A RATIONALE FOR THE DEVELOPMENT OF SCIENCE FAIRS AS A TOOL FOR EFFECTIVE SCIENCE RESEARCH EDUCATION

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Brief History

Science fairs have evolved to become a significant competition in pre-college education environments. In 1928 the American Institute of Science and Technology sponsored what is considered the first student science exposition (1999, Bellipani and Lilly). In 1921 a non-profit organization call Science Service from Washington D.C. formed science clubs throughout the United States. This led to the first National Science Fair held in Philadelphia in 1950. Its popularity was so great that it led to the first International Science & Engineering Fair (ISEF) held in Seattle in 1964. In 2007, ISEF has grown to include 1,511 students from 536 affiliated fairs from 51 countries (finalist directory, ISEF 2007). Whereas the staple of science fairs around the country are spaghetti bridges and erupting volcanoes in a middle school environment, the quality and sophistication of research projects, completed at the high school level, that compete at ISEF are often college level and beyond. It cannot be denied that ISEF has become the pre-eminent pre-college science research competition in the world and its scale and prestige has grown with Intel assuming title sponsor in 1998.

Definition

Science fairs are an exposition of scientific and engineering research, completed by an individual or small team (2 or 3), with the subsequent display and verbal explanation of the work to judges. Students are evaluated by established guidelines (http://www.sciserv.org/isef/judges/judges_criteria.asp), which include creativity, scientific thought, thoroughness, skill, clarity and teamwork (if appropriate). The combination of research and feedback (either in the way of competitive evaluation or a non-competitive poster session) is crucial because the broad, cross-curricular benefit of science, communication, mathematics, language arts, organization, metacognition, etc.

can only be realized with both requirements, (DeClue, 2000). Likewise, multiple intelligence-based models have been shown to be successful when students identify research that interests them and are given flexibility in presentation style, (Chowning, 2002). All of which are encouraged in a successful science project/fair environment. Chowning also points out the intangible benefits of pride and self-esteem development, the result of project accomplishment and (something as simple as) dressing up as well as team spirit and camaraderie during competition.

Curriculum Integration

Crucial to a successful science fair experience is its proper integration into the science curriculum. Inquiry-based education (http://www.thirteen.org/edonline/concept2class/inquiry/index.html) is central to the exploration theme inherent to science and engineering research. Done properly, inquiry-based education in a science classroom transforms the textbook into an open-ended search for knowledge. If a research theme, with exploration experiments, are placed in front of the student when content knowledge is taught then the student will soon recognize the truth of science being a growing body of knowledge rather than a static discipline.

In addition to inquiry-based education, the science fair expectations must be integrated into the calendar. Carrier (2006) suggests that the following timeline events become part of the classroom.

- Practice inquiry – August to December
- Topic selection – January
- Research and investigation design – February
- Investigations – March
- Presentation preparation – April
- Science fair – May

Naturally the timeline is flexible depending on many factors however, the establishment AND MONITORING of responsibilities and expectations are crucial.

The National Science Teachers Association (NSTA) recommends science fairs be voluntary for students but I disagree as does Abernathy and Vineyard (2001).

> *"As motivational theory suggests, at that developmental stage many young adolescents experience a decline in motivation and may need external motivators to help them engage in activities. If their experiences are positive and enjoyable, then students may later choose to participate for more intrinsically motivated reasons".*

In their research, they note that students report enjoying their science fair experience and would choose science fair or science olympiad activities if given several alternatives. They also note that students selected "pleasing teacher" above "working with friends" and "pleasing parents" above "preparing for my future", when completing a post-project survey. This may mean that students are more impacted by the immediacy of the event as opposed to long term rewards (big surprise). Another argument for project requirement.

