Science Olympiad:

The Role of Competition in Collaborative Science Inquiry

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Introduction

All data in the three-year (2000-2003) study of the impact of student participation in Georgia Science Olympiad revealed that within team student collaborative inquiry is a result of the overall team competition framework. Intensive within team collaboration to prepare for competition with teams from other schools is the pivotal characteristic that draws participants to this extracurricular science program. During observations at weekly school Science Olympiad meetings and across competitions (regional, state, and national), the enthusiasm and highly active engagement by students focused on applying science, engineering, and mathematics skills and principles to solve problems was palpable. Pairs or small groups of students from within the school team of 15 students worked in an intense and focused manner to become the team "experts" on selected events in which they would compete at tournaments. Students talked and debated issues; examined, recorded, and analyzed data; located and used diverse resources; used repeated trials to improve understanding and performance; and used team data from the previous competitions to inform changes in science procedures in their current Science Olympiad events. While Science Olympiad is an extracurricular activity in most schools, researchers observed similar active student science application in classrooms where teachers incorporated events in their instruction.

Background of Science Olympiad

In 2004, Science Olympiad, a forum for elementary and secondary students to showcase their scientific skills and knowledge, celebrated two decades of national competitions. According to Dr. Gerard Putz, president and co-founder of Science Olympiad, the organization was founded to improve the quality of math and science education and to reignite enthusiasm in those fields among students (Putz, 2005).

The State Director of Science Olympiad invites science teachers to volunteer as coaches, and then offers coach workshops for new coaches. Coaches can also attend national workshops if supported by their school districts. Coaches form teams with a maximum of 15 students to compete in up to 23 events at regional and state level tournaments within states. The top teams at regional competitions progress on to compete at state tournaments, and the top teams at both middle school and high school levels go on to compete in the national tournament. Team coaches invite local professionals, parents, and teachers to mentor students as they prepare to compete in their assigned or selected events. While pairs of students on each team prepare and study in depth for competition in a small number of the total events at a tournament, all team members must be knowledgeable about all events in case there is a time conflict in the tournament schedule that requires students to "swap"events with each other for competition. Event judges award points for participation, following the rules in the student manual, and effective application of knowledge and skills. Event points are tallied and compared across teams to determine which teams are among the top.

Need for the Longitudinal Study

Teachers across the United States encourage students to participate in extracurricular science activities like science fairs and Science Olympiad, but very little research has been conducted to determine the impact of such activities. Abernathy and Vineyard (2001) collected survey data from middle school and high school students at state level Science Fair and the Science Olympiad tournament in Utah to compare the two programs. They found that participation in Science Olympiad is more voluntary and is generally an extracurricular activity whereas Science Fair is often a course requirement. They found that Science Olympiad students enjoyed teamwork and thought the experience prepared them for their future. Data revealed significantly more males than females participating in Science Olympiad as compared to Science Fair. The authors suggested that the role of competition in Science Olympiad needs further investigation. There are no longitudinal studies of the impact of student participation in team competition structure of Science Olympiad.

Science Inquiry

Science Olympiad is an inquiry-based program. Inquiry-based science programs have been the goal in science education for four decades definitions and models have been generated in attempts to ensure students engage actively in science (Chiappeta and Adams 2004; Ingram et al. 2004; Martin-Hansen 2002; NRC 1996; Oliver-Hoyo et al. 2004; Rutherford 1964; Sternadel 2004; Tamir 1983). *Science for All Americans* (1989, p. 26) includes the assertion that “scientific inquiry is not easily described apart from the context of particular investigations” and presents characteristics of scientific inquiry as demanding evidence, blending logic and imagination, explaining and predicting, and identifying and avoiding bias. In addition, science is characterized as a “complex social activity” (AAAS, 1989, p.28). The National Research Council (1996; 2000) defined science inquiry and provided a guide for teaching and learning the national science education standards through inquiry. Scientific inquiry is defined (NSES p.23) as: “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.” The National Science Teachers Association Position Statement on Scientific Inquiry (2004) suggests that scientific inquiry “reflects how scientists come to understand the natural world, and it is at the heart of how students learn.” NSTA (2004) recommendations suggest that teachers help students understand that science is posing questions about how the world works and developing and conducting scientific investigations with no fixed process to make discoveries through systematic data collection and analysis using appropriate tools and instruments.

