EXAMINING A MIDDLE SCHOOL SCIENCE OLYMPIAD PROGRAM THROUGH SELF-STUDY

by

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Abstract

Each year, thousands of middle and high school students across the United States compete in Science Olympiad, an international science program designed to increase student interest in science and engineering through rigorous competitions. Through self-study data collected by one teacher, this paper will tell the story of four Michigan science teachers reflecting on their first year of coaching Science Olympiad at the middle school level and make instructional recommendations for teachers interested in implementing the Science Olympiad model into their classroom.
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Chapter I - Introduction

Statement of Problem

The goal of this literature review is to identify the positive and negative experiences faced by students and coaches taking part in a middle school Science Olympiad program. Accomplishments and roadblocks faced by coaches and students will be exposed under a theoretical lens in an attempt to more fully understand the underlying causes of the hindrances felt by both parties. This literature review aims to present the factors that make Science Olympiad an enjoyable experience for coaches and students alike and make instructional recommendations for implementing the Science Olympiad model into middle school science classrooms.

Theoretical Framework

This literature review will utilize Michael Moore’s theory of transactional distance (1993) combined with elements of self-study as a conceptual model and framework for research questioning and analysis.

Theory of Transactional Distance. Moore’s theory of transactional distance (1993) focuses on the transactional distance created by the teaching and learning process and its effects on learner autonomy. Moore is renowned for moving theorists “toward the realization of a pedagogical theory” (Garrison, 2000, p. 8). Transactional distance is not physical or geographic in nature, but is “pedagogical” (p. 22) and is function of transactional separation or distance between teacher and learner caused by elements of (1) dialogue, (2) course structure, and (3) learner autonomy.

The amount of transactional distance present in an educational program is dictated by the quantity of dialogue, structure, and learner autonomy (Moore, 1993). Moore
defines dialogue as the extent of constructive interaction that a course allows to take place between instructor-learner and learner-learner (1993). Courses with low or high amounts of dialogue may be of either high or low individualization. In Bernath and Vidal (2007), Moore gives examples of ways that high and low dialogue courses can have high or low capacity for individualization and notes that programs have “more dialogue or less dialogue, not either or” (p. 438). Figure 1 presents Moore’s argument on the relationship between course dialogue and individualization capacity.

**Figure 1. Examples of course dialogue and individualization**

![Diagram](image)

Moore (1993) refers to structure as the “rigidity or flexibility” (p. 24) that a course accommodates. Structure and dialogue have an inverse relationship, as increases in structure or course dialogue results in a decrease of the other. As structure increases and dialogue decreases, transactional distance increases. Dialogue and capacity for individualization have a direct relationship pertaining to transactional distance. For example, the less structured a course is the more individualized a course becomes as the opportunity for more dialogue between instructor-learner or learner-learner is able to take place. Figure 2 demonstrates these relationships graphically.
Moore (1973) lists examples of the extent of dialogue and capacity for course individualization and effectively organizes course attributes having more or less structure. By doing so, Moore is able to conceptualize the relationship between learning and teaching methods and transactional distance. Figure 3 initially appeared in taxonomy form in Moore’s independent theory of learning and teaching (1973) and was adapted to his theory of transactional distance (1993) when articulated 20 years later.
Figure 3. Typical Programs by Technology Used.

Learner autonomy is defined as the “extent to which in the teaching/learning relationship it is the learner rather than the teacher who determines the goals, the learning experiences, and the evaluation decisions” (Moore, 1993, p. 27) of his or her learning program. Depending on the structure, dialogue, and transactional distance prevalent in a course, varying levels of learner autonomy are required for a student to be successful. Learner autonomy and transactional distance have a direct relationship. Courses with high levels of transactional distance require learners to possess high levels of autonomy to be successful (Giossos, Koutsouba, Lionarakis, & Skavantzos, 2009). Course structure and dialogue affect levels of course transactional distance, which in turn affects the extent of learner autonomy required on behalf of the student.

Self-study. Self-study holds great, yet largely unrealized, potential to help teacher educators better understand and impact their practice. From its initial status as a soft research method to its present and growing respect in the education community as a
mechanism for improving practice and increasing the knowledge base on teaching, self-study is an emergent research design in need of new perspectives and strategies (Zeichner, 2007). Much has been written in the last decade about the components necessary for self-study to serve as a viable research design that integrates theory and practice (Loughran, 2004). It is widely held that self-study, like other scholarly endeavors needs to be “public, open to critique and evaluation, and in a form others can build on” (Shulman, 2004, p. 149).

Loughran (2004) warned that the title itself, self-study, connotes a research method centering on isolated introspection absent of public critique and dissemination; however, self-study is much more than merely reflection on one’s practice. Different from reflection, which “largely resides within the individual,” self-study challenges the interpretations we make of our own experiences (p. 25). I record my episodes through the lenses of my prior knowledge and beliefs, and the implications of my thoughts and experiences can be clarified and validated through open, broad, and critical review by my colleagues (Loughran & Northfield, 1998). In this self-study, I used two sources of evidence as my data set: my actions and reactions, and my personal analyses in the form of a weekly journal comprised of observations, critical questions, and reflection. Information and evidence commensurate with traditional research, the interpretation and analysis of those data require multiple points of view. This peer review serves as the catalyst to personal growth and to advancement in one’s scholarly community. Furthermore, when conducting research, validity is enhanced and bias is reduced when the data are corroborated by using triangulation. Triangulation can involve multiple
sources of data collection, often from different times, as well as, multiple interpreters of
the data (Fraenkel & Wallen, 2009).

**Research Questions**

This literature review will explore the quality, learning outcomes, and student
experiences of Science Olympiad programs in the United States. Through the use of self-
study data collected by one teacher, this paper will also investigate the perceptions of
four Michigan science teachers reflecting on their first year of coaching Science
Olympiad at the middle school level and their recommendations and insights as to the
instructional recommendations for implementing elements of the Science Olympiad
model into middle school science classrooms. The following research questions were
selected to provide a framework for analysis for chapter two of this research paper:

1. With regards to current U.S. educational reforms, what is the perceived academic
   quality of the Science Olympiad program?

2. To what extent are the learning outcomes of students participating in Science
   Olympiad comparable to learning outcomes of students learning science
   coursework in a traditional setting?

