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A Cross Case Study of Excellence in Science Fair Program Design

A dissertation submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy in Curriculum and Instruction

by

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July 2015  
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This dissertation is approved for recommendation to the Graduate Council.

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## Abstract

The purpose of this study was to identify components of schools with successful science fair programs. Ideally schools interested in starting or improving their science fair programs could find a way to emulate some of the identified components. Successful was defined by having received recognition on some level at the International Science and Engineering Fair at least nine out of the last ten years. Twelve schools were identified as meeting this definition and five agreed to participate in the study. The schools represented diverse geographic areas as well as types of schools. Included in the study was a private school, two public schools and two public magnet schools. Data were collected through surveys, interviews, observations and document analysis. The climate of the school and the climate of the community were key features identified as helping to foster successful science fair programs. Unique features were identified as being present at most of the schools. These included embedding science research in the curriculum, requiring participation in science research for all students, flexible scheduling and offering elective science research classes. As the nation is increasingly focused on preparing students to enter STEM fields it seems that including science research in the science curriculum and emulating some of these unique components of successful science fair schools would be worth pursuing.

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## **Chapter I**

### **Introduction**

The science fair began in the United States as a way to educate the public on modern scientific achievements (Dutton, 2011). Roots of the idea were planted by two different groups. First, the Society for Science and the Public, co-founded by journalist Edward Scripps and zoologist William Ritter was founded in 1921. The mission of this group was to promote science through education. The second group was the American Institute of the City of New York, which had hosted technology and invention exhibitions dating back to the mid 1800's as a way to share science innovations with the nation. These two groups joined forces in the early 1940's and the first national science fair was held in Philadelphia in 1950 (Berger, 1994; Dutton, 2011). The fair is now sponsored by Intel and known as the International Science and Engineering Fair (ISEF) bringing students from over fifty nations to compete for almost five million dollars in scholarships and prize money (Dutton, 2011; ISEF, 2013).

Popularity for the fair soared in the 1950's as did general interest in the nation's science programs. The impetus for this interest was the launching of Sputnik in 1957 and a concern that the United States was falling behind in math and science education (Gibbs & Fox, 1999). The nation was suddenly fueled by a competitive spirit and concern for national security and subsequently spent millions of dollars in programs in an attempt to ensure schools had successful math and science programs (McCormack, 1992).

Fast forward seventy years and the nation seems gripped by the same concern. Reports from international testing sources comparing science scores of different nations rank the United States sixth on the Trends in International Mathematics and Science Study (TIMSS), lagging again behind the Russian Federation (TIMSS report, 2011) and ranked 19<sup>th</sup> on the Program for International Student Assessment (PISA) in science literacy (PISA, 2009). The nation is

again concerned that students will not be prepared for careers in math and science and our national security and economy are threatened because we will not have citizens to fulfill the increasing demands for careers in these areas (Augustine, 2005). Responding to this concern, the United States Congress and President Barack Obama have devoted millions of dollars to education that emphasize science, technology, engineering and math, commonly referred to as STEM (Office of Press Secretary, 2012).

In 2005 a special committee from the National Academies Committee on science, engineering, and public policy (COSEPUP) was assigned by a non-partisan initiative in Congress the task of addressing a potential decline in innovation in regards to science and technology in the United States and to create a plan of the top ten actions to halt such a decline (Augustine, 2005). One recommendation from the Committee on Prospering in the Global Economy of the 21<sup>st</sup> century was to increase the number of students capable of pursuing degrees in science, engineering and math by exposing them to more rigorous courses in high school. Related to this, the committee mentioned the importance of providing middle and high school students with opportunities and incentives to do more advanced and inquiry type work and to be provided with research opportunities (Augustine, 2005).

Having students conduct an independent research project, such as that done in the science fair, appears to be a great fit for answering the call to promote STEM education and inspire more students to pursue careers in these areas. The science fair project is an opportunity to provide an authentic learning experience, perhaps the only authentic assessment, a school can usually provide to all students to support the study of sciences by allowing students to conduct independent research projects (Berger, 1994). In schools where students select their own topic a personal connection can be fostered between the student and his/her research. Ideally this connection will develop to the point in which a student might desire to pursue a career in the related field, but through research a student may also be exposed to subjects they enjoy more and

with which were not previously familiar. The science fair also helps the student in areas outside of science by enabling them to work on creative and inquiry-based thinking, to practice public speaking and to develop organization skills. The research and writing component of the science fair is a perfect complement to another initiative sweeping education today, the Common Core literacy standards (NGAC 2010). The science fair has many potential benefits for students who are given the opportunity to participate.

### **Purpose of the Study**

The purpose of the study is to identify factors that promote successful science fair programs. Identifying the unique features of successful programs can help provide guidance to schools with struggling programs or schools which would like to implement programs. While there are other ways to identify exemplary practices (McComas, 2005), for the purposes of this study success at the Intel ISEF was selected over recommendations and percentage of student participation as a form of measurement. *Successful* will be defined as those 9-12 high schools in the United States that have had winners of some form at the International Science and Engineering fair at least nine out of the past ten years. In order to compete at the ISEF students must have won at an affiliated regional, state or national fair.

The study has the following objectives:

- Determine the role various stakeholders have on the success of the science fair.
- Describe the way selected 9-12 high schools carry out and support science fair projects.
- Identify how selected 9-12 high schools integrate the science fair into other school requirements.

## **Significance of the Study**

The addition of Engineering in the Next Generation Science Standards (NGSS) and the general focus nationwide on aspects of STEM education have many schools looking for ways to modify or enhance current science programs. Schools are looking for direction into how to successfully implement programs that will enable students to be engaged in activities that support the new science education initiatives (Sahin, 2013; Tomas, Jackson, & Carlisle, 2014). The science fair is an opportunity for students to be involved in an independent research process, work at investigating solutions to current concerns of society and participate in science discourse with experts in related fields. This process aligns with many current curriculum initiatives, including Common Core in math and English (NGAC, 2010) and NGSS, specifically practices, dimension 1 and its connection to STEM education (Augustine, 2005; Bybee, 2010).

While there are general guidelines and recommendations for growing or improving a science fair, there is limited research on specific components of how schools implement, grow and sustain a science fair program. A case-study analysis of schools that have successfully implemented and supported science fair programs could provide guidance and resources to schools who are seeking help in implementation of science fair programs or hoping to improve a current program. Lessons learned from this project could lead to an increase in student participation in science fairs and potentially a greater interest in science related fields. Schools that have been reluctant to participate in science fairs in the past may be willing to get involved once provided with references and recommendations for implementation of a quality science fair program. Students who have been apprehensive about careers in science related fields will be exposed to authentic assessments and projects by participating in a science fair and will realize the wide range of opportunities available in the sciences. Conducting a case study on schools showing a history of science fair success could be very important to of science education.

The specific research questions guiding this study are:

- 1) What are the features of schools with successful science fair programs?
- 2) Who are the stakeholders in successful science fair programs and how do they contribute to the success of the program?
- 3) What impact does the structure of the school have on successful science fair programs?

### **Overview of Proposed Method**

The proposed project will examine five secondary schools in the United States that have been identified as having extraordinarily high success at the INTEL International Science and Engineering Fair to determine components of successful science fair programs. The research included individualized case studies with observations and interviews attempting to answer the main research question “what are the unique features of a successful high school science fair program?” This research should be considered a case study and not an ethnographic or participant observation study because the investigation takes place, within specific boundaries, as part of a contextualized phenomenon (Berg & Lune 2012). The schools were selected from a list of winners at the Intel ISEF competition for the past ten years by identifying schools with any tier of prize winner in multiple years. Prizes awarded at the ISEF include grand award winners, which are specialized for groups such as The European Union contest for young scientist, as well as five place level awards in each of the seventeen individual categories (ISEF, 2013). The assumption being made is schools that continually perform well at this high level of competition must have solid programs in place to ensure continued success. Twelve schools were identified as having winners in at least nine out of the ten years examined. Five of these schools were chosen for the study.

The researcher contacted each school and administered preliminary surveys as well as made arrangements to visit the school. Science fair preparations generally begin in the early to

mid-fall unless students are working on a continuation project. Most school fairs are in February with a regional fair in March; this time line is derived from the May date of the Intel International Science and Engineering Fair. The researcher was not singularly focused on the actual science fair as an event but support for and around the fair. It may aid the researcher to observe some component of the process in action.

The researcher was focused on four main areas in the data collection: assigning of the project, implementation of the project, implementation of the science fair and climate and attitude towards the science fair of various stakeholders. Questions related to each focus area are listed in appendix A. The researcher used a questionnaire administered both electronically and in a semi-structured interview setting to address each focus area listed above. Questions were be asked for each appropriate audience. Due to the variables in each program it was ideal for the questions to be asked in person to allow for follow up questions related to individual responses. The information was gathered from the five schools and the researcher looked for commonalities in procedure and practice that could serve to help others in successful science fair implementation. Observations were not limited to tangible items but also included climate and attitude of a school, and the researcher will be looking for such and reporting it in the research findings.

### **Assumptions and Limitations of the Study**

The schools that have been identified for the study are diverse; they vary in size and procedures for enrollment so this is a potential threat to internal validity. Of the participating schools two are traditional public high schools, two are public magnet/charter schools and one is a private school. The demographics of the schools vary widely (see appendix C). The diversity of the schools could potentially allow the final findings to be relatable to many different school environments. The population to be studied were secondary schools in the

United States that showed excellence in regards to the science fair by appearing to have successful science fair programs. Excellence in this case was defined as schools that *have a high showing* at the international fair or were considered to have successful programs due to the fact that the school has had at least one winner in a minimum of nine out of ten of the Intel ISEF competitions for the years 2004-2014. There is a risk that some schools with previously successful programs were missed by focusing only on this ten year period. Twelve schools were identified that met the criteria, and five were studied. This was decided based on recommendations for case study analysis (Hatch, 2002). Subjects were contacted at each school prior to the study to ensure that a representative sample has been collected for interviewing. It is the assumption of the researcher that since these schools are being highlighted for their success and excellence they wanted to participate in the study and were honest in answering the questions posed by the researcher. Because this research is taking a multi-case study approach there was already limited generalizability.

## **Chapter II**

### **Review of the Literature**

This chapter begins with the history of the science fair. This is followed by research related to the science fair, including benefits and criticisms. The present state of the science fair and areas for future research conclude this chapter.

#### **The Science Fair: Historical background**

Public exhibitions of science and technological innovations have a long history in the United States, dating back to 1828 (Dutton, 2011). The American Institute of Science and Technology offered these exhibitions as a way to educate the public on modern achievements and to award medals to inventors and scientists based on demonstration of distinguished work (Bellipanni & Lilly, 1999; Dutton, 2011). The focus of this group slowly shifted to students and the first student science fair was held in 1928 in New York City; henceforth all science fairs have been modeled off this original event (Bellipanni & Lilly, 1999). Another group instrumental for promoting science around this same time was the Society for Science and the Public. This group co-founded by journalist Edward Scripps and zoologist William Ritter in 1921 had a mission to promote science through education. In 1942 Scripps and Ritter's group, Science Service, conducted the first Science Talent Search, a program to recognize high school seniors who were excelling in science. The Science Service group and the American Institute of Science joined forces in the early 1940s and the first national science fair was held in Philadelphia, PA in 1950 (Dutton, 2011). Creating the non-profit group the Society for the Science and the Public, the initial fair started by the two groups grew from thirty finalists in 1950 to over three hundred in 1960 (ISEF, 2013) popularity for the fair soared during this decade as did a general interest in the nation's science programs. The impetus for this interest was most likely due to the launching

of Sputnik in 1957 by the Russians and a concern that the United States was falling behind in math and science education (Gibbs & Fox, 1999). The fair continued to grow and in 1964 the first international science fair was held in Baltimore, MD; known as the International Science and Engineering Fair (ISEF). Still primarily operated by the Society for the Science and the Public, the ISEF has been sponsored by the world's largest semiconductor chip making company Intel since 1997. The Intel ISEF attracts students from over fifty nations to compete for millions of dollars in scholarships and prize money (ISEF, 2013). While students have been participating in science fairs and other similar competitions for almost one hundred years, the recent research related to academic science competitions is sparse.

### **Benefits and Criticisms of Science Fairs and Student Participation**

One area of research related to the science fair and other academic competitions relates to what impact involvement in such a competition may have on a student. Generally research shows teachers feel the experience is beneficial to the students (Bunderson & Anderson, 1996; Grote, 1995; Rillero & Zambo, 2011). When a group of pre-service teachers were asked about science fairs (Grote, 1995) the teachers overwhelmingly responded they thought they were beneficial, yet few of them had actually participated in a science fair. Of participants in the same study, over 80% felt science research projects taught students about scientific methods, and less than 20% felt the lessons gained from doing a research project could be duplicated by classroom instruction (Grote, 1995). A study by Bunderson and Anderson (1996) found similar results. Even though only half of the pre-service teachers had participated in a science fair themselves, two-thirds of the respondents said the science fair promotes creativity and increases interest in science. These seem like glowing recommendations for having a science fair, but what evidence are these pre-service teachers using to back up their thoughts? Most science teachers have a strong opinion either for or against the science fair (Rillero, 2011), but these opinions are most

often based on personal experiences and preferences, not research. While not an extensive body of knowledge, there is research to support benefits to students from participating in the science fair. There is also research that presents criticisms of student involvement in the science fair.

These main areas are highlighted in Table 1.

Table 1. Summary of Research on Impact of Science Fair participation on students.

Benefits	Criticisms
Engagement in inquiry experiences  (Dionne, Reis, Trudel, Guillet, Kleinie, Hancianu, 2011; Rillero & Zambo, 2011; Sayer & Shore, 2001; Sumrall & Schillinger, 2004)	Not true inquiry  (Launius & Lenz, 2008; Magee & Flessner, 2011)
Engagement in authentic practices or authentic assessments  (Bellipanni & Lilly, 1999; Sahin, 2014; Woolnough, Guo, Leite, Almeida, Ryu, Wang & Young, 1997)	Lack of authentic work by students  (Abernathy & Vineyard, 2001; Launius & Lenz, 2008; Magee & Flessner, 2011; Sayer & Shore, 2001)
Increased motivation & positive attitude towards science  (Bahar, 2009; Bunderson & Anderson, 1996; Dionne, et al, 2011; Dutton, 2011; Jarowski, 2013; Ndlovu, 2013; Tomas, Jackson & Carlisle, 2014; Tuan, Chin, Tsai, & Cheng, 2005; Woolnough, et al, 1997)	Favors elite students  (Bencze & Bowen, 2009; Czerniak, 1996; Magee & Flessner, 2011; Sayer & Shore, 2011; Taylor, 2011)
Competitive nature  (Bernard, 2011; Dionne, et al, 2011; Romanello, 2005)	Competitive nature  (Bahar, 2009; Czerniak, 1996; Launius & Lenz, 2008; Magee & Flessner, 2011; Rillero, 2011)

### **Benefits and criticisms of Science Fairs and Student Participation: Engagement in Inquiry Experiences**

Proponents of the science fair state one of the benefits is the opportunity for students to engage in an inquiry experience (Dionne, Reis, Trudel, Guillet, Kleinie, Hancianu, 2011; Rillero & Zambo, 2011; Sayer & Shore, 2001; Sumrall & Schillinger, 2004). Sayer & Shore (2001)

state, in the science fair “Students are given the chance to play the role of knowledge-producer, rather than just consumer of knowledge” (p. 207). This aligns with the goals of inquiry as defined by the National Science Education Standards (National Research Council, 1996) and assessed as part of the science framework in the 2011 National Assessment of Educational Progress or NAEP (National Assessment Governing Board, 2010). According to the NSES (1996), inquiry is defined as “a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena” (p. 214). In the science framework for the NAEP (2010) it states “Inquiry is at the heart of knowing and doing science” (p. 113). The NGSS says inquiry involves the formulation of a question that can be answered through an investigation and stresses the connection inquiry has to physical, cognitive and social processes (NGSS Lead States, 2013). The ISEF supports the science fair as a product of inquiry by requiring the projects to be based on original research, designed and carried out by the student or team of students (ISEF, 2013). The actual occurrence of inquiry at the ISEF was researched in a study of over 700 ISEF judges at the 2005 Intel ISEF. The study was done by Rillero and Zambo both of whom were program evaluators of ISEF for three years. In the study over 90% of the judges surveyed said they felt the top projects were inquiry based (2011). The judges in this study also ranked critical thinking as the number one characteristic for student success in the science fair and encouraged schools seeking greater success to make sure science courses were inquiry-rich.