Chiappetta and Adams (2004) characterize inquiry-based science instruction as a multi-faceted approach with a shifting focus, depending on curricula, from presenting and exploring ideas related to specific concepts and content to focusing totally on attaining specific science process skills. The team competition structure of Science Olympiad results in naturally occurring problem-solving, highly creative, resource-based, hands-on science learning communities of students, parent volunteers and teacher coaches in middle schools and high schools. The diversity of events in Science Olympiad requires approaches and skills presented in the Chiappetta and Adams model and reflects other inquiry-based characteristics described above.

Research Methods

A multiple triangulation research design was used to enhance validity of data collected across sources. Multiple researchers were used so that each could conduct a case study in different regions of the state each year. In the original design, case study schools were to participate across multiple years of the project, but most were unable to participate beyond their one-year commitment. Multiple data collection methods were used throughout the study: individual interviews; focus groups; open-ended questionnaires, closed-response item surveys, participant observation, document collection, and informal conversations with parents and coaches at tournaments. Multiple data sources were used:

team coaches, school-level administrators, students, parents, tournament event managers, and the State Director of Science Olympiad.

A team of three to five researchers per year, collaborating with the Director of Georgia Science Olympiad, investigated the impact of Science Olympiad on students participating in Georgia middle school and high school teams over a three year period (2000-2003). While there was an informal elementary component to Georgia Science Olympiad, it was not included in the study of the more organized secondary levels. This study examined Science Olympiad in the state of Georgia, an activity of the Georgia Academy of Science and the Georgia Junior Academy of Science. Approximately 30% of Georgia middle and high school participated in Science Olympiad at the time of the study. The upper divisions, "B" (Gr. 6-9) and "C" (Gr 9-12), compete at regional, state and national tournaments hosted by universities throughout the state. We found public, private, parochial and home school teams enrolled in Georgia Science Olympiad with some schools entering multiple teams. An initial pilot study was conducted at four sites in Georgia in 1999 to determine the nature of implementation of Science Olympiad and to develop, pilot, and refine instruments to be used in the subsequent state wide study.

Each year of the project, data were collected from students, teachers, administrators, and parents at four case study schools and 16 associate schools. Students participating in the study were primarily "A" and "B" students who participated in a wide variety of other extracurricular activities such as band, debate team, sports, cheerleading, newspaper staff, and other academic clubs. Most were well-rounded students, but some indicated that non-Science Olympiad students often viewed them as "geeks" because they participated in a science activity. The engineering or device events attracted some students who previously had not been particularly interested in science and often were not top achievers in science courses.

In addition to student data, closed-response item questionnaire data focusing on the use of Science Olympiad events and materials in regular science classes and district curriculum were obtained from all Georgia coaches who registered a team to participate in regional tournaments. Data about the impact of Science Olympiad in schools were collected from school administrators.

Data were analyzed using multiple methods. Open-ended data from questionnaires and interviews were analyzed using the constant comparative method. Using this strategy, raw data were coded, collapsed, and compared within site, and across sites to determine categories that emerged from the data to explain the experiences of respondents and impact of Science Olympiad on participants. Data were analyzed by level (middle school and high school) and by gender (male and female) to determine differences in experiences and impact. Dichotomous data and Likert Scale data from student and coach surveys were analyzed by generating percentages of each sample that responded to each option for each question. Data were analyzed and a summary report was written each year. Within each yearly report a wide representative sample of data were included to support all findings. Specific data will not be included in this final report.

Findings

Data have provided a rich and in depth understanding of the diversity of uses and impacts of Science Olympiad in participating Georgia schools. Data across years of the study, and across data sources (students, coaches, parents, administrators) revealed that collaboration, problem-solving, and creativity are three of the most important aspects of participation in Science Olympiad for students.

While researchers identified multiple models of implementation of Science Olympiad, it was clear that the most significant determiner of incorporation of Science Olympiad events in regular science instruction was the degree to which an event is aligned with local, state and national science standards.

Cross-grade level learning communities that emerge naturally as a result of the Science Olympiad structure are critical to the success of the program. Students work during regular meetings (and frequently, at each other's homes in the evenings and weekends) in pairs or small groups of three or four to learn in depth the science for the events in which they will compete, develop skills necessary to be effective, and negotiate who will be responsible for various aspects of event preparation (e.g., identification of relevant resources, materials acquisition, in-depth content or skills focus, development of plans for experiments, generation of data collection strategies, and time management). Each student brings to the science problem at hand her science knowledge, skills, and expertise in creative collaborative problem-solving. At the middle school level, ongoing study groups frequently include parent or teacher volunteers.