3. What measures can classroom teachers take to increase student interest in the
   STEM fields?
Definition of Terms

The following terms are of substantial significance with regards to Science Olympiad and Moore’s Theory of Transactional Distance and will be used throughout this literature review to aid in answering the research questions.

**STEM.** Educational subjects covering science, technology, engineering, and mathematics (Toulmin & Groome, 2007).

**Inquiry Based Learning.** “Learning in which students seek answers to their own questions and are actively engaged in science process and critical thinking skills.” (Gibson & Chase, 2002)

**Learner Autonomy.** “Extent to which in the teaching/learning relationship it is the learner rather than the teacher who determines the goals, the learning experiences, and the evaluation decisions” (Moore, 1993, p. 27).

**Transactional Distance.** Function of transactional separation between the teacher and the student and is influenced by elements of dialogue, course structure, and learner autonomy (Moore, 1993).

**Next Generation Science Standards.** State-led and internationally benchmarked science standards set to be released in April 2013 (“Next Generation Science Standards,” 2013).

**Scientific Inquiry.** The activities through which students develop knowledge and understanding of scientific ideas (National Research Council, 1996).
Chapter II - Review of Literature

The goal of this literature review is to examine the quality, learning outcomes, and student experiences of Science Olympiad programs in the United States. Chapter two of this research paper aims to present the factors that make Science Olympiad a successful and positive endeavor for students and coaches.

With regards to current U.S. educational reform, what is the perceived academic quality of the Science Olympiad program?

A Country of Educational Reform

Over the last 70 years, educational reform in the United States has become a laborious and never-ending process for American students, politicians, teacher educators, school administrators, parents, and teachers (Bennett, 1996; Price, 2008; Wirt, 2011; Wissehr, Concannon, & Barrow, 2011). In 1944 an effort to increase the number of students studying at post-secondary institutions was made by Congress through the enactment of the Montgomery GI Bill. This bill provided millions of veterans with educational benefits while providing increased diversity and student enrollment at college campuses across the nation (Bennett, 1996). The Soviet launch of Sputnik on October 4, 1957 shocked millions of Americans and greatly intensified the emphasis on science and mathematics in American schools overnight. Prior the launch of Sputnik, American science and engineering innovation was at the global forefront (Wissehr et al., 2011) and the Soviet victory of the space race “left government officials, politicians, scientists, and educators scrambling to find ways to close the gap” (p. 368). As a result, in 1958, Congress passed the National Defense Education Act (NDEA), which was designed to
improve mathematics and science instructional methods in K-12 education while increasing the number and quality of U.S. scientists by providing low interest loans and fellowships to university students studying mathematics or science (Price, 2008). The 1960’s brought forth social change and policies aimed at providing equity for all students regardless of race, gender or disability (Futrell, 2010). The Civil Rights Act of 1964 ended racial segregation in public schools (Batten, 2011) and programs like Head Start, Upward Bound, and the Elementary and Secondary Education Act (ESEA) were implemented as federal “War-on-Poverty programs” (Katz, Gold, & Jones, 1973, p. 263) by President Lyndon B. Johnson. These programs were designed to give students from low socio-economic backgrounds opportunities that were once only attainable by students from more affluent backgrounds, in an attempt to level the academic playing field (Brown-Nagin, 2004) and provided significant federal funding for K-12 education for the first time in U.S. history. In 1972, Congress enacted Title IX of the Education Amendments Act, which states: “no person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving federal financial assistance” (Davies, 2004, p. 229) in an effort to protect women from sex discrimination in educational settings. In April of 1983, the National Commission on Excellence in Education released *A Nation at Risk: The Imperative for Educational Reform*, a 71 page report aimed at informing American citizens of their educational shortfalls and what can be done to overcome them. Examples of Japanese engineering, German innovation and Korean ingenuity, combined with reports of unexceptional international standardized test scores and complaints from American businesses and the U.S. military that high school
graduates are ill-equipped with skills to compete in the modern world without receiving instruction in remedial skills (National Commission on Excellence in Education, 1983). At the very least, *A Nation at Risk* instilled a sense of mediocrity in American citizens. “Our society and its educational institutions seem to have lost sight of the basic purposes of schooling, and of the high expectations and disciplined effort needed to attain them (National Commission on Excellence in Education, 1983, pp. 5 & 6). In an effort to increase student achievement, the Commission recommended to raise standards across five fundamental educational disciplines including: (1) more rigorous curriculum content, (2) increased standards and expectations of students, (3) increased student seat time, (4) improve teacher quality, and (5) reform educational leadership and the financial support of education (National Commission on Excellence in Education, 1983). Shortly after *A Nation at Risk* was released, *A Nation Prepared: Teachers for the 21st Century* (Carnegie Forum on Education and the Economy, 1986), was released by the Task Force on Teaching as a Profession. Unlike *A Nation at Risk* (1983), *A Nation Prepared* (1986) shifted the focus of increasing standards to increasing student achievement and fixated its attention on the professional development of teachers (Tharinger et al., 1996). This movement directly lead to the creation of the National Board for Professional Teaching Standards (NBPTS) which in turn, developed standards and a process for teachers to become nationally certified (Futrell, 2010). On January 8, 2002, President George W. Bush, in conjunction with the U.S. Congress, passed the No Child Left Behind Act of 2001 (NCLB), which placed an increased emphasis on standardized test scores, required all teachers to be highly qualified in specific subject areas, required all schools to make adequate yearly progress (AYP), and mandated that all students reach grade level
proficiency in mathematics and language arts by the year 2014 (No Child Left Behind Act, 2002). The increased emphasis on 100% student proficiency in mathematics and language arts has put a tremendous amount of pressure on school districts across the country and has inadvertently shifted resources from programs that don’t directly correlate to the No Child Left Behind Act’s (2002) accountability standards. Grey (2009), found that over 70% of school districts across the United States have reduced time spent teaching other subjects such as social studies, integrated sciences, art, music, and foreign language instruction in order to meet the AYP demands of No Child Left Behind (Marx & Harris, 2006; Wissehr et al., 2011) and in Michigan, funding for gifted and talented programs shrunk by 90% the year after the No Child Left Behind Act (2002) was endorsed (Cloud, 2007).