At the elementary level the instruction of science research and production of a science fair should include a similar component of inquiry as at the middle or secondary level. The complexity of design, parameters of topic selection and sophistication of data analysis would, naturally, be at an age appropriate level. The following key elements are:

- Inquiry; help students ask the question in such a way as to suggest another question until the student identifies a question that they can test.
- Set up an experiment that compares one thing to another within well defined parameters… a control vs. a variable. Keep test simple. Always stress safety.
- Collect data….time, length, weight, etc. Encourage students to measure something with a tool that can be enumerated and possibly graphed. Keep this data in a log book.
- Create some type of presentation where students can show their work.

Optional components could be team projects, invite parents to presentation, provide awards, word process a report, etc.

At the middle school level all components of the project become more age appropriate. Students should be expected to:

- Select a topic with a more real life application.
- Manipulate a larger test group.
- Collect data more precisely that can be displayed graphically.
- Construct a complete paper report to accompany the log book.
- Perform a literature search to help define parameters of the experiment.
- Display their work.

At the high school level projects again increase with complexity and sophistication but the core elements of inquiry, relevance, analysis and communication remain. Teachers should try to include the following in their assignment.

- Professional mentorship.
- Statistical analysis.
- A clear understanding between science research and engineering research.
- Internet AND scientific periodical reference.
- Attendance at a science fair judged by scientists and engineers.

Mentors

Mentorship for students doing science fair projects is a constant question. At all levels mentorship is encouraged but clear and unambiguous communication of expectations between teacher and mentor is essential. The teacher knows how and why the assignment is given and is responsible for age/individual appropriate instruction and guidance. The mentor must recognize and capitulate to the teacher in all matters relevant to the assignment. At the same time, however, the teacher should realize their role as a facilitator of the assignment and relinquish to the mentors that which is their expertise. At the high school level some students have the potential to quickly exhaust the knowledge of the faculty, the precision of the equipment and the time availability of the laboratory space. In these instances, it is appropriate to enlist the help of a professional mentor and this should be encouraged for the benefit of the student AND the mentor, (this is mutualism at its finest).

It is possible and beneficial for universities to become intricately involved in science fairs. DeClue (2000) explains how Southern Illinois University supports science fairs by visiting schools to discuss the scientific method, judges projects, mentors students and teachers and allows access of university equipment. Additionally, the university hosts an ISEF affiliated fair which sends student to the International Fair every year.

Likewise, Torres, et al. (1997) endorsed scientific companies to consider supporting science fair programs. In response to an acute shortage of nursing staff in the mid-1980's Massachusetus General Hospital (MGH) in collaboration with Timilty Middle School (urban Boston) created a Science Connections program to enhance middle school science education, educate urban early adolescents about professions in the health field, inspire them to pursue postsecondary study in the health sciences, and prepare them for rigorous academic work in high school. A component of that program was to increase student interest in science, give students an understanding of the scientific method and have students produce a science fair project. Torres, et al. report the project was a great success with the following comments.

- 78% of students indicate they would like to have a career at MGH
- When asked what they liked best about the program, students most often said "knowing their mentor" and "going to the hospital".
- 80% of the students rated the chance to learn about research as great or good.
- 71% of students report they are more interested in science than before the program.
- 99% of student participants believe the program will have long-term benefits for them, especially in the areas of education and careers.
- The mentors most common response about what they liked best about the progam was their relationship with their student and the satisfaction of teaching science to children.

Some tangible results of the program were one former participant received a scholarship to nursing school and another won a prize at the citywide science fair.

In the broader picture the program helped prepare students from low-income neighborhoods for well-paying jobs and it helped combat the widespread scientific illiteracy that characterizes much of the American society in this increasingly technological age.

Another collaborative effort began in 1987 when the Shell Company Foundation teamed with the National Urban Coalition to promote Say YES Project, (Beane, 1990). The project objectives included:

- improve competence and confidence of math and science teachers
- increase the math and science interests and skills of elementary school children of color
- involve parents and communities in math and science eduation
- increase the number of students of color who are prepared for advanced levels of math and science in secondary school

Whereas the project did not specifically target science fairs, Beane makes the following observation.