While there is little debate that the science fair is intended to engage students in inquiry, there is limited research to ascertain the effects of this specific type of inquiry process on the student. A South African study of over 300 students in seventh through twelfth grades specifically asked the students to compare the level and amount of inquiry they had in their science classroom versus while participating in the science fair. All of the surveyed participants had participated in the science fair at least once (Ndlovu, 2013). Researchers adapted the

Principles of Scientific Inquiry questionnaire (PSI-S), developed by Campbell, Abd-Hamid and Chapman to assess student opportunities for inquiry in the science classroom and in the science fair. An example of one of the Likert-type questions was “learners formulate questions which can be answered by questions” (p. 3633). Students were asked each question twice, once referencing the classroom experience and once for the science fair. Researchers found students overwhelmingly believed the science fair project was more inquiry oriented than their classroom experiences (Ndlovu, 2013) and they enjoyed the learner dependent aspect of the project. In a similar study conducted in Australia both students and teachers reported more positive attitudes towards science and increased confidence in science knowledge and skills after competing in the inquiry-based Wonder of Science Challenge (Tomas, Jackson & Carlisle, 2014).

These studies show students seem to enjoy being involved in inquiry activities but the question arises if involvement alone actually increases a student’s knowledge of inquiry. Beverly Jarowski (2013) gave sixth to eighth grade students a pretest and posttest to determine what impact participating in a science fair might have on their knowledge of inquiry. She found no significant difference between the student scores from the pretest to the posttest. This study could be used to show that science fairs don’t impact student knowledge of inquiry.

Some researchers argue the science fair as regulated by the ISEF does not actually support inquiry and the nature of science because it favors the step by step scientific method (Launius & Lenz, 2008 & Magee & Flessner, 2011). Variations on the science fair generally use this argument for reasons of starting a new program. Former Intel ISEF evaluator Peter Rillero, proposed a standards-based science fair at the elementary level, which would focus on promoting inquiry abilities and measure student projects against inquiry standards as opposed to other student projects (2011). PRISM, as suggested by Launius and Lenze (2008), opens up students to a broader array of projects such as science-themed collections and portfolios where students become experts on a science topic of their choice. A Kids Inquiry conference is set up like a

poster session at a professional research conference (Magee & Flessner, 2011). Promoters of this type of ‘fair’ contend it is more authentic because students are asking each other questions as opposed to being judged by an outside group, the assumption being their peers can ask good analytical questions (Magee & Flessner, 2011). While all promoters of these alternative types of science fairs cite benefits for the students; I was unable to find empirical evidence to support this claim.

Research has shown that students who participate in inquiry-based learning have increased motivation towards science (Bahar, 2009; Ndlovu, 2013; Tomas, Jackson & Carlisle, 2014; Tuan, Chin, Tsai and Cheng, 2005). A recent Canadian study supports this in relation to the science fair. A group of researchers designed a study to determine the motivating factors for students who participated in science fairs (Dionne et al., 2011). They identified five principal components related to the student’s motivation:

- 1) Interest in science content
- 2) Sense of self-efficacy
- 3) Assurance of achievement through rewards or gratifications
- 4) Social aspect of participating
- 5) Working strategies to gain scientific knowledge and methods

(Abstract, Dionne, et al., 2011, p.1)

The researchers found the number one motivating factor for participating in the science fair to be related to item 1, interest in science content. The science fair usually allows students to use an inquiry-based approach to investigate a topic related to their personal interest, this is different from most classroom investigations where the topic is predetermined by the teacher. Students also reported feeling fulfilled when they finished their projects (Dionne et al., 2011) some students attributed this to having their curiosity satisfied. In the study by Bunderson and Anderson mentioned earlier (1996) pre-service teachers who participated in a science fair cited a sense of accomplishment and the positive feeling associated with learning new concepts as aspects they enjoyed most about the experience, thus supporting the conclusions drawn by the

Canadian study.

The independent approach to research as supported by the science fair may appeal to some students, but not all. Bahar (2009) investigated the relationship between students learning styles and their performance and attitude towards inquiry projects. The Learning Style Scale was used to identify six types of learning styles: competitive, collaborative, avoidant, participant, dependent and independent (2009). The students were each given a different problem and then asked to carry out research designed to solve the problem. This differs from the science fair approach where students generally find their own projects. While the students in Bahar's study were assigned a research question, the method and process of investigation still occurred independently. Bahar found that students who were identified as independent, participant and competitive learners greatly enjoyed the mini-project and hoped to have more opportunities to carry out this type of research. This study could be used to support the claim that the independent approach of the science fair process could be motivating to some students. It would be interesting to redo the study allowing the students to select their own research problems to see if this appealed to a different range of learning styles and also giving each student the same research problem to see how that impacted attitudes of the different learning styles.

### **Benefits and criticisms of Science Fairs and Student Participation: Engagement in Authentic Practices**

Another benefit of the science fair is the independent research project acts as an authentic task and assessment or practice of the student's scientific process skills. Designing and carrying out an independent project based on a question rooted in personal interest can simulate how many scientists conduct research (Bellipanni & Lilly, 1999) and may even encourage students to pursue careers in scientific fields (Sahin, 2014; Woolnough, Guo, Leite, Almeida, Ryu, Wang, Young 1997). Bencze and Bowen (2009) found that students who participated in the science fair

were able to understand and follow such scientific process skills as argumentation and explanation of evidence. The researchers examined student logbooks, observed interactions with judges and conducted interviews with participants. Researchers in this study reported being “highly impressed with the advanced level of students’ discourse regarding what often were quite complex projects” (p. 247). In another study related to science discourse the students were found to increase their authentic ‘*science talk*’ while explaining their science fair project (Gomez, 2007). Gomez’s study was focused on science discourse and the ability of a student to move from *exploratory talk*, using nonscientific terms to explain phenomena, and *science talk*, which uses correct science terminology for explanations. Gomez found students who were able to engage in science talk were able to communicate findings more easily with judges and peers. The NAEP 2011 Science Framework stresses the importance of accurate and effective communication and using science terms and language appropriately (NAEP, 2010). Argumentation from evidence has also recently been included as an instructional goal in Next Generation Science Standards (2013). The science fair may assist teachers who are looking for ways to implement these elements into their curriculum and aid students in developing these scientific process skills.

In conducting science fair projects students often work with mentors at universities or other research institutions (Czerniak, 1996; DeClue, Johnson, Hendrickson, & Keck, 2000; Rillero & Zambo, 2001). This could promote the idea of a science fair project as an authentic practice by giving the student access to quality equipment and expert help in an authentic research setting. Working in a research lab enables students to take the project to a higher level (Bencze & Bowen, 2009; Rillero & Zambo, 2001). ISEF judges encourage students to work with a mentor when possible but warn the student must take ownership of the project (Rillero & Zambo, 2001). It has also been shown that student interest levels increase when they work in research facilities (Bernard, 2011). Schools have reported an increase in student participation by

secondary students when partnering with a local university (DeClue et al, 2009). Students seemed to appreciate the access to equipment as well as help generating ideas for research.

Proponents of the science fair believe it promotes authentic practice but some disagree (Abernathy & Vineyard, 2001; Launius & Lenz, 2008; Magee & Flessner, 2011; Sayer & Shore, 2001). Many students find projects on the internet that are merely demonstrations; the infamous baking soda volcano is the classic example of such a project. Some critics of the science fair question the amount of work actually done by the student as opposed to a parent or mentor (Launius & Lenz, 2008). In Czerniak's (1996) study this help from parents was specifically addressed by students reporting they did receive parental support to varying degrees. It should not automatically be assumed that working with a parent means the parent does the project nor should this support be seen as a negative towards the science fair. In a study of preservice elementary teachers by Bunderson and Anderson (1996) with preservice elementary teachers, even students who reported negative feelings about the science fair had fond memories of working on such projects with a parent.

A design feature of the science fair that may discourage projects solely created by parents is the requirement that students be available to discuss their project and take questions from judges, the idea being the student will only be able to adequately discuss the project if they have been involved (Sumrall & Schillinger, 2004). This does not always come to fruition however as the judge may have little time to speak to the students or the judges themselves are not highly qualified (Rillero, 2011). The level of questioning from the judges may not be enough to discern if the student was or was not the principal investigator. Some judges believe students who work with a researcher are less likely to be excited about the project because they may not have generated the research idea (Rillero & Zambo, 2001). Studies by Bernard (2011) and DeClue et al. (2009) seem to contradict this idea. Bernard shows that students did express an initial reluctance to do the project and said finding a topic was one of their greatest challenges. The

students ended up having a positive experience, perhaps because the mentor aided in finding a research question and eliminated the initial stress. De Clue et al. found students who were given the opportunity to meet with university faculty for initial input on projects helped students develop more specific student designs. Students do report feeling that teachers do not provide the help the students feel they need (Czernaik, 1996). This could relate to the positive attitude students have towards mentors.

One of the unique aspects of the science fair, the independent research project, has led to some criticism discrediting the supposed benefits associated with authentic assessment (Launius & Lenz, 2008). Since the project is done independently by the student, the research often occurs outside of the school day and/or classroom. This means the student work is not closely monitored. This has created a concern that students may cheat by modifying or fabricating data. Twenty five percent of students in a study done by Syer and Shore (2001) admitted cheating. This finding supports research by Shore and Delcourt (1995) when students spontaneously reported cheating in a study on creative ability with respect to the science fair. Many students cited pressure as the reason for cheating. Students expressed feeling pressure from parents to perform, pressure from time constraints imposed by deadlines of the fair, and in-direct pressure from the teacher because the project was tied to a grade. Despite the National Science Teacher Associations official position statement encouraging science fairs to be voluntary and emphasizing the learning experience over the competition element (NSTA, 2011), many schools still make it a requirement. Extrinsic motivation by grades to perform was one component identified in Dionne et al. (2011) but the inevitable anxiety tied to grades was not expressly mentioned. Students in a study by Abernathy and Vineyard also expressed a desire to please teachers and parents as a reward for participating in a science fair or Science Olympiad (2001).

It would be very challenging to determine what percent of students actually do cheat or misrepresent their data in their science fair projects, Syer and Shore recommend schools offer

after-hours assistance for students and require that projects be worked on in public, school labs, classrooms or libraries for example, to avoid the possibility of cheating (2001). Some say teachers should help students understand that disappointing or unexpected data can actually be useful (McComas, 2011), thereby eliminating a need for students to feel pressure to make up data and others argue that science fairs should be voluntary to alleviate pressure from those who lack interest (NSTA, 2011). Perhaps more teachers should express to students the idea touted by Albert Einstein that “the mere formation of a problem is far more often essential than its solution” (Einstein, as quoted in Bellipanni & Lilly, 1999).

### **Benefits and criticisms of Science Fairs and Student Participation: Competition**

Some students thrive under pressure and the opportunity for competition is seen as a benefit of the science fair. Research has shown that competition can be good for students and increase their sense of self-efficacy (Dionne et al., 2011). Students participating in the Canada-Wide science fair were asked to rank items according to perceived benefits from their participation. The students cited achievement and awards as the third most important factor for their participation in the event, behind interest in scientific content and self-efficacy in completing tasks and reaching goals (Dionne et al., 2011). While students were motivated by the idea of an award, it is important to note these students were surveyed before awards were given. It would be interesting to survey the students after the fair and see if this motivation had changed based on performance. It is important to consider that competition can encourage students to work at a higher level of performance (Bernard, 2011; Rillero, 2011). Even if the motivation is extrinsic, if students are pushed to do high quality inquiry work completion should be seen as a benefit. Some teachers report competition as a great way to push students to perform at higher levels (Romanello, 2005). Students also report being motivated by people from outside the school reviewing and critiquing their work (Bernard, 2011; Romanello, 2005).

While some research views competition as a good thing, others argue this is one of the biggest drawbacks to the science fair (Czerniak, 1996; Launius & Lenz, 2008; Magee & Flessner, 2011). Czerniak (1996) conducted a study aimed, in part, at examining the relationship between science fairs and student anxiety. Many students in the study cited pressure to perform from parents and school as reasons for working hard on a project. Czerniak argues these types of extrinsic motivators could have a damaging effect on a student's self-esteem. Bellipanni and Lilly (1999) say competition is usually reduced at the elementary level because of the risk that students will make a negative association with science because of damage to self-esteem from competition. Developers of programs like PRISM and Kids Inquiry conference, alternatives to science fairs mentioned previously, use the negative aspect of competition as a reason to steer away from the traditional fair (Launius & Lenz, 2008; Magee & Flessner, 2011; Rillero, 2011).

Rillero (2011) argues for a standards-based fair at the elementary level such that students compete against inquiry standards as opposed to each other making the projects more student-centered. A student's success is based on understanding and communicating of standards not on the quality of other projects. Also, the removal of the element of competition means the younger students are more likely to foster a positive feeling towards science. Rillero and other program developers see the benefits of inquiry one gets from the science project, but feel this element can still be obtained by students without the possible negative pressures of competition (Launius & Lenz, 2008; Magee & Flessner, 2011; Rillero, 2011). Bahar's research findings related to learning styles could be used to support the idea that some students do not perform well when faced with competition and therefore do not receive any benefits to learning (2009). Forcing students into competition with peers could impact their overall feelings towards science in a negative fashion.

### **Benefits and criticisms of Science Fairs and Student Participation: Increases motivation and positive attitude towards Science**

Research shows that allowing students to participate in an independent research project generally fosters a more positive attitude about science and increases student motivation (Dionne, et al., 2011; Jarowski, 2013; Tomas, et al., 2014; Woolnough, Guo, Leite, Almeida, Ryu, Wang, & Young, 1997). Jarowski's study (2013) tried to determine if participation in a science fair impacted student attitudes along with their knowledge of scientific inquiry. Overall she found that students' attitudes towards science increased with doing a science fair in the group that already had a positive view of science. In the group that initially had negative views of science, attitudes were not significantly changed by participation in the science fair (Jarowski, 2013). This study shows that science fairs can be used to foster a joy for science among those who already have a desire for the subject. In the Canadian research mentioned earlier (Dionne et al., 2011) the central factor for student motivation related to participants' interest in science. The Canadian study was done at a high level of competition implying a certain level of commitment to the project. Conducting this survey at a lower level of competition might yield different results if student participation is a school requirement.

### **Benefits and criticisms of Science Fairs and Student Participation: Favoring of Elite Students**

A criticism of science fairs that research has yet to quantitatively rebut relates to the idea that science fairs seem to favor elite students. The level of the projects that make it to the ISEF are quite impressive, some at a graduate level (Rillero & Zambo, 2011). This may favor students who have access to a research institute. Bencze and Bowen (2009) refer to students they interviewed as being rich in both social and cultural capital. In ten out of fifteen projects, students had access to research laboratories, a type of social capital. The interviewed students also had a discourse level much higher than their age would suggest, this was considered cultural

capital (2009). In the study by Syer & Shore (2001) over 95% of the participants were Caucasian and the majority had college educated parents. Other teachers report a similar idea that students with more educated parents are more likely to have success at the science fair (Czerniak, 1996; Magee & Flessner, 2011; Taylor, 2011). While Intel ISEF does not restrict entry of any type of school to their supported competitions, there are entry fees involved which could limit participation of some schools and students. There are instances of rural, lower socio-economic schools faring very well at high levels of competition (Dutton, 2011; M. Bland, personal communication, October 15<sup>th</sup>, 2013) perhaps refuting this area of criticism.

Some schools have made efforts to ensure a greater diversity among students who participate (Magee & Flessner, 2011). This can backfire as evidenced in a study done in South Africa (Taylor, 2011). Students from a small township in South Africa were initially excited to attend the regional school Expo. Many students said they were participating in the science fair with hopes of immediate and future success (Taylor, 2011). After attending the Expo, however, the students reported feeling inadequate and perceived themselves as failures. The students were very aware of the discrepancy in resources between themselves and most of the other participants. This caused some students to feel negatively towards science and decreased desire to repeat the experience of the Expo.