**International Standardized Test Scores**

An overwhelming number of articles pertaining to the low quality of United States schools refer to the results of the 2009 Programme for International Student Assessment (PISA) conducted by the Organisation for Economic Co-operation and Development (OECD) (Flanagan, 2009; Gardner, 2010; Gifford, 2010; Mathews, 2010; Mathis, 2010; Shaughnessy, 2010; Strauss, 2010; Welner, 2010; Xueqin, 2010). PISA tests were taken by 15-year-old students in 65 nations around the globe to assess student aptitudes in reading, mathematics and science (“PISA - Organisation for Economic Co-operation and Development,” 2013). The test results revealed that American students are in the middle of the pack when compared to their international counterparts around the globe, ranking 25th in mathematics literacy, 14th in reading literacy, and 17th in science literacy. Shortly after the PISA scores were released, U.S. Secretary of Education, Arne
Duncan stated that "the PISA scores released this past Tuesday were "a massive wake-up call", (Riddile, 2010) indicating that the mediocrity of U.S. students' international test scores is unacceptable and change must be brought-forth.

The Global Economy

With the recent arrival of China and India in the global economy, a massive number of hard working, intelligent people have entered the global workforce. The Chinese and Indians are hungry for work and can perform knowledge level jobs for a mere fraction of what they would cost in the United States. Traditionally, the U.S. has led the world in idea-driven workers and must continue to produce idea-driven workers if they want to remain a world power (Friedman, 2007). Because the Chinese and Indian economies are no longer closed, American companies have to work much harder in other areas to keep on top. Combined, China and India's population is 2.6 billion people (Google Public Data Explorer: China, 2013; Google Public Data Explorer: India, 2013), which is approximately 37% of the world population and nearly 8.25 times the current U.S. population of just over 315 million people (U.S. Census Bureau, 2013). The Chinese and Indians want the same luxuries Americans have, and they're willing to work hard to get them. Just ten years ago, a Chinese middle class family never would have dreamed of owning an automobile. With the tremendous growth of the new middle class, the Chinese are eagerly trading in their Schwinn bicycles for Nissan's, Chevy’s, Toyota's (He, 2006) and even luxurious European models like BMW’s and Mini’s, which have reported record sales in Asian markets (Ruddick, 2012) in recent years. Needless to say, China is on the up.
Paul Romer (Friedman, 2007), Stanford University New Economy Specialist, argues that "…there is a limit to the number of good factory jobs in the world, but there is no limit to the number of idea-generated jobs in the world. If you have the idea that there is an infinite number of human wants and needs, then there are an infinite number of jobs to be done, the only limiting factor is human imagination" (p. 267). Romer asserts that a high-quality idea-based good can literally be sold to every person on earth (i.e. Windows 7, Android, iOS), while knowledge-based goods have a physical cap. The growing economies of China and India aren't necessarily a bad thing for Americans, especially for American innovation. As a nation, we need to keep on the cutting edge if we want to maintain or improve our wages, which starts by giving the people of today the skills to solve the problems of tomorrow. Knowledge level jobs can and will be outsourced, pushing down wages for American knowledge-based and manual labor jobs (Friedman, 2007; Wagner, 2010). If Americans want to continue earning decent wages, they need to further their education in order to obtain jobs created by idea-based goods (ACT, 2011; Friedman, 2007). Although critical thinkers and innovators are what put the United States in a position as a global leader and a step ahead of the rest of the world, it’s the sheer number of American thinkers that’s keeping Americans afloat.

**Common Core State Standards**

In 2010, American College Testing (ACT) conducted an empirical study on the college and career readiness of 15 and 16 year old American high school students and cites the following reasons why the United States educational system is in desperate need of reform (ACT, 2011). Specifically the report found that (ACT, 2011, pp. 10-15):
1. The performance of U.S. students lags significantly behind the performance of students in many other countries.

2. Furthermore, while many nations show impressive improvements in student performance since 2000, the U.S. does not.

3. Within the U.S., ACT research has shown that students who are college and career ready when they graduate from high school are more likely to be successful in subsequent college and workforce training programs where they acquire the skills necessary for meeting the demands of a globally competitive labor force.

4. As states and districts implement college and career readiness standards, we should expect to see not just increased postsecondary success but also economic payoffs for individuals and the nation.

5. Increasing educational achievement in this country will also have a significant and substantial financial impact on the U.S. economy (Acemoglu & Angrist, 2000).

With a focus on college and career readiness (ACT, 2011), and forging citizens who can compete in the global economy, the Common Core State Standards Initiative (CCSSI) established educational standards with a purpose to “provide a consistent, clear understanding of what students are expected to learn, so teachers and parents know what they need to do to help them” while remaining “robust and relevant to the real world, reflecting the knowledge and skills that our young people need for success in college and careers” (“Common Core State Standards Initiative | Home,” 2013). The Common Core State Standards were released on June 2, 2010, and were developed as a state-led effort
by teachers, parents, school administrators and other experts in educational settings (“CCSSO - Implementing the Common Core Standards (ICCS),” 2013). The standards were developed with the highest state, national and international benchmarks in mind. Curricular standards from the highest-performing countries on the OCED administered Programme for International Student Assessment (PISA) were evaluated and used, in part, to develop the Common Core. The Common Core State Standards have only been developed in Mathematics and English Language Arts (“Common Core State Standards Initiative | Home,” 2013). Although states are not mandated to adopt the standards, the U.S. government has tied eligibility for high stakes grant incentives (i.e. Race to the Top) to adoption. As of January 15th, 2013, forty-five of the fifty states have fully adopted the standards (“Common Core State Standards Initiative | Home,” 2013). States that choose to implement the standards are required to base at least 85% of their Mathematics and English Language Arts curriculum on the Common Core State Standards by the year 2015. Texas, Virginia, Alaska, and Nebraska have not adopted the standards and Minnesota has adopted only the English Language Arts standards.