"Of special interest to the NUC is the apparent increase in participation in science fairs among Say YES participants. Teachers from three Say YES schools proudly reported at the end of the project's first year that their schools had participated in science fairs for the first time. In two cases the idea of a school science fair was born and nurtured by project teachers who had been "turned on " by Say YES. Another school observed an increase in the number of science projects developed and boasted of having nine winners in the regional fairs. During the second year one school reported an 80 percent school science fair participation rate, and two regional winners. This is significant because many persons currently working in scientific fields have related that they were positively influenced by the science fair project experience as youngsters."

Beane continues, *"Say YES is unique in demonstrating that student achievement is enhanced through informal, activity-based science and mathematics enrichment which brings together children of color and adult "significant others" from their homes or community".*

Standards and Assessment

The state of Wisconsin has a full set of science standard that includes science inquiry and application (http://dpi.state.wi.us/standards/scistanc.html). A review of those standards reveals the need for students to build hypotheses, design investigations, review previous research, collect data, etc. The case for inclusion of inquiry-based education, research projects and science fairs is not difficult as the goals and guidelines of science fair work dovetails perfectly with these standards.

Additionally, science fairs relate to the National Science Education standards; Science as Inquiry, (Bellipanni & Lilly, 1999). The inquiry standards state that students should "ask questions, plan and conduct investigations, use appropriate tools and techniques to gather data, think critically and logically about relationships between evidence and explanations, construct and analyze alternative explanations, and communicate scientific arguments".

A recognition of these and more specific science fair standards is valuable for teachers to establish evaluation rubrics. Especially at the elementary and middle school level it is beneficial for students to compete against these standards rather than each other. The focus should be on the individual's effort and should not be a judgement of worth based on comparison with another student's work, (Carlisle and Deeter, 1989).

Additionally, as mentioned earlier, science fair research requires skills in writing, technology, library skills, mathematics, speaking, etc. to complete. Indirectly, students completing science fair projects will be learning and practicing material that will enable them to meet a multitude of standards, (Frisby, 2005).

Assessment in science has traditionally been multiple choice and essay question evaluations based on content knowledge information. The explosion of scientific information over the last half century has exacerbated the problem and caused teachers and students alike to pick and choose what information is appropriate to learn and retain. It is unfortunate that some in the science education community have forgotten that science is also about inquiry and exploring. It appears that may be changing. "Today, reformers are calling for a qualitatively different curriculum and instruction more like the way that science is practiced and used; such authenticity and relevance motivate students and help them learn", (Stage, 1995). I think we have seen that change in the development of inquiry and application standards mentioned above.
Stage continues to explain how science fairs would be a perfect vehicle for authentic assessment in science. "A full assessment program must include not only the recognition that is called for by a multiple choice item but also the generation of responses that is required by a performance task".

Gender Participation

Participation of women in science and engineering careers continues to be problem many people feel needs to be addressed, (http://www.ericdigests.org/pre-9217/women.htm). It is no different in science fair competitions where at ISEF in 2007, 57% of the participants were male. In a study done by Abernathy and Vineyard (2001) they noted a 49% male to 46% female split in a high school fair but a 45% male to 53% female split in junior high. This may indicate that in junior high girls are drawn to science research but in high school boys are more interested. Further research is necessary to determine why. Abernathy and Vineyard make one other interesting observation as they compare science fair and science olympiad competitions. They note that more females chose science fair over science olympiad and suggest that the more highly competitive, team format of science olympiad may attract males more than females. This may provide rationale for females to be targeted for science fair competition.

