006). Preparation, practice, and performance: An empirical examination of the impact of standards based instruction on secondary students' math and science achievement. *Research in Education*, *81*(1), 53-62.
- Vygotsky, L. S. (1962) *Thought and language*. Cambridge, MA: MIT Press.