**STEM and Next Generation Science Standards**

In 2007, the Carnegie Corporation of New York assembled a task force comprised of the “nation’s most distinguished mathematicians, scientists, educators, scholars, business leaders, and public officials, to assess not only the current state of math and science education in the U.S. but also how to enhance to capacity of our schools and universities to generate innovative strategies across all fields that will increase access to high-quality education for every student in every classroom.” (Carnegie Corporation of
New York - Institute for Advanced Study Commission on Mathematics and Science Education Executive Summary, 2009, p. ii). In 2009, the Commission released a 76-page report titled *The Opportunity Equation: Transforming Mathematics and Science Education for the Global Economy*. The research team recognized that the relevance of the United States and the future of its democracy lies on the shoulders of the American youth and that a significant shift in the way children are educated must be implemented if the United States is to remain globally competitive. The Commission determined that in particular, American high school students’ science and mathematics literacy is performing dangerously below previous norms based on high school graduation rates, the regression of filed patents by Americans, an increasing high-tech trade deficit, poor U.S. performance on the 2009 Programme for International Student Assessment, and the results of the 2003 National Assessment of Adult Literacy (Carnegie Corporation of New York - Institute for Advanced Study Commission on Mathematics and Science Education Executive Summary, 2009). The Commission concluded that today’s students need high level skills in science, technology, engineering, and mathematics (collectively known as STEM fields) to survive globally in the 21st century. This immediate recommendation for action places STEM at the center of education to develop common standards in mathematics and science coupled with high quality assessments; improved teaching and professional learning; and the creation of a culture of mathematics and science into schools that cultivate student interest in STEM careers (Carnegie Corporation of New York - Institute for Advanced Study Commission on Mathematics and Science Education Executive Summary, 2009).
The results of *The Opportunity Equation* (2009), *Learning Science in Informal Environments* (2009), and *Rising Above the Gathering Storm* (2007) revealed the deficits in American students’ mathematics and science literacy skills and directly contributed to the collaboration of the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and Achieve to begin the development of the Next Generation Science Standards (“Next Generation Science Standards,” 2013).

Similar to the Common Core State Standards Initiative (2010), the Next Generation Science Standards are state-led and internationally benchmarked based on a quantitative analysis of educational reforms of countries whose students performed well on the 2009 Programme for International Student Assessment (PISA). The U.S. government is not mandating state adoption of the standards. States previously used the National Science Education Standards from the National Research Council (NRC) and Benchmarks for Science Literacy from the American Association for the Advancement of Science to guide the development of their state science curriculum standards. Although the current standards have proven to be of high quality, they are over 15 years old and do not address advances in educational technology or pedagogy. The Next Generation Science Standards are research-based, place a heavy emphasis on the STEM fields and use scientific inquiry, application, and design to develop students’ critical thinking and communication skills while exposing them to solving real world science problems. Through authentic experiences and assessment, students will become exposed to, and learn to utilize the skills that scientists and engineers use on a daily basis, dramatically increasing the level of scientific rigor and relevance in K-12 classrooms across the nation.
The Next Generation Science Standards are performance expectations and are not designed to replace states’ current science curriculum. Instead, they are meant to be used to supplement and guide states and local school districts, giving them the autonomy and flexibility to teach expectations in a manner that makes sense for each individual district.

**Historical Background of Science Olympiad**

Since 1984, the mission of the Science Olympiad competition has been “to improve the quality of K-12 science education throughout the nation by changing the way science is perceived and the way it is taught” (with an emphasis on problem solving and hands-on, minds-on constructivist learning practices)” (“Science Olympiad,” 2013). As an inquiry-based program (McGee-Brown, 2003), the hands-on, minds-on Science Olympiad events engage students from all 50 states in rigorous competitions across all STEM disciplines. Since the release of the National Science Education Standards published by the National Research Council in 1996, Science Olympiad has served as an exemplary model of a standards-based program (“Science Olympiad,” 2013). Science Olympiad generally takes place as an after school, voluntary activity with structure similar to other traditional extracurricular activities that K-12 schools offer like basketball or gymnastics. Some schools have utilized Science Olympiad as supplement to a gifted and talented program and others have implemented portions of the Science Olympiad model into their integrated science courses (McGee-Brown, 2003). Depending on their age, students compete in the high school Division “C” or middle school Division “B”. Schools outfit teams complete with coaches and a maximum of 15 competing team members who compete in the regional tournament, which generally consists of 20 events.
In Michigan, 15 regional tournaments are held annually throughout the state, using college and university campuses as host locations. Students compete individually, or in small groups, in a wide range of science events covering several disciplines. For middle school students, events fall in one of five categories: Life, Personal & Social Science, Earth & Space Science, Physical Science & Chemistry, Technology & Engineering, and Inquiry & Nature of Science. The 2013 competition featured the following events: human anatomy, forestry, rocks and minerals, food science, helicopters, mousetrap vehicle, metric mastery, and write it do it (“Michigan Science Olympiad - Home,” 2013). With exemplary team performance in the regional tournament, teams have the opportunity to advance to state and national tournaments (Abernathy & Vineyard, 2001; “Science Olympiad,” 2013). Science Olympiad coaches are typically classroom teachers, though it is not uncommon for coaches to reach out to parents and community members with expertise in STEM fields to assist with coaching duties.

To what extent are the learning outcomes of students participating in Science Olympiad comparable to learning outcomes of students learning science coursework in a traditional setting?

Since 1984, millions of students all over the United States have participated in Science Olympiad, however very little research has been conducted on Science Olympiad competitions (Abernathy & Vineyard, 2001). In a three-year study of Science Olympiad participants in Georgia high schools, McGee-Brown (2003) found through student questionnaires that collaboration, problem solving, and creativity are the three aspects of Science Olympiad most important to students. Abernathy and Vineyard (2001) looked at
the rewards of Science Olympiad most attractive to high school students. Students ranked “having fun” and “learning new things” as most important and second most important respectively. “Competing against other students” was tallied as the third most important aspect for males while females ranked “working with friends” as third most important. Other research has shown that Science Olympiad promotes student growth in social realms. Hounsell (2000), examined students’ perceptions of their own social and science skills as a result of their decision to participate or not participate in Science Olympiad in Delaware schools. Reflections and student surveys indicated that students who participated in Science Olympiad reported increased self-esteem, self-confidence, and heightened communication and teamwork skills compared to their non-participating counterparts (Hounsell, 2000). Science Olympiad provides students with challenging, dynamic events that require students to combine teamwork, content knowledge, science literacy, planning and cooperation in order to be successful (“Home Page | Science Olympiad,” n.d.). Baird, Shaw, and McLarty (1996) looked at the correlation between student’s science process skills and ability to solve logic problems and their performance at Science Olympiad tournaments. Although process skills and the ability to reason logically provide a solid science foundation for students, no correlation was found between high student performance on logic tests and high achievement at Science Olympiad tournaments (Baird, Shaw, & McLarty, 1996). The research supports several aspects of the Science Olympiad program that promote increased student motivation to learn science, increased teamwork and collaboration skills, improved social skills and self-confidence, and self-esteem (Brown & Duguid, 1991; Gibson & Chase, 2002; McGee-Brown, 2003; Wirt, 2011). However, at the time of this writing, a review of the
literature suggests that no longitudinal studies have ever been conducted to specifically
determine the educational impact of Science Olympiad on student achievement.