Research supports claims that participating in a science fair helps engage students in inquiry experiences (Dionne et al, 2011; Rillero & Zambo, 2011; Sayer & Shore, 2011; Sumrall & Schillinger, 2004), increase motivation (Bernard, 2011; Dione et al., 2011), and encourage positive attitudes towards science (Bunderson & Anderson, 1996; Dionne et al., 2011; Tomas et al., 2014). There is also research to support benefits to some students for participating in competitions (Bernard, 2011; Rillero, 2011; Romanello, 2005). Clearly, some contradictions in the literature warrant more research.

### **Current state of the science fair**

Interestingly enough as the education community of the United States seems focused on improving science education and promoting STEM initiatives, participation in and support for the science fair seems to be lacking. While overall numbers are difficult to come by, one county in Florida reported a 50% decrease from 2002 to 2004 (Thomas, 2004). According to a director at the Science for Society and the Public, many regional fairs are struggling to obtain the required number of schools to participate, thus indicating a nationwide decline (Harmon, 2011). Many teachers cite time constraints from teaching to standardized tests as a reason for non-participation (Harmon, 2011; Thomas, 2004). The pressure on many teachers to be accountable for student performance on end-of-course exams can cause previous time spent on independent projects to be eliminated in favor of focusing on specifically tested content. Another reason for a decline in science fair participation could be lack of resources and funding (Harmon, 2011). Many teachers volunteer their own time after hours and on weekends to help assist students with projects and have little support from administration in setting up and implementing the science fair. Regional and state fairs have also suffered from a lack of sponsorship which can cause fairs to close and require greater travel for students or limited opportunities to participate.

While these are all negative reasons for science fair participation to be on the decline one positive, at least overall for science education, could be the increase in other types of science competitions (Dale, 2010). Many schools now have robotics teams or Science Olympiad teams. There are also other science competitions like Toshiba's Exploravision and online science fair competitions such as the Google Science fair and the eCybermission which is sponsored by the Army Educational Outreach Program. Many teachers see the value in the science fair but do not have the class time or resources to devote to helping students with a project and an online fair can alleviate those concerns (Shapiro, 2012).

### **Areas of Further Research as Reconsidered by a Review of the Literature**

There are many research opportunities available, relating to students, teachers, and the structure of the fair itself. Much research needs to be done on the actual versus perceived benefits students receive from science fairs. Conducting more pre and posttest studies like Jaworski (2013) to examine if students really do increase an understanding of the nature of science could be one avenue of research. Bunderson and Anderson's (1996) study seems to suggest that age of exposure and frequency of participation has some impact on student attitudes towards the science fair. This is an area that calls for further research.

Investigating teachers' attitudes towards the science fair could also yield some interesting results. It was suggested by Bellipanni and Lilly (1999) that most science teachers are exposed to a science fair in their methods class. Is this really true? Does this exposure increase a teacher's confidence in helping conduct a science fair? Does the teachers' attitude impact the student's attitude towards the experience? Conducting a science fair takes a lot of time and many teachers are often left to their own devices to make this happen (Launius & Lenz, 2008), if teachers are provided a stipend or other type of compensation what impact does this have?

Studying the actual structure and implementation of the science fair itself could yield interesting results. Many schools cite the concern for paperwork and review boards as too confusing or time consuming for students and teachers. Researching programs like PRISM, Kids Inquiry Conference and standards-based fair to see if they appeal to those apprehensive of the intensity associated with the typical fair. Conducting research on student attitudes towards these could provide answers to possible ways to reform the International Science fair. Also do these alternative types of fairs have any impact on content knowledge or understanding of the nature of science? Researching the training of judges at local and regional levels could be also interesting to determine if there is a general standard of expertise or if the judging is more subjective at certain levels of competition.

As the science fair grows nearer to its centennial celebration it is interesting to reflect on how much of a constant it has been in science education while often staying in the background. The perceived decline in participation in the science fair at a time when science education and STEM initiatives are ever present seems ironic. Perhaps a renewed research interest in the science fair could bring it out of the shadows and into the twenty first century.

### **Chapter III**

#### **Research Method**

This chapter contains the research questions and a discussion of the methods used to answer those questions. The procedure for data collection and analysis is also included. This multiple case study applied surveys, observations and interviews of stakeholders to ascertain qualities of excellence in regards to the science fair. In this study all observations and interviews were conducted solely by the researcher. The interviews were based on the questionnaire in Appendix B. The observations were used to triangulate answers given from the questionnaires and prompt additional lines of questioning related to items specific to the school and climate. The research questions addressed were:

- 1) What are the features of schools with successful science fair programs?
- 2) Who are the stakeholders in the science fair programs and how do they contribute to its success?
- 3) What impact does the structure of the school have on science fair programs?

Twelve schools were identified as having shown excellence in science fair and five were included in the study. Each school was visited and various data were collected from each school. Various teachers, students, parents and administrators were interviewed at each school. The original research design was to have stakeholders at each school complete surveys prior to the researcher's visit. Upon visiting the school the researcher would conduct interviews with various stakeholders to triangulate and clarify data collected from the surveys. Every visit would also include observations of science fair related activities and would last for two days.

Interview questions and surveys were drawn from the guiding questions (Appendix A) and varied depending on the role of the person being interviewed. The interviews and surveys

were based on questioning to determine the role and attitude of all stakeholders in the science fair and to see what strategies their associated school has in place that contributed to the school's success and excellence in the science fair.

All schools were informed when initially contacted about the desired access for the researcher. However, the researcher was at the discretion of the school on who would participate in surveys and interviews and was not granted access to all groups at all schools. Unfortunately only two schools had all stakeholder representatives' complete surveys and due to extenuating circumstances two schools only had a one day visit, however, these did include time outside of the school day.

### **Selection of Cases**

Schools were selected for the case study by analyzing results from the last ten years of the Intel International Science and Engineering fair competition. The name of any school that placed at the ISEF was placed in a database to determine what, if any schools had winners over multiple years, the assumption being the more years a school had placed the greater likelihood the school had a strong science fair program in place. Seven schools were identified as having at least one winner every year and five schools had a winner nine out of the ten years. The identified schools are listed in Table 2. Five schools agreed to participate, two of the schools respectfully declined and one school was not contacted due to geographical constraints. Two additional schools expressed initial interest in being included but could not garner enough support from either teachers or administrators who were willing to participate. Administrators and teachers at the two remaining schools were contacted multiple times over a six week period via phone and email with no response.

Table 2. Identified Winners at INTEL ISEF 2004-2014

Winners every year 2005-2014	Winners at least 9 years from 2005-2014
Jericho High School, Jericho NY	Manhasset High School, Manhasset NY
Lake Highland Preparatory School, Orlando FL	DuPont Manual High School, Louisville KY*
Monte Vista High School, Cupertino CA	Fairview High School, Boulder CO*
Oregon Episcopal School, Portland OR*	Hankinson High School, Hankinson ND
Ossining High School, Ossining NY	Kalamazoo Math & Science Center, Kalamazoo MI*
Plano Independent School District, Plano TX*	
Thomas Jefferson High School for Science & Technology, Alexandria VA	

\* Indicates schools included in the study

Of the subjects to be used in the study two include public high schools, two are public magnet schools and one is a private school. Two had winners all ten years and three had winners nine out of the ten years. The schools are described here with additional data provided in Appendix B. All demographic data was obtained from each schools website and reflect numbers for the 2013-2014 academic school year.

Table 3: Overview of School Demographics

Name of School	duPont Manual High School	Fairview High School	Kalamazoo Math and Science Center	Oregon Episcopal School	Plano Independent School District
Location	Louisville, KY	Boulder, CO	Kalamazoo, MI	Portland, OR	Plano, TX
Type of School	Public Magnet	Public	Public Charter	Private	Public
Population	1856	2200	184	860	54,818
Grade levels	9-12	9-12	9-12	K-12	Pre K-12
Type of community	Urban	City	City	Metropolitan Area	Metropolitan Area
Majority Ethnicity	Caucasian	Caucasian	Caucasian	Caucasian	Hispanic

## **DuPont Manual**

DuPont Manual, referred to by most students and staff as Manual, was the first all magnet school for the Jefferson County school district in Louisville Kentucky, opening in 1984 (DuPont Manual, 2015). The building has been open since 1934, originally serving as an all-girls school and merging with the all-male high school Manual in 1950 (Heavrin, 1992). The building is located in downtown Louisville adjacent to the University of Louisville campus. Due in part to the history of the school it was decided to turn it into a magnet school when the school in operation began experiencing a decline in academics and discipline (McDaniel, 2005). Manual has since gone from one of the lowest performing high schools in the district to the number one high school in Kentucky and one of the most challenging high schools in the country (Best Schools, 2013; US News and World Report, 2015). Students must apply during the 8<sup>th</sup> grade for one of the five magnet programs within the school. The Youth and Performing Arts magnet (YPAS) is the original magnet beginning prior to the school being officially designated as such. The other magnets are Journalism and Communication, Visual Arts, Math Science and Technology, and High School University. The school operates on an A/B block schedule and enrolls close to 2,000 students (see Appendix B for detailed demographics) which are divided fairly evenly among the five magnets. Acceptance rates vary based on interested applicants each year. On average, approximately 1/3 of all applicants are accepted (DHMS, 2014)

## **Fairview High School**

Fairview High School is one of fourteen high schools in the large Boulder Valley School District. The district primarily serves students in Boulder, CO which is located about thirty minutes north of Denver. While many residents commute to Denver, Boulder has many entities itself that bolster this community. The University of Colorado, the National Oceanic and Atmospheric Association, the National Center for Atmospheric Research, and National Institute

of Standards Testing are a few of the local employers. Fairview, a 9-12 high school serves approximately 2200 students on a sprawling campus perched over a lake with a view of the foothills from the library that can distract even the most serious student. Colorado is an open enrollment state which means students are allowed to request to attend a school for which they are not zoned (Colorado Dept. of Education, 2013), or they can attend their home school which is the school associated with their residence. For the majority of the students, about 1600, Fairview is considered their home school, the rest of the students request to attend FHS with some of them driving from over an hour away according to assistant principal Sarah DiGiacomo (personal communication, February 25<sup>th</sup>, 2015).

Fairview operates on a modified eight period schedule; three days a week students meet with each class for fifty minutes and two days each week are allotted for a block class of an hour and thirty minutes allowing students to meet with each class for an extended amount of time. Like many of the schools in the Boulder Valley School District, Fairview has an open campus policy with students only required to be on campus when they have class. Depending on the grade level of the student they are required to sign up for a certain number of classes. Freshman and sophomores are required to take seven periods a day and can schedule one free period each day, juniors and seniors only have to schedule five periods a day but may schedule more if they chose.

### **Kalamazoo Area Math and Science Center**

Kalamazoo Area Math and Science Center (KAMSC) is a public charter school in Kalamazoo County, Michigan. The center began in 1985 with an endowment of 2 million dollars from the Upjohn Company. Upjohn, now known as Pfizer, is a pharmaceutical company that created the endowment as a way to enhance the math and science education of students in Kalamazoo County (KAMSC website). The partnership thrives today and the school is currently

funded based on the per-pupil money received from the state of Michigan, with additional money coming from the original endowment and supporting school districts.

In order to attend KAMSC a student must reside in Kalamazoo County; many students apply not only from public school but also private, parochial and home schools. Students apply during their 8<sup>th</sup> grade year to be accepted as incoming freshman and the school serves approximately 300 students in the 9<sup>th</sup>-12<sup>th</sup> grades. The first step in the application process is to take an entrance exam. Students receive their results on the exam along with information about what the scores mean. Students are then given the choice to continue the application process. An independent selection panel of twenty to thirty community members reviews all submitted applications looking at academic achievement, test scores, teacher recommendations and student essays. No distinction is given to home school district, ethnicity or gender. Seventy five students are accepted each year for the freshman class (KAMSC website).

Once accepted a student will spend half a day at KAMSC taking math, science and computer classes and half a day at their home school taking all other courses. School districts provide transportation for students to and from their home schools.

### **Oregon Episcopal School**

Oregon Episcopal School (OES) is a private school located on over fifty acres in the Portland suburb of Beaverton. The school serves over 800 students from kindergarten to twelfth grade. A boarding option is provided for 9<sup>th</sup>-12<sup>th</sup> grade students, but the majority of the students are day commuters. The school was originally established as a boarding school for girls in 1869 with a boys hall being added in 1962. In 1972 the two halls were emerged into the existing OES.

Tuition to OES varies depending on grade level, beginning at \$24,100 a year for kindergarten and increasing to \$29,300 for 9<sup>th</sup> -12<sup>th</sup> grade; financial aid and scholarships are available and the fee is increased for boarding students. The school is divided into a lower,

middle and upper school. The lower school consists of grades K-5, middle school is 6-8, and upper school is 9-12. Of the six science faculty at the upper school, four have Ph.D.s, one has an MD and one has a master's degree. Three of the four science faculty at the middle school have a master's degree.

While not advertised specifically as a math and science school, inquiry based teaching is widely emphasized on the school's website along with the science fair. Oregon Episcopal School is the only subject included in the study that had a winner ten out of the last ten years at Intel ISEF. An interesting note is that Intel is headquartered in the same metropolitan area as the school.

### **Plano Independent School District**

The second public school to be studied is actually the independent school district of Plano, Texas. Plano Independent School District serves residents in southwest Collin County, and encompassing the city of Plano, a large northern suburb of Dallas, TX. The school district reports having a pre K-12 total enrollment of 54,839 students in the 2014-2015 school year (Plano ISD website, 2014) divided among 72 campuses. The grade configuration for the secondary students is as follows; 6-8 is considered middle school, 9-10 is high school and 11-12 is senior high school. There are 13 middle schools, 6 high schools and 3 senior high schools and one academy school which serves students 9-12. The majority of the students are Caucasian with high minority populations of Asian and Hispanic students.

Plano ISD had a winner from at least one of the three senior high schools (11-12) and one of the six high schools (9-10) for nine of the ten years included in this study, one year there was only a winner from a senior high school. Since there was not one school with a winner every year it was decided to include the entire school district in the study. The three senior high schools are Plano West, Plano East and Plano. The six high schools are Clark, Jasper, McMillion,

Shepton, Vines and Williams. All of the schools except Vines had at least one winner during the studied time period.

### Data Collection

Structured and semi-structured interviews were conducted at each school with students, teachers and administrators. Parents were interviewed at three of the five schools. On-line surveys were completed by all stakeholder groups at two of the five schools. Three of the five schools were visited and observed for two days. Due to a snow storm Kalamazoo Area Math and Science Center was only able to be visited for one day. Due to school obligations Oregon Episcopal School was only able to be observed one day. Documents related to the science fair were obtained from all schools. Information is included in the table below.

Table 4: Types of data Collected by Subject

	duPont Manual High School	Fairview High School	Kalamazoo Area Math and Science Center	Oregon Episcopal School	Plano Independent School District
Completed On-line Surveys	Yes	Yes	No	No	No
Interviewed Students	Yes	Yes	Yes	Yes	Yes
Interviewed Parents	Yes	Yes	No	No	Yes
Interviewed Teachers	Yes	Yes	Yes	Yes	Yes
Interviewed Administrators	Yes	Yes	Yes	Yes	Yes

Table 5: Data collected on site visits

	duPont Manual High School	Fairview High School	Kalamazoo Area Math and Science Center	Oregon Episcopal School	Plano Independent School District
Length of Observation	2 days	2 days	1 day	1 day	2 days
Science fair related activities that were observed	Practicing presentations	Debriefing after district fair	Open lab for research	Open lab for research	District science fair
Documentation Collected	Paper and presentation rubrics Research timeline	Research course syllabus	Mentorship booklet Research course syllabus	Research timeline and due dates	Student handbook Teacher handbook Judges handbook

### Data Analysis

Upon completion of observations and transcription of interviews the researcher reviewed the transcripts and coded similar responses of individuals trying to ascertain the factors which are most impactful for ensuring the school's continued success in the science fair. The researcher was looking for elements of each school that were unique or multiple respondents expressed felt continued to the excellence of the school's science fair. This could include such items as requiring the science fair in early grades, partnerships with research institutions and elective research classes. Documents related to the science fair or science research programs were also collected and compared. These included but were not limited to syllabi from research classes, handouts to students and parents, and mentorship booklets.