The Big Picture

Although the reason for the reduction of science and engineering graduates in the United States vs. China and India are debatable, there is no denying that globalization has altered the landscape of science, technology, engineering and math (STEM) education and careers in the US. If the United States is to remain a STEM leader then it must recognize and focus on its strengths. Those strengths are:

- educational system
- entrepreneurial economic environment
- creativity and optimism
- pleuralistic society
- open immigration policy (at least for academics)

Friedman (2006)

As it applies to this paper, it is necessary to consider education and creativity from the list Friedman describes above because science fairs are embedded in our educational system and creativity is at the heart of science research.
Science, engineering and technology play an enormous role in the global economy. It is not by accident that some of the global giants in business are science/technology based: GE, Intel, Airbus, Microsoft, etc. The increase in the availability and use of technology is

bringing 1 billion more people into the global economy and opening the global workforce to multinational corporations. As a result the US economy must find a way to react to the outsourcing and downsizing of many jobs. Tom Friedman (The World is Flat, 2006) suggests the following strategies, which have a strong education/science fair component.

1. We need to do more to educate/interest native children in STEM.
   - “Sixty percent of top students are children of immigrants.” (pg. 335)
   - “A Romanian immigrant said what was being taught in the US in 7th grade is being taught in 4th grade in Romania.” (pg. 336)
   - “The number of science degrees produced in the US is down to 17th in the world and Asia produces 8 times more engineering bachelor degrees than the US.” (pg. 330)

The US is lagging behind the rest of the developed world in its STEM education and in response it is reducing its efforts to improve. Craig Barrett (Intel CEO) says there must be an all-out effort to improve science and engineering education, (pg. 359).

How does this relate to science fair?

“In 2004, the Intel Fair attracted around sixty-five thousand American kids, according to Intel. How about in China? In China there is a national affiliate science fair, which acts as a feeder system to select kids for the global Intel fair. Almost every single province has students going to one of these affiliate fairs. We have as many as six million kids competing, although not all are competing at the top level…but you know how seriously they take it. Those selected to go to the international fair are immediately exempted from college entrance exams and basically get their choice of any top university in China.” (pg. 335)

Friedman notes that David Baltimore (Nobel prize winning president of Caltech) recognizes that his best students at Caltech are coming from Public Schools;

“I look at the kids who come to Caltech, and they grew up in families that encouraged them to work hard and to put off a little bit of gratification for the future and to understand that they need to hone their skills to play an important role in the world. I give parents enormous credit for this, because these kids are all coming from public schools that people are calling failures.” (pg. 386).

At the same time G. Wayne Clough (president of Georgia Tech) has instituted a new admissions policy that encourages recruitment of engineering students with music experience.

"Don't send me engineers who can be duplicated by a computer. I am sending that work to India. Send me engineers who are adaptable – who can think across disciplines."

2. Friedman also recognizes the impact of creativity, imagination and empowerment in the United States' position in the changing global economy. *"Imagination is the product of necessity"* (pg. 563), and the people of United States have always been able to respond to time of adversity with incredible sacrifice, hope and creativity. This economic change is no different and we must implement programs that foster those qualities. Science research projects and science fairs depend on creativity. Moreover, they teach empowerment by requiring students select their own topic, encouraging them to select something they enjoy. The value of topic ownership gives the student a feeling of commitment and determination, much more than if a teacher had simply assigned a topic.

Freidman's most compelling theme in "The World is Flat" is the comparison between 11/9/89 and 9/11/01. 11/9 is when the Berlin Wall was broken and the sequestered countries of Eastern Europe joined the free world. 9/11 was the tragic day of terrorism. 11/9 opened doors, reunited people and fostered hope for growth (economic and social), development and cooperation. 9/11 closed borders, created fear and mistrust and stymied advancement in all areas. In the realm of STEM, science fairs epitomize an 11/9 world. Creativity, cooperation, collaboration, hard work, persistence, discipline, intellectual and academic commitment in areas of science, language arts, graphic arts, mathematics, technology are components of science fair work. The Intel International Fair brings together students from 51 countries, further demonstrating the benefit of eliminating geopolitical barriers, increasing contact and eventual trust between the leaders of tomorrow. Imagine 1,500 of the smartest high school students in the world getting to know each other in a safe and academically and socially stimulating environment. It doesn't get any better.

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