**What measures can classroom teachers take to increase student interest in the**
**STEM fields?**

In virtually all research studies, increased student engagement has shown to be
strongly correlated to increased student achievement. Wagner (2010) argues that when
students are engaged, the learning becomes meaningful, which in turn leads students to
begin thinking critically.

The qualitative case study by Watson, Mong, & Harris (2011) looked at teacher
and student experiences and perspectives of educational video games for in-class use
among four grade 10 history classes in a rural high school located in the Midwestern
United States. 98 tenth grade students, selected at random, made up the research
population. Data were collected by observation, focus group and individual interviews,
and document analysis. The research team videotaped and observed the 98 students in
four grade 10 history classes over five days. Days one and five consisted of traditional
classroom activities while days two, three, and four consisted of video game play. After
each class period, students were asked to take part in individual and focus group
interviews. Each interview participant was asked semi-structured questions with regards
to their perception of the use of the video game in their class, their past experiences with
both mainstream and educational video games, and their thoughts on the use of video
games for educational purposes. Student assignments consisting of short answer, essay questions, and a geography map quiz, were also collected for analysis.

Student engagement, teaching strategies, and classroom integration were identified as the main emerging themes. By using grounded theory, Watson, Mong, & Harris conclude that student engagement on video game days is higher than non-video game days and that the atmosphere of the class is considerably different on game (learner-centered) vs. non-game days (teacher-centered). Classroom observations and student interviews indicate that overall, students enjoyed the digital based learning because it provides an environment that is hands-on, fun, and challenging.

The research team felt that the most significant finding of the video game use in-class was the transformation of the classroom from a teacher-centered to learner-centered environment. In the teacher-centered classroom, the students were mostly unreceptive to the lectures presented by the teacher. In the learner-centered classroom, the students were actively making decisions while interfacing with the game, the teacher, and other students. Teacher-centered classrooms often promote the rote memorization of knowledge whereas learner-centered environments require students to think critically by supporting their ideas with reason and analysis.

With factory and knowledge-level jobs being constantly shipped overseas, now more than ever America needs to keep producing idea-driven workers who can think critically. Bill Gates, founder of the Microsoft Corporation was recited that students “...need to understand things in order to invent beyond them” (Friedman, 2007, p. 365) while preaching that the students of today are going to be using tools of tomorrow to solve problems that don’t even exist yet (U.S. Department of Education, 2008). Wagner
(2010) found a ubiquitous consensus among American business leaders that they are no longer looking for employees who can simply take directions from a supervisor, but rather those who ask questions and strive to find innovative solutions for challenging problems on their own. Of those interviewed, Mark Maddox, human resources manager at Unilever Foods North America, adds that "...in today's global environment...we're not competing for jobs just in neighboring towns. We're competing with Bangalore, India. It's a global competition. That's the challenge we're all going to face" (p. 19). The Common Core State Standards Initiative and the Next Generation Science Standards are pushing teachers to develop students’ ability to think critically, use higher order thinking skills, use problem solving skills like never before (“Common Core State Standards Initiative | Home,” 2013, “Next Generation Science Standards,” 2013). A number of researchers have found that students who are taught science using inquiry-based methods score higher on achievement tests as a whole than students who were taught using traditional, teacher centered methods (Gibson & Chase, 2002; Jalil & Sbeih, 2009). Tony Wagner, author of the book *The Global Achievement Gap* (2010) constructed a list of seven survival skills our children need to learn in school today, in order to compete in the global economy and the 21st century, tomorrow. Wagner (2010) notes:

1. Critical Thinking and Problem Solving
2. Collaboration Across Networks and Leading by Influence
3. Agility and Adaptability
4. Initiative and Entrepreneurialism
5. Effective Oral and Written Communication
6. Accessing and Analyzing Information
7. Curiosity and Imagination

Wagner’s proposed twenty-first century survival skills couldn’t stray much farther from the standardized testing and curriculum craze of the No Child Left Behind Act (2002). Instead, Wagner, a Professor of Education at Harvard University, focuses on developing interpersonal skills like communication, creative problem solving, adaptability, and collaboration among our students (Wagner, 2010).

Barak, Ashkar, and Dori (2011) investigated the effect of animated movies on students’ learning outcomes and motivation to learn. Their study looked at students’ understanding of scientific concepts, explanation ability and motivation to learn science among students in five elementary schools in central Israel. 1335 fourth and fifth grade students made up the research population. The experimental group consisted of 926 students at five elementary schools while the control group consisted of 409 students at two elementary schools. A Pearson Chi-Square test showed no significant differences between the experimental and control groups with regards to gender, class, parents’ occupation, and student involvement in after school extracurricular activities in science education.

The control group teachers used traditional teaching methods and taught science using only science textbooks and still-pictures for student learning. The experimental group teachers used traditional teaching methods and animated movies to support the science textbook. With the exception of the animated movies, the instructional methods of the experimental and control groups were similar. The students in both groups received the same amount of science instruction per week. Students were given Science Thinking Skills and Motivation to Learn Science questionnaires at the beginning and end of the
school year. Students’ academic achievement in science was determined by their report card grades. Results from an Analysis of Covariance test (ANCOVA) showed that students in the experimental research group had significant net gains over their control research group counterparts in the following questionnaire areas: students’ understanding of scientific concepts and phenomenon, students’ explanation ability, students’ motivation to learn science. Experimental research group students’ mean scores in science as reported in their report cards were higher than the mean scores of the control research group students and the standard deviations were lower.

Animation movies used to support ideas in a science textbook were more effective in encouraging students’ understanding of scientific concepts, explanation ability and motivation to learn science when compared to using only textbooks and still-pictures. Their research suggests that integration of animated movies into science courses may increase student performance and condense the space between high and low report card scores.