The data collected from interviews and focus group discussions were transcribed and coded into thematic responses based on researcher interpretation. There were some pre-set codes based on the nature of the research questions, but the researcher was also looking for

emergent codes when reviewing the transcripts. A non-response rate did occur as some schools did not complete the surveys. Questions similar to those on the survey were asked during the interviews so relevant data was able to be collected from all schools to be used in cross case analysis. Document analysis was also done to triangulate and clarify information gathered from surveys and interviews. Due to the qualitative nature of the study no statistical tests were done. Considering the support that was given by the subjects in data collection and member checking, it was decided to not use pseudonyms in quotes and descriptions.

## **Chapter IV**

### **Results and Analysis**

#### **Introduction and Organization**

The purpose of this research was to attempt to identify characteristics of schools with excellent science fair programs. Many people in science education are familiar with the science fair but could perhaps benefit from knowledge of factors that may contribute to exemplary practice in this area. Ideally this information could be shared with other schools who are hoping to start a science fair program or to try to grow a program already in existence. Twelve schools were identified as having continued success at the International Science and Engineering Fair (ISEF) and were thereby defined as having excellent programs. Of the twelve schools identified six had at least one winner nine out of ten years from 2004-2014 and six had at least one winner all ten of the years studied. Five schools agreed to be included in the study; for a list of all the schools and years studied see Table 2.

Two overarching themes emerged after observing and conducting interviews at the five schools that were the focus of the study. These themes were the climate of school and the climate of the community. Encompassed in these two themes were the roles of stakeholders, the structure of the science research program and the resources of the community. This chapter includes an overall description of the five schools that participated in the study along with in case analysis of data collected from the individual school. The case studies are presented here in abbreviated version, the full case studies are presented in the appendix. The information from all schools participating is analyzed through cross case analysis with a description of how the emergent themes were seen at each school.

It is important to include some background about the role I played in data collection. As a former science teacher, I participated in science fairs begrudgingly my last two years of teaching

at a public high school. I had been approached earlier in my career about being involved but had always declined because of the concerns I had about time commitments and fitting it in with the curriculum, two common concerns of many teachers who don't participate. Once exposed to the science fair and seeing its potential for students to learn authentic science I regretted that I had not been involved previously. This was a partial motivation for my dissertation topic and subsequent research.

Keeping in mind my potential bias, my research was focused not on outcomes from participating in science fairs, but on identifying components of schools that have excellent science fair programs. Excellence was defined as those 9-12 high schools in the United States that have had winners of some form at the International Science and Engineering Fair at least nine out of ten years from 2004-2014.

The questions guiding the research were:

- 1) What are the features of schools with excellent science fair programs?
- 2) Who are the stakeholders in the science fair programs and how does each contribute to the success of the program?
- 3) What impact does the structure of the school have on science fair programs?

### **Models of Excellence in Science Fair**

#### **Demographics and Data Analysis**

Five schools out of twelve that met the definition of excellence as designated by the study were studied as part of the process. Of the schools included in the study, one is a private school, one is a public charter school, one is a public magnet school and two are traditional public schools. General information is included in Table 3, with more detailed information in Appendix C. The schools varied in enrollment and demographics but none would be classified as rural. Several are located in large metropolitan areas, with one considered to be urban. With one

exception the majority of the students are Caucasian.

Eleven of the twelve schools identified as meeting the definition of excellence were approached for inclusion in the study; the five subjects represent all of those who agreed. Of the remaining six; two declined, two never responded even though numerous attempts were made to contact them, one initially agreed and then declined and one agreed too late in the research process for inclusion. One school was not approached due to travel restrictions of the researcher.

Information from each school was analyzed to identify themes that answered the research questions. All interviews were transcribed and coding was used to analyze interviews and survey responses. Questions related to science fair structure generally utilized pre-set codes while those related to support and opinions of excellence gave way to emergent coding. Documents collected and notes from observations were used to triangulate the data and provide further information for analysis. Completed case studies were sent to a school representative for member checking.

### **duPont Manual High School**

duPont Manual, a public school in Louisville Kentucky, is an application based magnet school open to any student in Jefferson County. Students must apply during the 8<sup>th</sup> grade for one of the five magnet programs within the school. Students must complete an application packet which includes; transcripts showing grades and attendance, teacher recommendations, and response to a magnet specific essay. The process is competitive and the school acceptance rate fluctuates from year to year ranging from a quarter to half of the applicants being accepted (G. Zwanzig, personal communication, January 26<sup>th</sup>, 2015).

The Math, Science and Technology (MST) magnet was the primary focus for this research. Students in the MST magnet are grouped together to take their core math and science classes with designated MST teachers. Elective math and science classes are open to students in other magnets but enrollment priority generally is given to MST students (B. Barr, personal

communication, January 26<sup>th</sup>, 2015).

### **Science Fair Program**

The science fair started at Manual in 1984 and became a requirement for all Math, Science and Technology students' in grades 9-11 in 1990. "Our program didn't really have a focus...to give us an identity we had to have something so I really pushed for the research side" said 33 year teacher veteran Glen "Skip" Zwanzig (personal communication January 26<sup>th</sup>, 2015), science teacher and science fair director since its inception at Manual. The program started only with the students in Mr. Zwanzig's classes participating and then grew to include all students in the Math, Science and Technology magnet.

Students are given deadlines related to the project and points for completion of the research and research paper which together account for approximately 20% of their total course grade. Teachers order supplies and open labs after school or on weekends to help students conducting research, "we accommodate the kids the best we can" (G. Zwanzig) but the actual experiment is expected to be done outside of class. Class time is provided to help students with research ideas, paperwork and presentations. Depending on the grade level and teacher the amount of time may vary; there is more flexibility with the content in the 9<sup>th</sup> grade curriculum so quite a bit of time is spent on research techniques and science fair related processes.

Science Independent Research is a course offered to students in 11<sup>th</sup> and 12<sup>th</sup> grade and students are only admitted with the approval of the instructor. In this course students are expected to work with a mentor in a research lab and are given release time from school to do so. The instructor will help a student find a mentor but many of the students arrange for these themselves according to Bob Barr the current instructor. Many students work in labs at the University of Louisville due to Manual's proximity to the campus. It is important to note that many of the students, not just those in the independent research class, work with a mentor.

While all students in the MST magnet are required to do a science research project, not all students are required to participate in a science research competition. All students must give a ten minute research presentation to their class, but most students are given the choice of participating in the science fair or other science competition like Kentucky Junior Science and Humanities Symposium. Some teachers offer extra credit for participation in a competition and it is a requirement for students in the Independent Science Research class.

The Manual science fair is held in the commons area of the University of Louisville campus and is run by the Science Fair parent booster club initiated by Zwanzig many years ago, “I started that about 10 yrs. ago and it’s been getting bigger and bigger, they took it out of my hands...sure was nice, because it took too many hours” (G. Zwanzig, personal communication, January 26<sup>th</sup>, 2015). The parents arrange for the judges and prizes and also raise money to help with the cost of the fair and of sending students to state and international competitions, “we’re basically event planners” said Rachel Chancey president of the booster club.

### **Fairview High School**

Nestled at the foothills of the Rocky Mountains, Fairview High School is one of fourteen high schools in the sprawling Boulder Valley School District. The district primarily serves students in Boulder, CO which is located about thirty minutes north of Denver. Boulder is home to many science research institutions including the National Oceanic and Atmospheric Administration, National Institute of Standards Testing, and the University of Colorado.

Fairview is a 9-12 high school serving approximately 2200 students on a sprawling campus perched over a lake with a view of the foothills from the library that can distract even the most serious student. Colorado is an open enrollment state which means students are allowed to request to attend a school for which they are not zoned (Colorado Dept. of Education, 2013), or they can automatically attend their home school. For the majority of students, about 1600,

Fairview is considered their home school, while the rest request to attend FHS. Like many of the schools in the Boulder Valley School District Fairview has an open campus policy with students only required to be on campus when they have class. For example, a senior enrolled in five courses would have two free periods. Fairview is a high performing academic school and has a climate of relaxed intensity. Due to the open periods students are found filling the halls and library at all times of the day but are generally seen studying instead of goofing off. The school has a robust Advanced Placement and International Baccalaureate program with 73% of the students enrolled in at least one AP or IB class.

### **Science Research Seminar**

Schools in Boulder Valley have been involved in the Cordon Pharma Regional Science and Engineering Fair, an ISEF affiliated fair, for over thirty years. About nineteen years ago the school district decided to set aside funds for a class specifically devoted to science research and helping students prepare and participate in the science fair. The school district set aside funds to create a course called Science Research Seminar (SRS) at each high school in the district. Each high school is required to allocate one period a day in a teachers' schedule for the course.

Originally the SRS class was supposed to only have ten students in it to allow a better mentoring experience for the students. As funding has remained the same and interest has grown at Fairview this number is now open ended with the current teacher having twenty one students in the course this year. In the last ten years, or those encompassing this study, the SRS class has had three different teachers. Each teacher has had a slightly different approach to the program but the overall premise of the course has remained the same; students sign up for the course as an elective and are given release time from school to work at home or with a mentor at a research institution or university. Dr. Paul Strode, current SRS teacher, has a meeting each spring with interested students to ensure they understand what is expected from the course, below is the description from the course syllabus.

The objective of SRS is (i) for students to learn about the human endeavor of scientific research, (ii) to learn how statistics fit into scientific research, and (iii) to experience planning, performing, and communicating real, original research. The general class structure is more free form than a traditional class. Therefore, students must be self-disciplined and self-motivated.

SRS course syllabus, Dr. Paul Strode, Fairview HS

Along with reading a non-fiction science book over the summer, students are expected to secure a mentor. While students do not have to work with a mentor the majority of the students seem to do so, teachers will help students find mentors or act as a mentor for a student but projects are usually not done at school merely due to space. Not every student who participates in the science fair is enrolled in the SRS class, some students do not have room in their schedule for the elective so they will work with Dr. Strode or another science teacher on ensuring their project is ready for entry into the fair, other students will take the class for multiple years.

### **Kalamazoo Math & Science Center Case**

The Kalamazoo Area Math and Science Center (KAMSC) is an example of what can happen when business, politics and education can cooperate and work in partnership to benefit a large community. The application based math and science center began in 1985 in Kalamazoo County, Michigan with an endowment of 2 million dollars from the Upjohn Company. The school is currently funded based on the per-pupil money received from the state of Michigan, with additional money coming from the original endowment and supporting school districts.

Once accepted a student will spend half a day at KAMSC taking math, science and computer classes and half a day at their home school taking all other courses. Freshman and sophomore students come in the morning from 8-10:30 and juniors and seniors attend in the afternoon from 11:30-2:00 with the option to take an additional class from 2:10-3:00. School

districts provide transportation for students to and from their home schools. The school operates on a unique schedule that allows three different lengths of class time; 45 minutes two days a week, ninety minutes once a week and 180 minutes once a month. The school also has open lab most Wednesday nights from 6-7:30 where students can come and work on homework or research.

Many of the students attending the Kalamazoo Area Math and Science Center are the top academic students in their home districts and seem thankful for the opportunities provided at KAMSC that perhaps their smaller home district could not provide. Students take advantage of the opportunities the school affords them and are passionate and excited about their education. During my research visit I was able to attend an open lab night and even with the threat of a winter storm approaching, about eighty students showed up to work on research projects, get help with homework or prepare for upcoming exams, most of the teachers were also present.

### **Science Research**

Research Science is a course all students at KAMSC are required to take which is embedded in their other core science courses. Students in the 9<sup>th</sup>, 10<sup>th</sup> and 11<sup>th</sup> grade complete the requirements for Research Science as part of their Biology, Chemistry and Physics courses. At the end of their junior year, students take an exam and if they pass with an 80% or above and have completed the requirements from the following three years, they are given credit for Research Science on their diploma. The Research Science course takes a scaffolding approach with the knowledge acquired each year building off the previous content. For example in the 9<sup>th</sup> grade students perform meta-analysis research in an attempt to understand research design by reading research articles on a related topic. The projects completed are not entered into the science fair competition.

If these student projects are not entered into the regional fair then where do the KAMSC projects come from? In addition to the required Research Science course students can sign up for

a science research based elective. The Research Team and independent research courses are semester courses generally taken in tandem by juniors and seniors. Students in the class are expected to complete the research project for any core course they are taking in addition to the project for Research Team. Students must apply to be in the class and Dr. Goudie is in charge of enrollment. Interested students meet with Dr. Goudie the spring semester prior to enrollment in the course to discuss research ideas and expectations. Students on the Research Team are paired with a mentor and given some class time to work in an off-campus lab. Great attention is paid to pairing a student with an appropriate mentor and Dr. Goudie even facilitates an interview so both parties are provided the opportunity to determine if the partnership will be a good fit.

Only the projects completed by students on the research team are entered in the district science fair competition, which interestingly enough consists of very few projects from other schools. All of the science research projects are displayed at the KAMSC science open house night in the late spring.

### **Oregon Episcopal School**

Oregon Episcopal School (OES) is a private school located in the Portland, Oregon suburb of Beaverton. Tuition to OES varies depending on grade level, beginning at \$24,100 a year for kindergarten and increasing to \$29,300 for 9<sup>th</sup> -12<sup>th</sup> grade, financial aid and scholarships are available and the fee is increased for boarding students.

Science is a big focus of the Oregon Episcopal School and administrators emphasize the inclusion of inquiry based teaching in all subject areas. Science is not taught in the lower school as an isolated course, but there is a science specialist who teaches or assists teachers in the lower school classes once or twice a week and introduces inquiry based projects to the students. In the 6<sup>th</sup> grade OES students have science for the first time as a subject and this is also when students become involved with the science research program which continues through the 11<sup>th</sup> grade.

## Science Curriculum and Science Research

The science research program began about thirty years ago with Dr. Bill Lamb. Dr. Lamb was dedicated to the idea of inquiry and helped shape the science program at OES around this important concept according to Jordan Elliott head of the Upper School “(he) really helped us make this commitment to inquiry and this understanding that the kids were going to have a better experience learning about science if they were hands on with it and even better if they were designing and implementing a project” (personal communication, January 6, 2015).

Conducting an independent research project is a required part of core science classes in the 6<sup>th</sup> through the 11<sup>th</sup> grades, accounting for about a quarter of a student’s grade. About this same percentage of class time is devoted to the research process. In the upper school, time is usually not spent on experimentation but instead on helping students with items related to writing and preparation, “because of the huge diversity of projects that we have, the class time for experimentation doesn’t help pay for most projects.” B. Daglan, science teacher and lab director, (personal communication, January 6, 2015). Students in the middle school are given class time to work on actual experimentation and have a smaller research window than those in the upper school, four to six weeks versus twelve. Another difference in the middle school is that students in the 6<sup>th</sup> grade do not participate in the Aardvark Science Expo, the school fair for OES; instead they have a science showcase night which allows students to practice communicating their findings to others but takes the pressure of competition away from the novice researchers.

For all other students, science research begins the first day of class with idea generation. Some students have already started research over the summer, with OES teacher approval, but many others are still searching for ideas. There is some push for students to do projects related to the course they are in, for example students in 9<sup>th</sup> grade Physics should try to do Physics related projects.

As much as I can I steer my students to do Physics related projects because then I have rabbits when those units come up later in the year and I get a dividend..... I figure if I'm investing Physics curriculum time in this I want to get something back if I can.

(R. Orr, personal communication, January 6, 2015)

The twelve week experimentation/data collection window begins for the upper school in October and ends in January. Labs are available after school and some weekends and holidays for students to conduct their experiments. The school has two dedicated research directors who share responsibilities related to the science fair and science research in addition to some teaching duties. These teachers, along with others, supervise the students during open lab time. The school has a lab dedicated solely to independent student projects and can be viewed through a large glass window from the shared science teacher office.

Many grades are given along the way and tare sheets are collected to ensure students are progressing in their research. Students are not necessarily encouraged or discouraged to work with mentors outside of school but very few do. In the 2014-2015 school year less than 20% of the upper school students were working with outside mentors.

## **Plano ISD**

Plano Independent School District encompasses the city of Plano, a large northern suburb of Dallas, TX. The school district includes thirteen middle schools, grades 6-8, six high schools, grades 9-10 and three senior high schools, grades 11-12.