Coaches asserted that the nature of Science Olympiad events (presentation of problems with no single solution or process) and requirement that students work in pairs results in students becoming persistent and creative collaborative problem solvers. Students begin to consider experimentation and problem-solving as long term endeavors as they work on events. Coaches claimed that students learn the importance of trial and error to modify procedures based on data they generate and analyze. High school coaches explained that students learn to tackle problems in new contexts and analyze problems systematically using improved problem-solving and critical thinking skills. Students at both levels also developed and use problem-solving strategies to address social problems within their teams.

The vast majority of both middle school and high school students characterized their experiences in Science Olympiad as "challenging" and "fun." The vast majority of students claimed that Science Olympiad experiences directly impacted their views about the importance of collaboration among scientists. Many students identified collaboration as the key to scientific inquiry. They found that pooling knowledge, experience, and skills stimulated creative problem-solving among participants that resulted in more focused applications of science, engineering, and mathematics concepts. Students found application of science to "real world" problems a challenge that required identification and use of new resources. Focusing on particular events with a partner enabled students to "specialize" in a few areas of science in which they were interested.

The primary motivation for students to study and work so intensely was to be able to demonstrate through better skills and application, a higher level of knowledge of science and engineering concepts and principles than students on competing teams at tournaments. One high school student's characterization of the within-team collaborative process is highly representative of most students' descriptions: "pooling all our knowledge, experience, skills, creativity and luck to pull off top places in each event." Students enjoyed winning medals and recognition in individual events, but the primary motivation for most teams is to generate enough points across individual events to be among the top teams (approximately 20%) that progress to the state level competition where the top two teams in each division progress to the national competition. Students, coaches, and parents revealed that performing well at tournaments brings the team and school high positive recognition and enhances student pride in their academic accomplishments.

Students across levels and years of the research characterized their involvement in Science Olympiad as fun, exciting, and challenging and find participation in tournaments on university campuses informative. Between 83% and 97% of both males and females at middle and high school levels indicated that participation had increased their general enjoyment of science. Between 50% and 75% of student questionnaire respondents yearly asserted that they enjoy their regular science classes more as a direct result of their participation. Most Georgia Science Olympiad participants are “A” or “B” students (in part due to grade requirements for participation in extracurricular activities), however, between 17% and 50% of students across years claimed that participation resulted in improved science grades. Between 70% and 90% of the students identified new science content and skills they learned as they prepared for events. Parents claimed that participation in Science Olympiad had increased their child’s knowledge of science and science skills as well as improving achievement. Parents also said that participation improved problem-solving skills, critical thinking skills and creativity in their children.

More than three-fourths of student respondents across years of the study indicated that they have learned new science content or skills that they had not studied in their regular science classes. The vast majority of students’ open-ended written responses describing what they had learned were “event-specific” (the knowledge and skills described were specific to the events they studied for tournaments). Other responses were more general with students claiming to have learned experimental design, logical thinking, organizational skills, measurement, metric system, engineering, merging mathematics and science, or application of concepts from specific areas of science (physics, chemistry, geology, earth science, life science, astronomy and anatomy).

There were two major findings about the social impact of Science Olympiad on participants. First, most students claimed that they now believe that men and women are equally competent in science (see Table 1). For our sample, there was a slightly higher impact on this perception for females across levels than males. Some high school students responding “no” explained they believed that before participating in Science Olympiad. The cross-gender, cross-level collaborative structure allows students to experience and appreciate each other’s strengths.

Table 1. Percent of students responding “Yes” to the question: “Has participation in Science Olympiad resulted in a view that both women and men can be equally competent scientists?”

Date	**MS males**	**MS females**	**HS males**	**HS females**
2000/01	91.1%	100%	80.9%	89.5%
2001/02	82.8%	94.2%	73.1%	84.4%
2002/03	81.9%	93.7%	75.7%	85.4%

Second, students’ group skills improved. Students, parents, and coaches claimed that as a direct result of Science Olympiad participation, students learned to compromise, value other people, work with people of different ages and grade levels, and get along with people they never thought they could previously. Students indicated that they felt stronger academically and knew they competed better when working collaboratively because they learned to share ideas, experiences, and knowledge and thus were more focused, effective and efficient competing against other teams. Parents said that their children had improved teamwork and social skills, increased self-confidence and self-esteem, were more self-motivated, exhibited more enthusiasm about doing science, and took pride in their accomplishments.