The research team felt that animation movies used in conjunction with assignments and classroom discussion improved students’ motivation, self-efficacy, interest, understanding of scientific concepts, and ability to explain scientific concepts. Because the animation movies were relevant to the students, they were engaged in learning and in return were “encouraged to explore new concepts, provide possible answers to daily life questions, and participate in class discourse”, all of which require critical thinking. Chapter three of this review will attempt to analyze several facets of Science Olympiad and distinguish the structural factors that can make inquiry based learning a positive and successful experience for students.
Chapter III – Results and Analysis Relative to Problem

The intent of this literature review was to explore the quality, learning outcomes, and student experiences of Science Olympiad programs in the United States. This review utilized the following three research questions, Michael Graham Moore’s Theory of Transactional Distance, and elements of self-study as a conceptual framework for questioning analysis.

1. With regards to current U.S. educational reforms, what is the perceived academic quality of the Science Olympiad program?
2. To what extent are the learning outcomes of students participating in Science Olympiad comparable to learning outcomes of students learning science coursework in a traditional setting?
3. What measures can classroom teachers take to increase student interest in the STEM fields?

Chapter three provides an overview of the research findings and recommended structural implementations for Science Olympiad coaches to consider when developing and employing a Science Olympiad program using Moore’s Theory of Transactional Distance as a critical lens. This chapter will examine the structural factors that make Science Olympiad successful for students and coaches.

Science Olympiad Overview of Research Findings

The mission of the Science Olympiad competition is “to improve the quality of K-12 science education throughout the nation by changing the way science is perceived and the way it is taught” (“Science Olympiad,” 2013). The Science Olympiad mission and
objectives are supported with constructivist teaching and learning practices that allow students to use scientific inquiry to solve problems through investigations, content knowledge, and project construction (Robinson, 2004). Science Olympiad events engage students from all 50 states in rigorous competitions across all STEM disciplines. Science Olympiad provides students with challenging, dynamic events that require students to combine teamwork, content knowledge, science literacy, planning and cooperation in order to be successful (“Home Page | Science Olympiad,” n.d.). Science Olympiad has served as an exemplary model of a standards-based program (National Research Council, 1996) and will continue to do so under the newly released Next Generation Science Standards (“Next Generation Science Standards,” 2013).

The research reveals that students who participate in Science Olympiad programs report positive learning experiences across varying disciplines. Through Science Olympiad reflections and student surveys, Hounsell (2000), found that students who participated in Science Olympiad reported increased self-esteem, self-confidence, and heightened communication and teamwork skills compared to their non-participating counterparts. The academic impact of Science Olympiad on student achievement remains to be a question without a conceivable answer as the existing research suggests that no longitudinal studies have ever been conducted to specifically determine the educational impact of Science Olympiad on student achievement. The impact of Science Olympiad on student choice of pursuing a STEM career has found a significant body evidence of the relationship between students participating in competitive science events and their career choices. In a study of 1,488 college freshman, Forrester (2010), found that students who participated in Science Olympiad and other competitive science events as a K-12
student have higher science self-efficacy and are more likely to choose to major in science, technology, engineering, or mathematics in college.

**Theory of Transactional Distance Applied to Structure**

As an inquiry-based program, Science Olympiad events are student-led and student-centered. Contrary to the courses many students are exposed to in K-12 schools, the construction based events in Science Olympiad can be solved in an infinite number of ways as “students rely on their creative and problem solving skills to determine a workable solution” (Wirt, 2011, pp. 20-21). On the traditional assessment events, students must use teamwork, scientific literacy, cooperative learning, and research skills to complete the given scenario or task. Students prepare for Science Olympiad events in varying settings. A majority of K-12 schools participating in Science Olympiad sponsor a voluntary, after school program although some schools do offer Science Olympiad in part or as a whole during the school day (Wirt, 2011). Due to the unique structure of Science Olympiad, it is not generally taught using teacher-centered authoritarian teaching methods (Breyfogle, 2003), but instead relies on other methodologies that encourage and support a learner-centered environment.

Collaborative discussion (Kanuka, 2011; Zhan, 2008), course design (Filimban, 2008; Lou, Bernard, & Abrami, 2006; Simonson, Schlosser, & Orellana, 2011), and constructive interaction (Lou et al., 2006) were cited amongst researchers as important considerations for instructors aiming to facilitate learner-centered environments. Researchers suggest that course design takes precedence over other variables for educators with claims that “if the design is effective, instruction will also be effective”
In a survey conducted to determine specific elements of distance education considered unfavorable, undergraduate university students cited the following as inconvenient elements when enrolled in a self-study (student-centered) course (Bouhnik & Marcus, 2006, p. 300):

- Lack of a firm framework tends to encourage laziness
- A high level of self-discipline is required
- Absence of a “learning atmosphere”
- The learning process is less efficient, when compared to a “face-to-face” learning format, and requires the students to dedicate more time to learning the subject matter
- Lack of interpersonal, direct (non-mediated) interaction

An examination of the effect course design has on success applied under Moore’s theoretical framework has brought number of profound themes to light.

Course structure and dialogue affect levels of course transactional distance, which in turn affects the extent of learner autonomy required on behalf of the student. Moore (1993, 1973) has hypothesized many relationships between learner autonomy, structure and dialogue. For example:

- When learner autonomy is low the need for structure is high
- When structure is low the need for learner autonomy is high
- When structure increases, dialogue decreases
- Programs with low dialogue require a high degree of learner autonomy
Figure 4 illustrates the relationships between course structure, capacity for individualization, dialogue, transactional distance, and learner autonomy. Transactional distance and learner autonomy have a direct relationship, as increases or decreases in transactional distance require increases or decreases in levels of learner autonomy for a student to be successful.

**Figure 4. The Relationship between Learner Autonomy and Transactional Distance**

The theory of transactional distance suggests that students need higher levels of learner autonomy, self-efficacy, and self-regulation to be successful in courses with high levels of transactional distance. Relationships of transactional distance are not limited to only one variable. Transactional distance is a relative rather than absolute value and that as a function of dialogue, structure, and learner autonomy, an infinite amount of variations of transactional distance exist in educational programs (Moore, 1993). Transactional distance in education is not its own entity, but rather as a “subset of the universe of education” (p. 22) and because of this direct relationship, transactional distance between the teacher and learner subsists in all educational programs on some
level, even if minute. The question remains as to how learner centered environments can be structured to accommodate students with low levels of learner autonomy, self-efficacy, and self-regulation.