Plano ISD's science fair program began in 1984 when science teacher Becky Wussow and husband Dr. Jim Wussow (now an assistant superintendent) decided to start a science based research club for students, "I thought that getting kids doing research was important" (J. Wussow, personal communication, February 11, 2015). The LASER club (Learning About Science and Engineering Research) quickly spread to other high schools in Plano ISD. Says

Karen Shepherd former science teacher who is now the science coordinator for the district, “once I heard they were going to do it at Shepton, I wanted one at my school” (K. Shepherd, personal communication, February 10, 2015). The first science fair was hosted in 1985 by Clark High School and included 40 projects. The current requirements for those who participate in the science fair are as follows:

- A research project is required for students in honors science classes in grades 7<sup>th</sup> & 8<sup>th</sup>.
- A student enrolled in an honors science classes in 9<sup>th</sup> and 10<sup>th</sup> grades can either do a research project or a research paper.
- An advanced science research course is offered for students in the 10<sup>th</sup>-12<sup>th</sup> grades.

A certain number of students must be interested in the course and space must be available in the schedule for it to actually be offered at the school.

- All high schools & senior high schools offer a LASER club focused on science research

(K. Shepherd, personal communication, February 10, 2015; Plano ISD website, 2014)

To help teachers and students organize a science fair project the district has created handbooks provided to students at the beginning of the year; there is a K-6 handbook and a 7-12 handbook as well as teacher handbooks (see Appendix D). Teachers and students in the middle school use the handbook as part of their curriculum and spend every Friday on some topic related to the science fair. Students are not generally provided any class time for experimentation but time is spent on helping students come up with a project and helping them understand information related to identifying variables and writing a hypothesis.

Each school is responsible for conducting their own science fair and grading of projects. Some schools have a LASER club sponsor responsible for this or a science fair coordinator, and some schools rely on parent volunteers. Karen Shepherd and two other district employees look at the paperwork for every student. For the 2014-2015 school year, the state implemented an online

program called Oracle to help manage the over 4,000 projects. Karen Shepherd also helps teachers if they need judges.

The district conducts its own fair prior to the regional fair; bringing together all the winners from the different schools into a dress rehearsal of sorts. Prizes are awarded and feedback is provided, but every student at the district fair is already eligible to participate in regional, and winning the district fair does not immediately send you to state. Teachers say they like the idea of giving students a chance to practice their ‘elevator speech’ and experience the feeling of being in the higher pressure environment. The judges are encouraged to provide good feedback and constructive criticism that will help the students at the regional fair. In meeting with the judges on the morning of the fair Karen Shepherd mentions a project from last year that did not place at the district fair but due to judge’s feedback the student was able to improve and won an award at Intel ISEF.

### **Emergent themes within Models of Excellence**

All of the five schools included in the study are unique in their locations, school structure and organization of the science fair. There are some commonalities that exist between the schools, the climate of the school and the climate of the community were broad themes that emerged from the data collection. Embedded and interwoven within the climate of the school and the community three themes emerged; the roles of stakeholders, the resources of the school and community, and embedded science fair components in the curriculum.

### **Roles of Stakeholders**

One of the initial aims of this study was to determine who the stakeholders are in support of exemplary science fair schools and what role they may play in the success of the program. The identified stakeholders were students, teachers, administrators and parents. Community members emerged as another group of stakeholders in the form of judges, mentors, and financial sponsors.

All of these groups were present at all schools but their role in the science fair varied.

**Students.** Students are the participants in the science fair and so the role they play is important to a school. The students at all of the schools have self-selected at some level to be involved in the science fair. Students at duPont Manual, Kalamazoo Area Math and Science Center and Oregon Episcopal School have all applied to the school; KAMSC students have additionally applied to be a part of the research team. Students at Fairview have all elected to sign up for the science research class or participate in their own free time. Some of these students also sought out attendance at Fairview over their home school. The students in Plano ISD have self-selected either by choosing to be in an advanced level science class, by taking the elective science research class, or by being involved in the LASER club.

The focus age group for this study was students who would be eligible for competing in the senior high division of the Intel ISEF Science Fair, or those students in the 9<sup>th</sup> through 12<sup>th</sup> grades. Students in the 7<sup>th</sup> and 8<sup>th</sup> grades are able to compete in the junior division at ISEF affiliated fairs, but the highest level of competition for these students is at the state. Table 6 focuses on the student stakeholders, comparing what students are involved in science fair at each school. Even though it fell outside of the focus area it is significant to note that Plano ISD and Oregon Episcopal School both have students participating at the junior level of competition. In addition, both duPont Manual and Fairview receive some students who have participated at the junior level depending on the middle school they attended. Only the Kalamazoo Area Math Science Center does not currently have science fair at a feeder middle school.

It is important to remember when looking at the numbers in table 6 that Plano ISD incorporates twenty-three buildings for the 7<sup>th</sup>-12<sup>th</sup> grade so while the number of projects is significantly higher than the other schools, the percentage of students involved in the science fair compared to those enrolled in the same grades is equal to Kalamazoo Area Math and Science Center and significantly less than Oregon Episcopal School. Additionally, both Kalamazoo Area

Math and Science Center and Oregon Episcopal School have students participating in a research project at younger grades but they are not involved in a science fair competition. Students in the 9<sup>th</sup> and 10<sup>th</sup> grades at KAMSC participate in a science research day at the school and 6<sup>th</sup> grade students at OES have a science research night.

Information regarding demographics of each school was presented in Table 3 and Appendix A. The following table highlights similarities and differences between the schools in regards to the operation and participants of the science fair.

Table 6: Participants in the Science Fair at each school

	duPont Manual	Fairview	KAMSC	OES	Plano ISD
Grades Involved in Science Fair	9-12	10-12	11 & 12*	7-12	6-12
Approximate # of Students Involved in Science Fair	400	25	50	450	4000
Approximate # of Students Eligible for Intel ISEF	400	25	50	270	2100
% of Students in School, Participating in SF & Eligible for Intel ISEF	21%	1%	27%	85%	27%

**Teachers.** All of the schools in the study seem to benefit from a community of teachers supporting one another, but most began with one tenacious teacher. Fairview would be the exception to this because the Science Research Class was started at all schools with a district mandate. Skip Zwanzig (duPont Manual), John Goudie (Kalamazoo Area Math and Science Center), Bill Lamb (Oregon Episcopal School), and Jim Wussow (Plano ISD) all had one thing in common, a passion to teach students science in an authentic manner. Their enthusiasm and drive helped lay the foundation for the current programs at their schools. Zwanzig and Goudie are still actively involved but both are hoping to retire soon. To show how dedicated these men are they are both involved in the process of finding and training their own replacements to ensure the programs they have built do not die. Zwanzig recruited a teacher from another school who

was involved in science fair to come to Manual to work with the independent research class as well as ensuring his former student teacher was hired because she had shown a passion for science research. “I’m just here to try to help them; I can’t go on too much longer.... You can’t just do it with one person. Science Fair kind of grew with me and it’s more than I could ever handle by myself now” (G. Zwanzig, personal communication, January 26, 2015). Dr. Goudie, with support from Kalamazoo Area Math and Science Center director Dr. Tarnoff, secured funding for an apprentice to work closely with him this year to show the intricacies of the research class and research team, says Dr. Tarnoff “this is not the kind of position where in general you know you are going to be teaching Physics...doing this position you really need to have someone working with you” (personal communication, January 28, 2015).

The science teachers at all of the schools are involved in the science fair either directly or indirectly, with the exception of duPont Manual and Plano; at Manual it is only the science teachers in the Math, Science and Technology Magnet who are involved and in Plano it is only those who teach the honors science classes. Kalamazoo Area Math and Science Center, Oregon Episcopal School, and Plano ISD all have teachers or personnel that have release time to dedicate to science fair/research related tasks. Fairview and Manual have dedicated teachers for one section of a research class, but this is still considered student contact time. Science teachers at Fairview who are not involved in Science Research Seminar are indirectly involved in the science fair because they teach inquiry based science and immerse the students in lab, helping to lay a foundation for those students who opt to take the Science Research Seminar class. The unique embeddedness of the science research class at Kalamazoo Area Math and Science Center means all teachers are involved in having students do science research, even if they don’t enter these projects in the science fair competition.

Teachers who are involved in science fair usually give up free time to help students. Teachers at every school mentioned staying after school or coming in on weekends to help

students with research. Generally the bulk of this responsibility will fall on the research director or research class teacher, but at Oregon Episcopal School and Kalamazoo Area Math and Science Center the other teachers are heavily involved in manning labs after school and on weekends.

Experience with research seemed to be a common thread among teachers at three of the schools. Teachers at Oregon Episcopal School are specifically hired based on their research experience. Jordan Elliott, head of the Upper School describes an ideal science teacher at Oregon Episcopal School, “we have to go out and find people who have done research who understand research and have demonstrated experience and also want to be teachers who want to work with kids.” (personal communication, January 6, 2015). This statement is supported by the fact that of the six science faculty at the upper school four have Ph.D.’s, one has an MD and one has a master’s degree. Three of the four science faculty at the middle school also has a master’s degree.

Some of the teachers at Fairview also have science research in their backgrounds. Paul Strode, the current Science Research Seminar Teacher, has a Ph.D. in Ecology and Environmental science and regularly contributes to research journals and works with the Howard Hughes Medical Institute on creating and evaluating science curriculum. He also has taught courses at the University of Colorado. Dr. Tracey Clement is a former research scientist in physics who worked in that field for twenty years before transitioning into teaching science at Fairview. Dr. Helen Petach took a leave of absence last year to participate in a science fellowship with AAAS working on environment and health programs for the government. Dr. Petach taught the Science Research Seminar course before Dr. Strode holds a Ph.D. in Physics.

John Goudie, science research coordinator at Kalamazoo Area Math and Science Center, has a Ph.D. in science education and has done master level work in Biology and Chemistry. Dr. Michael Tarnoff, director of Kalamazoo Area Math and Science Center, has a

Ph.D. in Physics and taught at Western Michigan University before becoming an administrator. Three of the other science and math teachers at Kalamazoo Area Math and Science Center also have advanced research related degrees.

**Administrators.** Administrators at some level in all of the participating schools have shown they place value on science research and the science fair. duPont Manual, Fairview, Kalamazoo Area Math and Science Center, and Plano ISD show support by allotting funds for an elective science research course to be offered and dedicating part of a teachers class load as such. Administrators at Oregon Episcopal School, duPont Manual, Plano ISD and Kalamazoo Area Math and Science Center show value for the science fair by supporting the inclusion of science research in the curriculum, at the expense of losing some content. By even creating schools like Kalamazoo Area Math and Science Center and duPont Manual, district administration has shown support for science, which these schools have turned into support for science fair. Oregon Episcopal School and Kalamazoo Area Math and Science Center both have dedicated funding for research directors as well as providing funds for the printing of posters.

While the administrations of all the schools studied place some value on science fair/science research, it is not necessarily at the top of the priority list for all districts. duPont Manual has the support of the building administration, but receives very little financial support from the district. There is a feeling that duPont Manual has taken the brightest students from all the other schools in the district (source) and has made district administration very cautious about appearing they are doing anything special for the school. duPont makes up for the external lack of district support by having a strong parent booster club to help with fundraising.

Plano ISD shows great support for the science fair at the district level; providing resources for the fair, release time for teachers, and integrating the role of fair director into the duties of the science curriculum director. However, at the building level there seems to be quite a bit of discrepancy in regards to the importance of science fair. Some teachers were not even told

it would be part of their duties until after they were hired, some schools have very high levels of mandatory enrollment on the elective research class, making it hard for the class to make. Other schools are allowing teachers to let students opt out of science fair even though it is supposedly mandated by the district at certain levels.

Fairview has support from the district for the Science Research Seminar class, but recent funding cuts mean even with increased student interest another section will not be provided to the teacher so if he wants to accommodate more students he has to be willing to have larger class sizes. “They’ll never give us more money...we can’t afford to offer the program that we have now.” (S. DiGiacomo, personal communication, February 10, 2015). Even in this affluent district, the science teachers at Fairview could not afford to do the number of labs they do if it were not for parent donations.

**Parents.** Providing financial support to schools and students is one of many ways parents support the science fair. The level of parent involvement varied greatly from school to school; from running the fair to only taking their children to the lab.

Parents at all of the schools are involved in the science fair itself as judges, primarily if they have a science background. Those parents with science backgrounds also serve as formal and informal mentors at all schools. At Kalamazoo Area Math and Science Center and Oregon Episcopal School parents are encouraged to be more informal mentors, only guiding students with the research process or experimental design; at Plano, Fairview and Manual parents serve as formal mentors allowing the students to work in research labs with them.

duPont Manual probably has the most involved set of parents with the Science Fair parent booster club. What was so surprising was they were so surprised that this was uncommon, “you have booster clubs for band and football, why not science fair?” said parent Ted Smith (personal communication, January 26, 2015). These parents are intricately involved in the actual operation of the science fair which was not present at any other school. They are the ones who

arrange for the judges, secure the location and funding for the fair, and run the fair including set up and organization of projects, and awards ceremony.

It should be noted again that duPont Manual, Kalamazoo Area Math and Science Center, and Oregon Episcopal School have an application process, so there is a level of parent involvement in merely enrolling a child in some of these schools. Many of the parents I talked to also had spent money on helping their students buy materials for projects, pay for printing a poster or helped drive them to meetings with mentors, this implies a certain amount of social capital is available to the students.

It should also be noted that two of the schools said they try to encourage parent involvement as little as possible. Administrators at Oregon Episcopal School and Kalamazoo Area Math and Science Center both said they try to discourage parents from helping their students with projects and this is sometimes done best by not involving parents in any aspect of the science fair. At Oregon Episcopal School parents may be a part of the 6<sup>th</sup> grade exposition night but are generally only judges if there is a shortage. Kalamazoo Area Math and Science Center has only judges from the community, some may happen to be parents of past or future students but not current students.

**Community Members.** While not initially identified as a group of stakeholders; the role community members play in the science fair became evident during data collection. Community members are called on to be judges and mentors in all of the schools included in the study. Many of those who participate are in some way connected to the school, usually as parents. But others seem to see it as an outreach opportunity or way to encourage young scientists.

At the Plano ISD district fair one judge from a local university said he was encouraged by his department chair to participate as the science fair is seen as a possible research tool. He said he feels as if the university has a stake in “wanting to help grow domestic STEM students” (Plano Judge, personal communication, February 11, 2015). Zwanzig estimates that over half of

the students at duPont Manual work in research labs, many at the University of Louisville, and knew of four students just this year who were offered scholarships based off the relationship G. Zwanzig, personal communication, January 26, 2015).

Students on the research team at Kalamazoo Area Math and Science Center must work in a lab and students at Fairview must have a mentor even if they are working independently. Some students in Plano ISD will seek out mentors for research labs, of the fifteen senior high students I talked to all of them had done their work in a research lab. Curriculum director Karen Shepherd estimates more than half of the students worked with outside mentors, basing this partly on the paperwork she helps process. Less than 20% of students at Oregon Episcopal School during 2014-2015 reached out to community members for mentorship. This is about the average according to research director Bevin Daglan, students are not told they can't use an outside mentor but are encouraged to utilize the school resources. Having students work together in the school lab is an intentional goal of the faculty.

They're not at home in their garage, they're in here with a dozen other people and their waiting for their stuff to boil and so their like 'hey what are you doing over there?' so they discuss their research together....they're explaining their research. It's like this is how science happens.

(B. Daglan, personal communication, January 6, 2015)

### **Resources of the Community**

Identifying community members as stakeholders naturally leads to a discussion of the community resources. The importance of living in a community that had supporting resources was a theme that came up at every school. Almost verbatim one person at each school said 'where else can you find a community with these resources?'

All of the schools in the study benefit from community partnerships with research universities. Some of these are heavily involved in providing mentors, such as the University of

Louisville (duPont Manual), University of Colorado (Fairview), and Western Michigan University (Kalamazoo Area Math and Science Center). Universities provide other support in the form of judges or resource support such as helping with research design.

At Fairview and duPont Manual there was some concern expressed over continued access to the Universities for research. The University of Colorado recently had two Nobel laureates in physics and this has increased enrollment in the department and limited the amount of research spots for high schools students according to Dr. Petach. At duPont Manual teachers and parents estimate that about two hundred students work in labs at the University of Louisville. This is a huge number even for a large university. Recent issues about liability have come up and working with high school students can create challenges, according to Cindy Corbett, a Biology professor.

So you have to be a little creative if you're going to have high school students' work with you, the stuff I do in my lab is very expensive and I can't hand that stuff over to someone else, even an undergrad much less a high school student. So those are some of the concerns that come up. I have seen several labs take in high school students and give them small manageable projects, usually under the supervision of graduate students, because that gives them mentoring experience as well but you just have to be creative.