Implementation Models

We discovered a variety of models for implementing Science Olympiad across schools in the study. At both high school and middle school levels, the predominant model of implementation of Science Olympiad is as an extracurricular activity with science teachers incorporating a few events into their regular science curriculum. Between 50% and 75% of the teachers each year reported integrating Science Olympiad events in regular science instruction. Many teachers have cross-class student competitions to encourage collaborative studying and preparation. Middle school coaches commonly use experimental and device events and high school coaches use lab and device events in regular science classes (event classifications and descriptions can be found at www.soinc.org and in the yearly *Science Olympiad Coaches Manual and Rules* and the *Science Olympiad Student Manual*).

A second middle school model observed in a few schools is to offer Science Olympiad as an exploratory course or gifted and talented course where all students study general science skills and content required for all events. A third model observed in one parochial middle school involved all teachers across the curriculum and all students studying the science content and skills required in all Science Olympiad events. This model was unique and particularly exciting and engaging. The goal in this school was to enable students to experience and realize that science impacts all aspects of our lives and to experience teachers in all areas teaching science.

Problems and Creative Solutions

The two greatest problems that students had with Science Olympiad were trying to accommodate competing schedules of other extracurricular activities and finding enough time to meet with partners to adequately prepare their events. Parent data supported these student claims. Parents overwhelmingly identified the number one problem as lack of time to research and prepare for events the way their children wanted to. Parents also identified the problem of multiple extracurricular activities being scheduled at the same time as Science Olympiad meetings. Parents also identified the problem of lack of knowledge of the tournament schedules ahead of time so that students would be sure of the events in which they had to compete. Students address problems of time constraints by meeting on afternoons in addition to Science Olympiad team meetings, meeting in students' homes at night and on weekends, and communicating via e-mail about events. In order to be prepared for tournament schedules that might prohibit a student from participating in an event that she/he prepared for, students learn the material for events other than the ones they are scheduled for at tournaments so they can cover for other students if necessary.

Coaches across years of the study and across grade levels indicated that the three greatest difficulties in implementing Science Olympiad as an extracurricular activity and also integrating events in science classes include: insufficient funds for equipment and materials; insufficient time; and insufficient assistance in helping students prepare for events. Coaches and other teachers work creatively with parent volunteers to address these problems. Some common strategies to address resource shortages include: use of parent volunteers/mentors with science, engineering, or mathematics expertise; donations (funds or materials) from local science oriented companies/industries; fund raisers (letter campaigns, student activities, parent initiatives); writing grants to obtain financial assistance; PTSA support; donations from school partner businesses in the community; and donations from community-based groups (e.g., Kiwanis, Rotary).

Students, parents, and coaches feel that the program is of such high quality that it is worth trouble-shooting any problems that arise in order for students to be able to participate in Science Olympiad.

Conclusions

Science Olympiad as an extracurricular activity and a component integrated into the regular science curriculum has a range of positive impacts on middle school and high school students' attitudes toward and performance in science. Teachers interested in challenging their students to use their science and mathematics knowledge and skills in collaborative creative problem solving might consider starting an extracurricular Science Olympiad program in their school, adopting or adapting some of the Science Olympiad events to incorporate in regular science classes, or generate new problems for courses that are more appropriate for their students and contexts while reflecting the structure and format of Science Olympiad.

Engaging students actively in solving scientific problems that do not have a single predetermined solution demands that students work together, seek and use diverse resources, and test different experimental strategies while generating and using data to determine effectiveness of any strategy. Evaluation of student skills in resourcefulness, creativity, use of appropriate science skills, generation of a valid solution, collaboration, and effectiveness of using science and mathematics concepts and principals to explain findings and solutions would replace pencil-and-paper examinations in some areas.

Student preparation for events is challenging, engaging, and often frustrating. Students become involved with trial and error science in which they generate, analyze, and use data from their trials to improve their knowledge and performance. Applying science and engineering concepts to accomplish broadly defined events with pre-defined (limited) materials and rules requires planning, materials preparation, identification of diverse resources, research, and extensive time. Students do not seem to mind any of that. In fact, they become self-motivated, creative problem-solvers as they move toward competition with students on teams from other schools.

Based on all findings across years, we strongly suggest use of the Science Olympiad collaboration-competition model at middle school and high school levels to enhance student motivation to learn and apply science, engineering and mathematics concepts and skills.

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