Using the theory of transactional distance as a conceptual framework, one can hypothesize that students with low learner autonomy require learner center science courses designed with the following characteristics to be successful:

- Rigid structure
- Less individualization
- Increased interaction with instructor
- Ample opportunities for interaction with other students

Using the theory of transactional distance, one can also hypothesize that self-regulating, autonomous students can be successful in science self-study courses designed with more liberal attributes including:

- Fluid structure
- More individualization
- Less interaction with instructor
- Little or no opportunities for interaction with other students

Although many parallels exist between student participation in Science Olympiad and increased student self-esteem, self-confidence, and heightened communication and teamwork skills (Hounsell, 2000), the review of the existing literature suggests that no longitudinal studies have ever been conducted to specifically determine the educational impact of Science Olympiad on student achievement. In chapter four, Moore’s Theory of Transactional Distance (1993) is used in conjunction with the observations of a Michigan
science teacher coaching Science Olympiad. Through the use of self-study data, the successes and challenges of coaching Science Olympiad at the middle school level are used to make instructional recommendations for teachers implementing the Science Olympiad model in the classroom.

Chapter IV – Recommendations and Conclusion

Chapter four of this review will utilize self-study data collected by one Michigan middle school Science Olympiad coach applied under Moore’s Theory of Transactional Distance (1993) as a critical lens to make instructional recommendations for teachers wishing to implement elements of the Science Olympiad model into middle school science classrooms.

Experiences as a Science Olympiad Participant

Initially, my own experiences as a middle school science student were less than spectacular. Science class often consisted of an assigned chapter reading, answering the questions at the end of the selection followed with a chapter test on four or five sections every few weeks. Repeat. My outlook on science changed in 7th grade when I participated in Science Olympiad. As I recall, my partner and I were assigned to take over the an event titled “Trajectory” where we were required to construct a catapult-like device that launched a tennis ball into a sandbox several meters away. I remember the hours we had put into the event, researching catapult designs, studying elements of flight trajectory and reading the dense event manual over and over to make sure we fully understood the rules and construction parameters. It was the first time in my educational career I remember doing science, as opposed to reading about science. Even though I thoroughly enjoyed
my Science Olympiad experience as a middle school student, it did not come without its fair share of frustrations and complexities. After nearly a dozen different designs acompañed by an equally perplexing number of launch tests, my partner and I had finally found a workable solution. Butterflies in my stomach kept me up hours past my bedtime the night before and nightmares of losing the instructional manual I had written for our device haunted me. The day of the competition had finally come and my partner and I were ready. We walked in to the gymnasium calm, cool, and collected. But something wasn’t right. The sandbox the tennis ball was supposed to land in was elevated about one meter off the ground and the instruction manual I had written for our device assumed that the sandbox was flush with the ground! In a panic, my partner and I scurried through the event rulebook, looking for the fine print that stated that the sandbox would be elevated. Except it wasn’t fine print. Before our eyes, plain as day, the rules manual clearly stated: When given target distances and heights, teams should be able to calibrate their device for the most accurate launch possible. With our launch time scheduled in just a few minutes, we had to act fast. After quick deliberation, we ultimately decided to use the “guess and check” method. On our first try, we would simply ignore the fact that the sandbox elevated by one meter and would calibrate the device solely based on the distance at hand. After launching and evaluating our device’s shortcomings, on subsequent tries we would either under or overshoot the sandbox using the data in trial one as a starting point. Our idea wasn’t perfect, however, we did utilize techniques we had come to master while building catapult prototypes. Our first shot was a bit short of the sandbox. After some minor adjustments we managed to squeak out three accurate shots of the four allotted, which was good enough for third place!
Recommendations

Through self-study, educators are afforded the opportunity to explore their current practices (Loughran & Northfield, 1998) while uncovering living contradictions as educational practitioners (Whitehead, 1989). The purpose of this self-study was twofold: (1) to further explore and understand the challenges, frustrations, and dilemmas of coaching Science Olympiad at the middle school level; and (2) to investigate elements of the Science Olympiad model that could prove useful in my own classroom. In this self-study, I used two sources of evidence as my data set: my actions and reactions, and my personal analyses in the form of a weekly journal comprised of observations, critical questions, and reflection. Like Brubaker (2012), I did not formally involve my colleagues in this research study. However, through daily conversations with my colleagues and students I was able to informally affirm my own observations and beliefs, which were recorded in my reflective journal.

This self-study became self-initiated (LaBoskey, 2004) after conversing with my colleagues one day after practice early in the season. It was only our second practice of the year and already we were exhausted. As science teachers in the building, we had recruited 36 sixth, seventh, and eighth graders to take part in a voluntary, after school Science Olympiad program. Our initial perception was that four coaches could easily accommodate the needs of 30-40 students. After all, our current teaching loads gave us class sizes of 28-32 students for one teacher so with four teachers coaching we assumed that we would have more than enough hands to go around. After the first week it became evident that we may be able to “teach” science to 30 of our own students in the traditional classroom setting, but we would need many more hands to engage 36 middle school
students in true hands-on, minds-on, constructivist learning. After our second meeting, each coach had the feeling of being stretched dangerously thin. I was constantly being pulled from one group to another, redirecting and guiding students on everything from rocks and minerals and Michigan forestry, to bridge building and helicopter construction. Other teachers directed groups working on the equally varied topics of food science and mousetrap vehicles, to road maps and mastering the metric system. From a coaching standpoint, it became clear that the first step to making Science Olympiad a successful endeavor would be to expand the size of the coaching staff. With a little coaxing and persistence, our coaching staff did eventually grow as we recruited one veteran teacher with a consumer science background and another with expert knowledge in industrial arts and applied sciences. At the regional competition I had an opportunity to converse with a few area coaches who utilize a student to teacher ratio of 2-3 students for every coach by recruiting parents, teachers, community members, and high school students as volunteers. Many successful teams have enough coaches to allow each to concentrate their efforts on just one or two events.

Challenges.