(C. Corbett, personal communication, January 25, 2015)

Dr. Goudie says liability issues for Kalamazoo Area Math and Science students have been solved by using contracts. "We have contracts. It turns out that in Michigan if you are a public institution then you have the liability because you are a government institution, so that's the way we went and the way Western accepted it." (personal communication, January 28, 2015). He did mention that doing research in hospitals has become more difficult due to HIPPA laws, so students no longer pursue those options.

Universities are not the only community partners in proximity to the schools. The cities and surrounding areas in which all of the schools are located have research institutions and science and engineering based businesses. Portland, OR has been called the Silicon Forest and is home to many technology based businesses including Intel, sponsor of the International Science and Engineering Fair. The National Oceanic Atmospheric Administration and the National Institute of Standards and Technology are both headquartered in Boulder, CO. Pfizer and the Kellogg Biological Station are just two of the research institutions located close to Kalamazoo, MI. Plano is close to numerous companies in the Dallas metroplex area including Exxon, Johnson & Johnson, Texas Instruments, HP Enterprise Services and research institutions like the Research Institute of Dallas and Baylor Medical Center. Louisville has many medical research institutions and is also the headquarters of GE Commercial and Industrial.

### **Embedding Science Research**

A final theme that emerged in looking at the schools was how science research was embedded into the curriculum or culture of the school. The schools researched all operated under different systems as was shown in Table 2 and had a variety of different schedules. Even with all these differences, Fairview was the only school that did not require students in core science classes to carry out a science research project at some point. It should be noted that the Boulder Valley School District in which Fairview is located does have a firm foundation of inquiry in the district science curriculum beginning in the elementary grades so students are exposed to scientific processes throughout their education even if they are not required to complete science fair projects.

**Program Structure.** Before discussing the science curriculum it is important to take a look at the overall structure of the school and how it relates to the science fair and science research. Fairview, Kalamazoo Area Math and Science Center, and Oregon Episcopal School all

implemented flexible scheduling in their schools. Fairview has a schedule allocating one extended class per period each week, allowing extended time for labs in science classes.

Kalamazoo Area Math and Science Center had a unique schedule allowing two extended class periods each week for every class, and one extra-extended class each week for one period, rotating on a four week schedule, again allowing for extended time for labs.

Oregon Episcopal School has the most complicated schedule of all, operating on a six day rotation. Administrators said the idea is to allow for teachers and students to see each other at every possible time. A teacher will see their first period class in every time slot possible, not just first thing every morning. As I saw three teachers and an administrator studying the large color coded chart in the office trying to figure out what schedule they were on, I asked why they didn't just do a two day schedule flipping the morning and afternoon classes. I was informed that under that system you wouldn't actually see the students at all times, just two. duPont Manual does not operate on a flex schedule, but they do provide a block schedule to allow for longer lab periods. Plano ISD is the only school that does not offer any type of extended lab period.

Plano ISD does integrate time into their curriculum for science fair along with Oregon Episcopal School, Kalamazoo Area Math and Science Center, and duPont Manual. Fairview does as well, but only in the Science Research Seminar class. If time is given in a core class it is usually related to topic generation, research design, or practicing presentations. Teachers and administrators at Fairview, Kalamazoo Area Math and Science Center and Oregon Episcopal School said the science curriculum was lab-based to lay a foundation for students doing science research. Dr. Petach at Fairview summed up the school's philosophy when she said "one of the things that's really important to me is to make sure that students have really high class experiences, which they're not just in a class where teachers are talking all the time." Benno Lyon at Oregon Episcopal School said many teachers try the flipped classroom approach to allow more time for labs. Administrators Dr. Tarnoff, Kalamazoo Area Math and Science Center

and Jordan Elliott, Oregon Episcopal School, both mentioned inquiry-based teaching as being an important component of all the courses in their schools.

Table 7: How science research is included the curriculum and graded in each school

	duPont Manual	Fairview	Kalamazoo Area Math and Science Center	Oregon Episcopal School	Plano ISD
Science Research Project Required in Core Curriculum	Yes 9 <sup>th</sup> -11 <sup>th</sup>	No	Yes 9 <sup>th</sup> -11 <sup>th</sup>	Yes 6 <sup>th</sup> -11 <sup>th</sup>	Yes 7 <sup>th</sup> -10 <sup>th</sup> grade honors classes
Grade given for Science Research Project	Yes, 20%	Only in SRS	Yes	Yes, 25%	Yes, varies
Research Class Offered as Elective	No	Yes	Yes	No	Yes
Science Fair Required	No	Yes, for students in research class	Yes, for students in research class	Yes	Yes 7 <sup>th</sup> & 8 <sup>th</sup> and research class students

**Science Competition.** As mentioned previously, all schools but Fairview require a science research project from students at some point in a core science course. duPont Manual, Kalamazoo Area Math and Science School and Oregon Episcopal School require students to do a project for multiple years, no matter what level of science they are taking. Students at Plano ISD that are enrolled in honors classes must do a project for multiple years as well. While all schools require a research project, not all schools require students to enter their project into the science fair. Schools have different ways of determining which students should compete.

All students in the Math Science and Technology magnet at duPont Manual are required to do a science research project, not all students are required to participate in a science research competition. All students must give a ten minute research presentation to their class, but most students are given the choice of participating in the science fair or other science competition like

Kentucky Junior Science and Humanities Symposium. Some teachers offer extra credit for participation in a competition and it is a strongly recommended for students in the Independent Science Research class. Some students may be encouraged not to enter a competition if the teacher feels the project is not high quality, says Zwanzig “We don’t want kids to embarrass themselves so we won’t send those (with weak projects)”. However, if a student wishes to compete in the school fair they are allowed (G. Zwanzig, personal communication, January 26, 2015).

Students enrolled in the research science class at Fairview and Kalamazoo Area Math and Science Center are required to enter the science fair and also encouraged to enter other types of science competitions. There are a few students at Fairview not in the research class, four this year, who did an independent research project and competed in the science fair. At Kalamazoo Area Math and Science Center students not on the research team present their research projects at the project day which is held in the middle of May. Awards are given for best project in various subjects, but this is not affiliated in anyway with ISEF. As a matter of fact students I spoke with were not really aware of such a competition until they were already enrolled in the research team. “When I first started working last year I didn’t know there was any type of competition so I just went in purely to get experience. And then I guess the competitions and the awards were just icing on the cake” (KAMSC senior, personal communication, January 27, 2015).

At Oregon Episcopal School all students in the 6<sup>th</sup> -11<sup>th</sup> grades must do a science research project, but 6<sup>th</sup> graders participate in their own science showcase as opposed to competing in the science fair. This allows students to practice communicating their findings to others but takes the pressure of competition away from the novice researchers. Taking the 6<sup>th</sup> graders out of the competition also allows for experimentation to start later in the year, when students have more fundamental knowledge of science process skills and also when they do not have to compete

with the 7<sup>th</sup> and 8<sup>th</sup> graders for resources such as equipment and space. Benno Lyon, 6<sup>th</sup> grade teacher, advocated for changing the process for 6<sup>th</sup> graders several years ago:

A lot of kids were just lost in the process; it was just too soon for them. I had a lot of support in the school when I started bringing it up, like pedagogically does this make sense? Like swimming lessons, you don't just throw the kids in the pool and say swim you give them some waders and let them figure it out.

(B. Lyon, personal communication, January 6, 2015)

An additional advantage of the change has been 6<sup>th</sup> graders get to see the completed projects of their slightly older peers and so are provided with good and bad examples to draw from before completing and presenting their own projects.

Plano ISD has administrative guidelines on who should do a science project and also who should enter the science fair. According to students and teachers I talked to there is not consistency across the schools. Students in honors science classes in the 7<sup>th</sup> through 10<sup>th</sup> grades are supposed to do a science research project but some schools interpret that as allowing a research paper. There is also some inconsistency at the high school and senior high school level on how students are given grades for the research projects. For example when talking to two sophomores from different schools one said she was being given extra credit for doing the science fair and the other said it was a part of her grade. This student went on to say her teacher told her if she didn't place out of the school science fair she would have been given an automatic 75%.

There is also some inconsistency at the middle school level on requiring a science project or allowing for an alternative type of assessment. One teacher I spoke with said she allowed her students in 8<sup>th</sup> grade the option of doing a science project or they could do a research paper, build a webpage, create a video or create a fictional story around a research related topic. A senior high school teacher said he is seeing more teachers at that level offer the projects as an optional

assignment with fewer of the students taking up the offer.

Another difference at Plano is each school is responsible for conducting their own science fair and grading of projects. Some schools have a LASER club sponsor responsible for this or a science fair coordinator, and some schools rely on parent volunteers. Different schools have different methods of grading projects and conducting fairs. Teachers I talked to at one school said they do not divide students into categories at the school; they just select the top projects across the board. Another school divides the students into categories and awards prizes based on judge's scores. In another school the teachers select the top projects from their classes to compete at the school fair so there is less work for the judges.

In Plano the amount of projects each school is allowed to send forward to the regional fair is 2% of the campus enrollment. This means the smaller percent of the school's population that is competing in the fair, the more students that can move onto district; hence the seeming ambiguity from some schools on how they select projects to move forward. If a school has 400 projects out of 400 students, 2% would be significantly less than top winners in every category, but significantly more than only grand prize winners.

One aspect of the science competition that was not considered initially by the researcher is at what level a school enters the competition. There are four levels of competition generally associated with science fairs: school, regional, state, and international. Students who win at their school fair are the representatives at the regional fair. Students who do well at regionals, usually those who win 1<sup>st</sup>, 2<sup>nd</sup> or 3<sup>rd</sup> place overall, are eligible to go straight to the international level. Projects that place 1<sup>st</sup> or 2<sup>nd</sup> in their categories, usually, are eligible for state. Projects that do well at state are then eligible for the international level. The amount of projects eligible for Intel ISEF may fluctuate slightly from year to year at each level of competition depending on guidelines from ISEF, number of other fairs taking place, and budgets of regional and district fairs. For example the Cordon Pharma Regional fair that Fairview participates in was able to increase the

number of students they sent to the Colorado state science fair this year because another regional fair was consolidated into theirs. Table 8 shows participating levels of competition for the research study schools and if the schools host their own fair.

Table 8: Levels of science fair competition at research study schools

	DuPont Manual	Fairview	KAMSC	OES	Plano ISD
School Fair	No	No	No	No	Yes
District Fair	No	No	No	No	Yes
Regional Fair	Yes	Yes	Yes	Yes	Yes
Only school involved in regional fair	Yes	No	No*	Yes	No

\* According to Dr. Goudie other schools are invited but often do not come or will send limited projects.

It is significant to notice four of the five schools first enter science fair competition at the district level. This means that all of the schools projects are immediately eligible to move on to the international level. In Plano ISD, the students must first win at the school level to make it to regionals, an additional hoop for the project to jump through if you will.

It is also important to notice from Table 11 that essentially three of the five schools are the only schools represented at the regional fair in which they participate. This means that for duPont Manual, KAMSC and OES they are assured some student projects will move onto the international level of competition every year. Not to take anything away from the caliber of these projects, but since competition from other schools has been eliminated it does seem as if they have an unfair advantage. For example if you compare KAMSC and Fairview, which have about the same number of student projects, you realize the odds of a Fairview student placing at Intel ISEF are much less than those of a KAMSC student. For a Fairview student to make it they have to place high either at regionals or at state, both of these competitions have hundreds of students. A KAMSC student only has to compete with 25 other projects at their regional fair, all from their same school. Dr. Goudie does not even take the students to the state level because he doesn't

want to take them out of school, he does have the students participate in the Junior Science and Humanities Symposia (JSHS).

Students' participating in other science research competitions is another factor related to program set-up that many of the schools shared. All of the schools mentioned participating in JSHS, some other competitions mentioned were Siemen's, Westinghouse and ISWEEP. As one Plano parent put it, "they have worked so hard on the project, why not show it off as many places as possible" (personal communication, February 11, 2015). duPont Manual and Plano ISD also have Science Olympiad teams and OES, KAMSC and duPont Manual have robotics teams. While these clubs are not directly related to science research they may be representative of a high interest in STEM fields at the school.

**Science Curriculum.** The science fair was the focus of this research but I was told more than once to use the term science research instead. Many educators I spoke with echoed duPont Manual science research teacher Bob Barr's sentiments below.

One of the things I try to do, is when you hear me talk about science fair you rarely hear me talk about science fair. I talk about it as research. Because it's a lot easier to get people interested in doing research if you don't couch it as science fair, science fair comes with this connotation of backboards that you put in your closet when you're done and never look at them again and it's negative.

(B. Barr, January 25, 2015)

All five schools do in fact spend class time focused on science process skills and experimental design even in classes where students will not enter into the science fair competition.

duPont Manual, Oregon Episcopal School and Plano have a similar scaffolding approach for embedding science research into the curriculum. At duPont Manual students spend a majority of the fall semester of their ninth grade science course becoming exposed to basic research techniques and how to write a research paper and also begin to discuss project ideas. The setup

of the class is discussed in the quote by Skip Zwanzig below who created the course and has taught it multiple times.

I spent the first two months just doing little labs where they had to analyze data, analyze experiments; determine what makes a good hypothesis. How do you do a controlled experiment versus a non-controlled experiment? I would give them some basic statistics; chi square, t-tests...during that time they come in with project ideas and we sit down and talk about it, sometimes I sit with a kid for an hour going through magazines to get ideas.

(G. Zwanzig, personal communication, January 26, 2015)

Teachers at Oregon Episcopal School and Plano take a similar approach but start in the 6<sup>th</sup> and 7<sup>th</sup> grades respectively. Approximately  $\frac{1}{4}$  and  $\frac{1}{5}$  of class time is spent respectively at each school on science research related topics. Plano utilizes the district wide handbook to teach elements of research and Oregon Episcopal School tries to embed it more in the labs students are doing related to the content. Admittedly at all three schools time is taken away from content to focus on research skills and processes. At the younger grades teachers say this is not as much of a problem because there is more flexibility in state curriculum. For example ninth grade science in Kentucky and 7<sup>th</sup> and 8<sup>th</sup> grade science in both Oregon and Texas is integrated science. This allows the introduction of different types of labs and research processes according to the teachers I spoke with.

Oregon Episcopal School does face some challenges as the students get into the upper grades and time for research limits time for content. Teachers and administrators point out the emphasis of the Oregon Episcopal School curriculum is on science research and not science content and feel this approach is beneficial to students. Oregon Episcopal School has tried to mitigate some of disadvantages related to their approach by offering science elective classes in focused areas that may not be given as much time in a content course. For example, Physics is offered in the 9<sup>th</sup> grade at OES and is Algebra based; a Calculus based advanced mechanics class

is now offered for seniors in response to student concern about taking Physics in college. Rob Orr says teachers are constantly asking for alumni feedback and the students response is usually positive, “they say I was two chapters behind everybody else but I was the first person selected for laboratory research assistant, that’s not bad, two chapters they can do in a summer”. The benefits to students are the experience with research can help interested science majors on college applications as well as providing research opportunities at the undergraduate level. Working on an independent research project can foster skills that will help all students not just those pursuing science careers. Jordan Elliott, who is not only head of the Upper School but also an OES alumnus, felt the experience influenced other academic areas.

I was actually talking to a friend yesterday and he was an English major and I was a religion major in college and the skills that we learned in science research were directly applicable to doing work in a different field. Just how do you find your sources, how do you have a project, how do you manage your timeline....I believe that learning science is best done through an inquiry approach and there’s a huge benefit to a students’ academic skills from doing that project.

(J. Elliott, personal communication, January 6, 2015)

Even with student support and award winning science projects, there is still some concern from parents that OES does not offer advanced placement courses for science but the school administration has no plans to alter the curriculum to accommodate those programs.

Kalamazoo Area Math and Science Center has an embedded actual research class in the core science classes, but due to the extended block scheduling of the school there is still ample time for content. To make this unique class within a class approach work, the research director and the teachers have to work closely together to ensure this “well-oiled machine” as director Dr. Tarnoff calls it, stays running so smoothly with the goal being to give students a ‘research experience (that) can help students develop a meaningful understanding of science concepts and

phenomenon and apply them to real world problems’ (from Research Science: Introduction and Objectives, appendix D). Students and teachers feel that the embedded research element is instrumental to the school’s success at science fair. “....it really introduces the idea of research so it’s not as foreign as it might be to a lot of people. And so when you see research team you’re not as worried about it and you actually think you might aspire to do it” (KAMSC student, personal communication, January 28, 2015). Director Dr. Tarnoff is proud of his school for giving students the opportunity to see what it actually means to participate in science and students feel the same way, “right from the beginning we do really intensive research that we would not get at our home schools and that definitely helps...” (KAMSC senior, personal communication, January 28, 2015).

Fairview again is the only school that does not require an independent research project from students in core science classes. However, the school and district seem to place great emphasis on science and work to ensure a strong foundation so that students who wish to enroll in the research elective are ready. Students in the BVSD are exposed to science early with FOSS instructional specialists beginning in kindergarten. The science department at Fairview was deliberately built from the bottom up with the best teachers being put in the lowest classes to try to change student attitudes about science according to assistant principal and former science teacher Sarah DiGiacomo.

We get the best teachers and put them with the kids who hate science and they’re not good at science and they can’t do science and we really develop those classes. Nobody fears science at this school, nobody says ‘I can’t do science’”.

(S. DiGiacomo, personal communication, February 10, 2015).

Generally time is not given for research in the school day unless a student is in an elective research class. All schools said it would be too hard to do research at school due to diversity of projects and space in the classroom. Table 7 shows the comparison of schools and

science fair/research in their curriculum.

duPont Manual, Fairview, Kalamazoo Area Math and Science Center, and Plano ISD all have an elective research class. The nature of the class was established with the idea that students apply for the course and are then given release time from school, during the scheduled period for the research class, where they are allowed to leave campus and work in a research institution with a mentor. The application process seems loose at each school with all teachers saying the point is generally to determine interest level of the students. Students are allowed to take the course for more than one year at all four schools.

Students at Kalamazoo Area Math and Science Center are required to work with mentors and this is carefully facilitated by Dr. Goudie. Dr. Goudie takes the idea of mentors very seriously and strongly disagrees with placing students in research labs before their junior year believing a certain level of maturity should be present. He does this just as much for the student as the professor, wanting it to be a positive experience for both. The partnership with the Upjohn company, now Pfizer, helped to build the program. "The Upjohn company gave me a badge, so I always went to try to talk to scientists to see if there was a lab I could use with students and I pilfered equipment" (J. Goudie, personal communication, January 28, 2015). From the initial days of taking leftovers Dr. Goudie has created a mentoring partnership with Pfizer along with Western Michigan University, Kellogg Biological station and a new animal genetics company Zooetis just to name a few.

Students are not expected or even encouraged to find their own mentor. When the student initially meets with Dr. Goudie to discuss their research ideas he begins the search for the right mentor. Once the student begins the program in the fall Dr. Goudie will go with the student to tour the research facility and to meet with the prospective mentor. Dr. Goudie has also created a ten page brochure he gives to prospective mentors which describes the course, and the expectations for the student and mentor. Dr. Goudie also meets with students and mentors

throughout the course of the year to ensure the partnership is progressing and to assist in troubleshooting. The weekend prior to my visit he had spent two hours in a coffee shop with two young ladies and their mentor trying to help them work through a technology problem.

Students at Fairview must have a mentor to help support them through the project but they do not have to work in a research lab. Dr. Strode helps facilitate these partnerships but as the number of students in the class has grown he increasingly relies on the students to help find their own mentors. One young lady worked on her project related to photovoltaic cells in her garage, but had a local university professor as a mentor who helped her obtain certain materials and offered guidance.

Students at duPont Manual and Plano are helped by the teacher if they are unable to locate a mentor. According to teachers at both schools this usually is necessary about fifty percent of the time. Teachers are encouraged to check with mentors during the course of the year to ensure the relationship is working smoothly but Bob Barr at duPont Manual says this can be challenging for him with over forty students in the research class. Students at these two schools do spend some class time practicing their presentations in front of class members but no additional assignments are required. Kalamazoo Area Math and Science Center students do not have additional course requirements to be on the science research team but they have all taken the embedded research course taught by Dr. Goudie in their other science courses. This is discussed further in the curriculum section.

Release time to work with on research is not the only goal of the Science Research Course at Fairview. In the last ten years, or those encompassing this study, the SRS class has had three different teachers. Each teacher has had a slightly different approach to the program with Dr. Strode taking the most rigorous approach to the course according to Dr. Helen Petach the SRS teacher before Dr. Strode. “Paul I think has the most rigorous approach to doing SRS, he feels strongly about statistical analysis, proper hypothesis generation, a formal layout of the

scientific process” (H. Petach, personal communication, February 10, 2015). For example, students have always been expected to write a paper, but Dr. Strode’s approach is to have the students write a scientific paper as if the students would be submitting it as a manuscript for a journal. To prepare them for this and for having a greater understanding of science research in general, he has students spend a great deal of time in class reading and discussing scientific research articles as well as working on statistical analysis. Students also write a Research Proposal that is due before they can begin any research. The Research Proposal is similar to what a student might write for a Master’s Thesis proposal, complete with a literature review in the introduction.

Dr. Strode says he wants the course to be about scientific thinking not just about doing one project. As one student said on a survey response “Dr. Strode would teach us how to correctly read and analyze scientific articles as well as allow us to practice presenting and talking about science” another student said “The Science Research Seminar teacher is an excellent resource in regards to learning how to be scientifically literate.”

Along with reading a non-fiction science book over the summer, students are expected to secure a mentor. While students do not have to work with a mentor the majority of the students seem to do so, teachers will help students find mentors or act as a mentor for a student but projects are usually not done at school merely due to space. Not every student who participates in the science fair is enrolled in the SRS class, some students do not have room in their schedule for the elective so they will work with Dr. Strode or another science teacher on ensuring their project is ready for entry into the fair, other students will take the class for multiple years which is fine with Dr. Strode “I like having students who have been in the class before, they are a great resource and motivation for the other students.” (personal communication February 11, 2015).

During the 2014-2015 school year there were six students working on research projects who were not enrolled in the class. Of those six, four had previously taken the class. There is

some disagreement at Fairview about the impact of the course on the schools success at science fair. While all high schools in BVSD have the Science Research Seminar class, Fairview is the only one out of fourteen high schools in BVSD who has a high level of success at the state and International level of Science fair competition.

Table 9: Policies on mentorships at each school

	duPont Manual	Fairview	Kalamazoo Area Math and Science Center	Oregon Episcopal School	Plano ISD
Policy on Outside Mentors	Encouraged	Required	Required for students in research class	Not encouraged	Encouraged for students in research class
Who is responsible for finding mentors	Students, some help from teachers	Students, some help from teachers	Science research director	Students	Students

As mentioned previously all of the schools allow students to work with outside mentors, either using them as an advisor or working with them in a research lab. The schools vary in the emphasis they place on this but the judges that I spoke to at Plano ISD and duPont Manual commented that they preferred to see ‘garage’ projects or those that weren’t done in a lab. They said it was challenging to discern what level of involvement a student actually had in the research question and design in some of the sophisticated research lab projects. Judges said they appreciated the projects, even if they were simpler, where the question was clearly based on an interest of the student or came out of a student’s own experience. During the presentations I was able to observe at duPont Manual the teachers all asked the students “How did you come up with this idea?” hearing the backstory that gave life to the research idea did make the projects seem more authentic.

## **Conclusion**

The five schools involved in this study were selected for their history of excellence in science fair competitions. While all of the schools had the same outcome of excellence, by having multiple science fair winners, examining the differing processes that created this outcome was the purpose of this study. Initially the schools appeared to be different in many ways. The five schools are all in diverse geographic locations, have small and large student populations, operate under varying school configurations, and have access to different financial and community resources. Despite all these difference it was revealed that the schools had many similarities.

The important roles of stakeholders, utilizing resources of the community, and embedding science fair components in the curriculum were all common elements found at the five schools. Even though each school did not have access to the same resources and the roles of stakeholders were slightly different at each school, the commonality was that the schools actively cultivated some partnering relationship with community members. While some of the components might be harder to re-create, like convincing NOAA to move to town, many of the identified elements contributing to success could be emulated in other schools.

## **Chapter V**

### **Discussion and Recommendations**

The science fair began as a way for the public to be educated and made aware of scientific achievements (Dutton, 2011). Almost one hundred years later the original science fair model still exists, but the ‘scientist’ explaining their achievements are students. While some view the fair as outdated a visit to a science fair will reveal many projects related to current issues of concern and research in science.

#### **Summary of Purpose and Method**

As the STEM movement grows across the country; schools are looking for the best way to implement initiatives that will encourage students to enter the fields of science, technology, engineering and math. In March the government announced \$240 million dollars in commitments from both the government and the private sector to prepare more students to enter STEM fields. This was announced at the White House science fair which the president started in 2010 as a key component of his Educate to Innovate campaign (White House Press Secretary, 2015). Even with renewed interest from the government the science fair is not viewed as a good thing by all. Many people still think of science fairs as outdated and the mere mention of the word can elicit groans from parents, students and teachers alike (Schank, 2015). If asked, many educators and parents would most likely agree that students doing an inquiry based project on something they are interested in would be an authentic assessment of great value, but the science fair project is not always viewed in this light. Time, resources and willing teachers, are challenges in creating a successful science fair program.

Not all schools have stepped away from the science fair. Many schools have chosen to embrace this tradition and continue to value its place in the current education landscape. The

purpose of this study was to research schools that had been identified as having excellent programs in hopes that elements of their success could be shared with others and perhaps help bring the science fair into a new light for some. Twelve schools were identified as being excellent by looking at winners from the Intel International Science and Engineering Fair over the last ten years. Five schools were included in the research and data were collected using on-line surveys and structured and semi-structured interviews with parents, teachers, students and administrators. Each school was visited during some part of the science fair process and observations were made. Data were also collected and triangulated using document analysis. The research questions were addressed by themes that emerged from analyzing the case studies of which summaries are presented in chapter 4 and full case studies can be found in the appendixes. Documentation addressing the research questions and related findings can also be found in the appendixes.

### **Discussion of findings**

The main question driving this research was, “What are the factors that promote successful science fair programs?” The primary goal of the question was to be able to create an ideal sample program or identify elements of excellence that other schools could perhaps emulate. The schools highlighted in this research study have many features in place that could contribute to their success at the science fair. The two overarching elements found to contribute to the excellence of the school’s science fair program was the climate of the school and the climate of the community. The school is in control of some of the features related to its climate, including teachers, curriculum and students, and has carefully worked on them over time. The climate of the community including resources, parents and community partnerships, are outside of the schools initial control, which makes them harder to re-create but not completely unattainable.

### **Features of schools with successful science fair programs**

The first research question to be answered is “What are the features of schools with excellent science fair programs?” The schools highlighted in this research study have many features in place that could contribute to their success at the science fair. Four unique features were found in the schools that could lead to excellent and successful programs: requirement in curriculum, elective research science class, student selection and alternate scheduling. All of these unique features combine to create the climate of a school that is enthusiastic about science research and posed to have an excellent and successful science fair program.

At more than one school, when asked why the school did so well at the science fair students, teachers, parents and administrators, replied it is because students are required to do a science fair project. It seems simple, but for students to have a chance to excel you have to first afford them the chance to participate. By requiring it and taking an element of student choice out of it, you are potentially exposing students to something they would not have willingly signed up for but might end up becoming passionate about.

As the educational community continues its use of high stakes test, it was refreshing to meet teachers and administrators who are willing to forsake critics and ‘give up’ class time for focused instruction on nature of science and science process skills. All schools that require students to participate in science research also provide supports for students to have a foundation of science process skills. While these may be phased out as the students advance in grades, curriculum has been created or targeted to give students the basic research skills and statistical tools they need.

Fairview is the only school that does not have a required research component in the core science classes, but many of the students are exposed to science fair during middle school. While Fairview does not have a research component in the core science classes the science

department's dedication to inquiry based science helps to make the transition to independent research much easier for the student. All of the other schools make some effort to embed research elements into their curriculum. Students are partially being prepared for the competition but more importantly they are being prepared for life as a potential scientist.

Talking about the competition aspect of the science fair does lead to some negative connotations and concerns that are highlighted in research (Bahar, 2009; Czerniak, 1996; Launius & Lenz, 2008; Magee & Flessner, 2011; Rillero, 2011). Many cite the pressures of competition, especially at young ages, as being harmful to students. At OES, the younger students participate in a science fair that is more similar to the Kids Inquiry Conference as proposed by Magee and Flessner (2011). Students at Plano ISD and duPont Manual are not required to enter the actual science fair competition; they are only required to do a project. While all students at Kalamazoo Area Math and Science Center do a science project, only those on the research team are allowed to enter a competition. Teachers at several schools said they wanted the process of science fair to be rewarding for students and did not want the students to let the pressure of the competition get in the way of the inquiry objective of the project. Bahar's research on learning styles could be applied here in the fact that a competitive, an independent student is more likely to be comfortable in a high pressure environment and therefore present themselves and their project better. One young lady I observed could not give her presentation to the class for practice because she was so nervous. While the project was high caliber the teacher said he would not make her enter the fair if she did not want to.

While schools may not make everyone compete there is also an element of eliminating the poor projects from ever entering the competition. It was obvious that the schools are very proud of their success and do not want to embarrass the students or waste the judges time by not having high caliber projects at the science fair. Teachers do everything they can to encourage high quality projects from the students but at three of the five schools projects determined to be

poor by the teachers never even make it to the science fair. Citing the large number of projects the schools have they say teachers are given discretion to decide which projects will be included in the school fair. Competing in the science fair may not be a required part of all the school curriculums, but an expectation for those who do compete to do well is certainly present.

Competition is not all bad as research by Bernard (2011), Dionne, et al. (2011), and Romanello (2005) shows and it was certainly a motivating factor for many students. In interviews with students at all schools except Kalamazoo Area Math and Science Center comments were spontaneously made regarding the competition and a desire to excel. This is not to suggest that there is not a competitive nature at Kalamazoo Area Math and Science Center, the trophies and awards lining the hallway would suggest otherwise, just to say the students interviewed were not particularly motivated by competition. Several students mentioned the experience of failure as being a motivating factor to work harder on the next year's project. Two of the students who won top awards at ISEF last year both had a 'failed' project their first year out. Teachers, parents and judges all agreed that what students learned from the process was more important than the outcome, supporting opinions offered by McComas (2011) encouraging teachers to show students disappointing data can be useful.

One can debate the pros and cons of requiring students to be involved in the competitive aspect of the science fair, but one pro that comes out of requiring students to conduct research is that no teacher is an island. While some teacher support groups may be larger than others, no one teacher at a school was involved in the science fair alone. By requiring the project in the curriculum or the course in a district, teachers are immediately part of a Professional Learning community where they can support and sustain one another. Considering the time and energy involved to help guide student's the science research process and paperwork components of the science fair competition, having a support group seems very important for long-term success at the science fair.

Another curriculum component that was uncovered during the research study is the idea of a dedicated research class. All but one of the schools in the study offers an elective research class for interested students. Most people familiar with the science fair have heard of students working with mentors, but not many schools allow time in the school day for students to do this. Research by Bernard showed that students became more interested in science projects when they had the opportunity to work in research facilities (2011). DeClue et al. also cited the benefits of partnering with a local college to secure mentorships. Providing time in the school day for students to do this could be more attractive to multi-tasking students with very busy schedules or to professors and community scientists who do not want to have to come in after hours or on weekends to help a student. Providing time in the school day for science research is also very helpful for teachers. This extra time can either be used to teach advanced research skills, or to cultivate mentor partnerships, or catch up on grading that piled up from spending the weekend helping students in the lab. Dedicated time for science research in the school day could be a critical component to encouraging and sustaining involvement for both teachers and students.

Another unique component that all of the schools in the study share is the students they have involved in the science fair process. All of the students have self-selected to be involved in a school or a class where participating in science research is a requirement. Students at duPont Manual and Kalamazoo Area Math and Science Center all applied to these schools specifically because of their reputation as being excellent math and science schools. Students at Oregon Episcopal School applied and paid a sizeable tuition to attend this prestigious school with a growing reputation for being an excellent STEAM school (J. Elliott, personal communication, January 9, 2015). Students at Fairview signed up for the elective science research class and some attend Fairview even though it is not their home school because of its excellent academic reputation (S. DiGiacomo, personal communication, February 10, 2015). Students at Plano ISD who participate in science fair are those who have signed up for honors science classes or

elective research classes or those who chose to participate in after school clubs. While it may be hard to determine the level of motivation that participating in a science research project has on these students' decisions to sign up for these classes or schools, it cannot be overlooked that the students involved in science fair at these schools are self-motivated and most likely have some interest in science..