Throughout the season, coaches and students alike struggled through a series of challenges and frustrations. The biggest obstacle faced by coaches was getting students to use the scientific method and think critically about the possible solutions for the Science Olympiad problems and events. The unique structure of Science Olympiad makes events fun, but very challenging for students. The events engage students in problems that do not have a single predetermined solution and forces students to work collaboratively to form creative solutions. Students must use scientific inquiry to generate hypotheses and test
experimental strategies while collecting data and making inferences about failed trials.

Limited funding for our Science Olympiad program proved to be a doubled edged sword. Unlike other school teams with a sizeable Science Olympiad budget, our team relied on recycled goods, parent and teacher donations, and out-of-pocket purchases by coaches to rally the supplies needed. In a positive light, our lack of supplies forced students to be resourceful and creative because we simply didn’t have the money or supplies to waste. In a MacGyver-like fashion, ordinary objects like pencils and paperclips became bridge trusses and frames for helicopter rotors. Through this process, students became well versed in creating scaled down models out of inexpensive materials or drawing prototypes before being given the materials needed to begin the final construction for the competition. As a first year Science Olympiad program, our team lacked veteran leadership and experience from student and coaching standpoints. Of 36 team members, only six were in eighth grade and nine were in seventh grade. The lack of upperclassmen gave several sixth grade students the chance to compete right away, an opportunity they may not have otherwise been afforded. During the first several weeks of practice, students’ previous experiences in teacher-centered, authoritarian classrooms shined. Often times, students would look for coaches to enable them, seeking instant gratification for the answers to their questions instead of using resources in the classroom or searching the depths of the internet for guidance. Students seemed to appreciate the freedom of exploring solutions to events amongst their peers, though they often struggled with the concept of solving problems with “no single solution or process” (McGee-Brown, 2003, p. 5).
**Successes.**

Although our school had a high number of students come out for the Science Olympiad team, the lack of familiarity of the individual events and structure of the competition by the students and coaching staff made it impossible to prepare and compete in all 23 events the first year. As a team, we decided to focus our time and energy on doing a few events really well, as opposed to entering students in more events with shorter amounts of time to prepare for each. Considering our lack of experience, this approach worked well as the students earned a respectable 6th place in our region even though we failed to field a team for every event. While our small amount of success at the regional competition was exciting, I would argue that the foremost achievement of the year was seeing the students engaged in their events during practice. One day during practice, I took a step back for a moment and glanced around the room to find 36 sixth, seventh and eighth graders looking at diagrams, reading technical documents, drawing ideas on the whiteboard, testing hypotheses, arguing with their classmates, constructing prototypes, and most importantly, experiencing science as real scientists. It was truly incredible to witness middle school students so engaged in academics on a 100% voluntary basis after regular school hours. Throughout the season, student interest and motivation to do well in science seemed to increase, along with students’ scientific literacy, process, and critical thinking skills. Not only were students learning and engrossed in the scientific process, but they were doing so and having fun at the same time.
Implementation into the classroom.

After observing the obvious student enjoyment and what I perceived to be overwhelming benefits of the Science Olympiad program, I began reflecting on my own teaching and asked myself how I could begin to implement elements of the Science Olympiad program into my own classroom. I began this process by examining the Michigan 6th grade science curriculum and sought out curricular themes that would accommodate Science Olympiad events as modes of authentic assessment. I realized that although seemingly worthwhile, this practice would not come without other implications. With curricular objectives mandated by the state, my current practice of teaching science an inch deep, a mile wide would need to be reversed to a mile deep, inch wide process. As a trial, I selected two Science Olympiad events to implement into my teachings over the next eight weeks. Students who were already involved in the Science Olympiad program were excited for the opportunity to mentor their peers in events they already had background knowledge on and provided the class with invaluable leadership. By employing Science Olympiad events into the curriculum, I was able to shift my teaching practices from a teacher-centered to primarily student-centered environment which revealed one profound finding I had not previously considered. Congruent with McGee-Brown (2003), I found that the Science Olympiad team members were all “A” and “B” students in their school science classes. In my trial implementation of integrating the Science Olympiad model into the classroom, I observed several “low achieving” students thrive in the learner-centered environment that invites students to be creative problem solvers. This realization has led me to recognize that Science Olympiad teams should not be comprised of only the “A” students from sciences classes, but should be made up of
well-rounded students who possess the ability to use critical thinking and problem solving skills. In the eight week trial of implementing two Science Olympiad events into the curriculum as a form of authentic assessment, the mini-competitions were won on both occasions by students whose report cards are generally filled with “C’s” and “D’s” as opposed to “A’s” and “B’s”. Much to my surprise, several students regarded by their classroom teachers as “high achieving” performed poorly on the authentic assessments. This finding, although minute at this time, has made me think differently about the correlation between student achievement in the classroom and their ability to make contributions to the Science Olympiad program.

**Areas for Further Research**

A review of the literature reveals many gaps in the research with regards to the Science Olympiad program and its effects on student achievement. To further answer my research questions, I would want to perform additional research of the effects of the Science Olympiad program on student achievement by implementing elements of the Science Olympiad program into the classroom. Few studies have looked at the effects of science competitions on student achievement and even fewer specifically cite or make reference to the Science Olympiad program. Although the research suggests a correlation between student participation in Science Olympiad and increased student self-esteem, self-confidence, and heightened communication and teamwork skills (Hounsell, 2000), a review of the existing literature reveals that no longitudinal studies have ever been conducted to specifically determine the educational impact of Science Olympiad on student achievement.
Summary and Conclusion

Implementing real-world experiences into the classroom is essential practice for teachers preparing students for the rigors of the 21st century. Classroom environments where students take control of their own learning experiences serve as a fundamental piece for developing students’ higher order thinking skills. As a standards-based program, the collaboration-competition model of the Science Olympiad program fulfills many benchmarks established by the Common Core State Standards and the Next Generation Science Standards curriculums. With an emphasis on problem solving, hands-on, minds-on constructivist learning practices, scientific inquiry and critical thinking, the Science Olympiad program is a student-centered authentic science experience.

Self-study methodology provided me with a useful and powerful tool to reflect, critique, and improve upon my practice as a middle school Science Olympiad coach and teacher through a critical lens. Through observations, critical reflection, and journal keeping, I was able to explore and understand the challenges and frustrations I faced as a Science Olympiad coach. More importantly, through this self-study my students and I have benefited from my reflective journal and observations as I was able to take elements from the successes our team experienced and implement those into my science curriculum.
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