A final unique component that was present at three of the five schools is alternate scheduling. All of the schools except Plano ISD and duPont Manual routinely alternate their schedule with an emphasis on extended class time in most cases. duPont Manual operates on a modified A/B block schedule allowing every class to meet at least twice a week for ninety minutes allowing time for labs. Oregon Episcopal School does not alternate the length of the fifty minute class period but it does alternate the time, so that every class period has the opportunity to be the first or last class period of the day to allow for extended lab time. Fairview operates on a schedule that allows for each class period to meet for an extended time once a week, again allowing for extended time for labs. Regular classes are fifty five minutes and the extended period is eighty five. Kalamazoo Area Math and Science Center has the most unique schedule, changing not only weekly but also monthly to allow for each class to meet for an extended time of two hours each week and then also for half a day once a month. This allows time for extended labs and field trips to research labs and libraries.

Plano ISD and duPont Manual do not have any alternate schedules that may be beneficial in regards to the science fair. However, both of these schools do allow time in the school day to work on science fair related items and also have after school assistance provided to help students with projects. duPont Manual also operates on a modified block schedule which allows classes to meet for ninety minutes twice a week. This provides time for extended labs on a weekly basis.

The climate of a school is a critical element to the success of the school in regards to the science fair competition. The unique features of these schools all work together to help create

their climates of success. Motivated students, focused curriculum and flexibility of staff and scheduling help to embed the science fair into the culture of a school.

### **Stakeholders in the Science Fair**

The second research question this study sought to answer was “Who are the stakeholders in the science fair programs and how do they contribute to the success of the program?”. The climate of the school has an impact on stakeholders but so does the climate of the community. The original stakeholders identified were students, parents, teachers and administrators. During the course of the research community members arose as another important group that helps contribute to the success of a science research and science fair program. Motivated teachers and students are important features for promoting success at science fair but involved parents, supportive school districts and community partnerships can also play a role.

As stated previously all of the schools in the research study have students who have self-selected to be involved in the science fair program at some level. Two of the schools, duPont Manual and Kalamazoo Area Math and Science Center, are specifically advertised as being math and science schools and while Oregon Episcopal School does not specifically market itself that way, as middle school head Scott Herdister put it “STEM is just what we do here” (personal communication, January 6, 2015). The students participating in the science fair at all the schools are bright and motivated; which cannot be ignored when looking at factors of success. This supports research by Dionne et al. (2012) and Jarowski (2013) related to motivation levels of student’s participating in science fair. It can be assumed if students are signing up for a math and science school they have an interest in STEM related subjects and would therefore be excited about doing a science research project.

The students found at the research schools could also support the criticism of the science fair that the process favors elite students (Bencze & Bowen, 2009; Czerniak, 1996; Magee & Flessner, 2011; Sayer & Shore, 2011; Taylor, 2011). While only one of the schools in the research study was a private school, the application process involved in attending two of the other schools does show a level of parent involvement which implies the students possess social capital. Teachers and administrators also mentioned at every school that the connections and resources of the parents could be beneficial to some students.

It is great to have motivated students, but if you do not also have dedicated teachers willing to put time and energy into the science fair, then the chances of success at the science fair are minimal. Teachers are critical to help create a climate of importance and value around the science fair in general. Dedicated teachers started all of the studied programs and continue to help the programs thrive. Some being so dedicated they won't walk away until they know the program is being left in good hands (i.e. Zwanzig and Goudie). A teacher's attitude towards the science fair seems to influence a student's attitude as voiced by some students in the research study. Many students commented on the importance of support from teachers in both the surveys and interviews. A sample response from one Fairview student "All credit goes to Dr. Strode, our research seminar teacher. He is a practicing biologist and a fantastic teacher who doesn't cut us any slack and pushes us to achieve more than we thought we could." It is important that the teacher sees value in the process of independent research and is thereby encouraging to the student in order for the student to have a desire to facilitate the process for themselves.

The teachers are also important in creating a climate of importance and value around the science fair in general. Interestingly enough, even at schools with a history of success, like duPont Manual and Plano ISD it can still be challenging to get all teachers to buy in and be willing to make the level of commitment sometimes required to maintain a program. Skip Zwanzig says at duPont getting teacher buy-in has been a battle for years "a lot of teachers don't

want to do it because of the research. They would tell the kids they had to do it, but they would never spend any time helping them.” This supports informal research done through surveys by Vidya Rachivandra, a parent at duPont Manual. As president of a software company Rachivandra has developed software to help teachers organize information and paperwork related to the science fair. To promote the product she visited several teacher conventions including national and regional National Science Teachers Association conferences. Coming from a school that is so focused on science fair she said she was surprised to see the lack of participation from teachers nationwide, saying many seem excited about it but cited lack of resources and time as the reason for their lack of participation (V. Rachivandra, personal communication, January 25, 2015).

Small stipends are offered to some teachers in Plano ISD and duPont Manual, but according to Glenn Zwanzig once he divides the \$300 stipend he receives into the hours he works after school and weekends, they pay is he thinks is about a nickel an hour (personal communication, January 25, 2015). When discussing this versus the minimum four digit stipends teachers who help coach athletic activities get paid, the duPont Manual booster club gets incredibly angry. Instead of trying to compensate teachers for extra time after school, schools like Oregon Episcopal School and Kalamazoo Area Math and Science Center try to help mitigate teacher burn out by hiring support staff to help the teachers and giving teachers release time to help students. Not all schools may have the financial ability to do this, but volunteer groups, like the duPont Manual parent booster club, could be formed to help.

Parents are involved in many ways in the science fair process. The level of involvement varies from high level involvement like serving as a mentor to low level involvement of being willing to donate money to buy a poster board. The commonality is they are aware enough of the process and value education in general enough to pay attention to the needs of students and schools. At duPont the parents stepped in to help supplement the lack of support from the school

district by forming the aforementioned booster club which runs the school science fair. At Oregon Episcopal School, Fairview and Kalamazoo Area Math and Science Center the parents have confidence enough in the other supports in place to not interfere with the school program. Oregon Episcopal School administrator Scott Herdister says they encourage parents who want to help find other ways of supporting similar programs at the school like sponsoring Lego Robotics or Math Counts. As far as the science fair goes he says “we work hard communicating you got to let your kids do it and if they fail its low risk failure.” Fairview assistant principal Sarah DiGiacomo says the parents at Fairview are very supportive but hands-off in regards to helping their students with projects “they (parents) care a lot and have a lot of trust in the educational system”. Both of these types of relationships were created over time and suit the needs and desires of the school. Most importantly all of the parents have taken an interest in their students by enrolling them in these schools and placing them in an environment that cares about science research.

Administrators are also stakeholders in the science fair and garnering their support can be very important to having a successful science fair program. Administrators provide financial resources like hiring support staff or paying to send students and teachers to competitions. They also provide support in more subtle ways like allowing teachers to be involved in the hiring process to ensure that new science teachers are excited about working with students in the science fair process. Skip Zwanzig is not provided many financial supports from his administrator due to limited funds in the school, but he does have final say in who is hired to work in the Math, Science and Technology Magnet even being allowed to recruit a specific science teacher from another school. Allowing students to leave campus during the independent research classes at duPont Manual, Fairview, Kalamazoo Area Math and Science Center and Plano ISD may seem like a small thing, but from my experience in public schools this could not happen without administrative support.

All of the schools in the study have cultivated community partnerships with research institutions or business organizations. Some of these are heavily involved in providing mentors, such as the University of Louisville or the University of Colorado, and others provide primary support in the form of judges. Having access to research labs allows students to work on highly advanced research projects which help them to compete at the international level. While there is talk about the value of creativity and student directed projects, looking at the list of winning project titles at ISEF, the majority are very complex leading you to believe they had to be carried out in a research lab setting. Several students also commented on how working in a lab setting initially helped them understand research design and they were then able to take what they learned and do an independent project at home. The value of exposing students to authentic science research cannot be overlooked when identifying elements related to excellence.

All of the schools rely on community partnerships to provide qualified judges who are an important but perhaps overlooked essential element. Judges provide key feedback which can help encourage or discourage students and can help shape future projects (Rillero & Zambo, 2011). Judges sometimes make very subjective decisions on quality projects if they are not educated in the area, merely by the presentation of the display. Having enough judges to spend quality time visiting with students and hear the students talk about their projects is an invaluable part of the research process. Many parents volunteer their time to serve as judges, but the benefits of getting other members of the community involved can help foster a relationship between the schools and businesses that can spill into other areas in a community (T. Smith, personal communication, January 25, 2015).

The climate of the community supporting the school science fair is very important and can be directly related to level of support of the stakeholders. The level of involvement of community members may be different but without some supportive body outside of the school it is challenging to support a program of excellence and cultivate success in the science fair. These

relationships have to be cultivated over time and there must be willing participants on both ends who are passionate enough about science research to reach out of their comfort zone into a perhaps unfamiliar world.

### **Structure of School**

The final research question to be answered is “What impact does the structure of the school have on science fair programs?” The schools in the study included a private school, two public schools and two charter schools so the seemingly lack of consistency among schools would initially lead someone to think the structure of a school does not have an impact on science fair programs. But when answering this question it is important to think of structure as encompassing the type of school, the students attending the school and the scheduling allowed. These elements were shown to have some impact and while they have already been slightly addressed with other research questions but will be re-summarized here.

The structure of the school does seem to have an impact on the success of the school at the science fair with three of the five schools having controlled enrollment. duPont Manual and Kalamazoo Area Math and Science Center are both highly competitive application based charter schools pulling students from the entire county. At both schools less than half of interested students are generally accepted. One student feels they are even the best students in the state commenting in their survey “duPont Manual High School is filled with the best students in Kentucky”. Oregon Episcopal School is a prestigious private school with a growing reputation as a STEM school. By controlling enrollment these schools are ensuring a population of high achieving students which could translate well into motivated students doing science fair projects.

Another element of private and charter schools that could be a factor is the ability to be more flexible with student expectations, scheduling and curriculum. duPont Manual and Kalamazoo Area Math and Science Center were specifically created to help students interested in

science and science research. Students seek out and enter the school fully aware of the high expectations they will face. Oregon Episcopal School is able to spend time in their core curriculum on science research for all students due to the priority placed on it by the administrators and again parents and students enroll in the school fully aware of the expectations.

The two public schools in the study, Fairview and Plano ISD, both also allow time in some of the curriculum for science research and science fair but they also face some challenges. The greatest challenge they face is consistency and this can be attributed to the size of the districts. Plano ISD has nine schools serving 9-12 grade students and Fairview is one of fourteen high schools in the Boulder Valley School District. While both of these districts have allotted resources for science research it is challenging to ensure that there is consistency among the schools in how these resources are being utilized. Every honors science teacher in Plano ISD is given the Science Fair Handbook, but the time allotted in class to focus on science research processes at each school varies along with the types of projects accepted by the teachers as well as how credit is given. While Fairview High School has consistently had a strong showing at the regional science fair from students in their science research seminar class, the other schools in the district that offer the same class seldom have students that even place. Dr. Strode has shared his syllabus with other teachers across the district but has received little feedback. When he asked if any of the teachers would like to meet to talk about their classes when I came for my research visit, none responded.

The type of school does seem to have some impact on success at the science fair. A school that selects its students may have an advantage over a larger school with open enrollment. However, as two large public schools included in the study show while there may be challenges with these types of schools they can still have successful science fair programs.

### **Sample Science Fair Program Modeled after Excellent Science Fair Schools**

Some schools may look at the information presented here and not see any similarities between themselves and the identified schools causing them to discount the elements of success as being applicable to their own circumstances. However, I would argue that any school could emulate the identified characteristics with a little imagination and initiative.

If I were to create a successful program I would start with an embedded inquiry science curriculum for all ages and begin the science fair process with an independent research project in the 8<sup>th</sup> grade. I would combine the Plano ISD, Oregon Episcopal School and Kalamazoo Area Math and Science Center approaches and have students in this younger grade be given time in class and with the teacher to develop a good research question and understand the design process. Guided and open inquiry labs would also be a part of the regular curriculum to help students get comfortable with developing and researching scientific questions. The projects allowed at this age would be more diverse trying to excite a variety of students (Launius & Lenz, 2008); acceptable projects would be scientific collections, investigations, inventions or literature research on a scientific topic. In the 8<sup>th</sup> grade there would be no judging component or requirement for entry into the science fair, answering the concern that starting this early can instill anxiety in students (Bahar, 2009; Czerniak, 1996; Launius & Lenz, 2008). There would be an exposition type component where students would present their project at a Science Open House. This would give students initial experience in condensing information into an understandable way and also in talking to others about science.

In the 9<sup>th</sup> grade students would be required to do an actual science research project and would also be expected to participate in a school science night where they had to explain their research to parents, students and teachers, emulating what real scientists do at conferences (Magee and Flessner, 2011). At this grade level students would be allowed to decide if they wanted to be judged in the actual school fair. Mentors would not be allowed at this point, but lab

time would be available after school and on the weekends for students to conduct research. This would help ensure the students were doing their own projects (Sayer & Shore, 2001) and also allow the teacher to see how the students were progressing. This would be the similar to what was expected of students in the 10<sup>th</sup> grade but while all students would be required to do a project, only students in honors science classes would have to compete in the science fair. For students in the 11<sup>th</sup>-12<sup>th</sup> grades the school would offer an elective research class and would allow students to work with outside mentors. This would allow those students who have a passion for science research to pursue it at an advanced level. Burn out would potentially be avoided, by students and teachers, if only those students who have a desire to do so are conducting research at this advanced level.

Table 10: Sample Science Research Program Overview

	8 <sup>th</sup> Grade	9 <sup>th</sup> Grade	10 <sup>th</sup> Grade	11 <sup>th</sup> Grade	12 <sup>th</sup> Grade
Students Participating	All	All	All	Students enrolled in elective research class	Students enrolled in elective research class
Type of Project	Varies	Research	Research	Research	Research
Competition Expectation	No	Optional	Yes for students in honors class	Yes	Yes

Creating an exemplary curriculum cannot happen on paper alone. Climate of the school and community were identified elements of success at all of the studied schools. One important element of this is exposing people to the current face of the science fair to replace their negative images of parent made volcanoes and similar projects (Shank, 2015).

To help create a climate of the school conducive to science fair it would be important to show science research is valued. Offering teachers involved in the fair a stipend or providing support materials would be very helpful. Involving teachers across disciplines could also foster a supportive climate. Following the example of Kalamazoo Area Math and Science Center and

having students from advanced statistics classes teach the student beginning research is very collaborative and beneficial for all teachers and students. Displaying science fair projects prominently is another way to foster good feelings and perhaps plant the seed for future scientists. A young man from Fairview who placed at ISEF as a sophomore was inspired to sign up for the research class after seeing a poster in the Fairview library while on his initial orientation visit to the school. Inviting students from the middle school to view the projects at the high school would also be a simple way to plant the seed of research in a future scientist. To help teachers of younger grades be supportive of the science fair you could also have senior high students or those involved in the elective science research class present mini science lessons in elementary classes. This could help the students practice presenting information in front of an audience and perhaps also help provide the younger students with peer mentors.

Building a climate outside of the school that supports the science fair is another crucial factor to success. While most of the schools in this study had local resources for students to utilize as research institutions there are alternatives for schools that may not have this access. Mentors can be accessed through Skype and students can also sign up for summer research institutes offered by several state universities. In Arkansas alone the University of Arkansas at Little Rock offers opportunities for high school students to work in research labs over the summer and the University of Arkansas in Fayetteville offers a variety of engineering research camps for students. Connecting with retired scientists in a community can also provide mentoring relationships with students.

Research institutions do not have to be the only businesses that can be looked to for support. Any local business could provide sponsorship for students to attend competitions, purchase research materials or pay for poster printing. Allowing student's access to employees for data collection could be another way a business could support a student's science fair project. Contacting local media outlets to show what research students are doing can help generate

interest in the science fair in the community and help get rid of the volcano images of old.

A final component of an ideal science fair program would be to have teachers that are familiar with the research process. Every teacher who helped to start the science fair program at these identified schools of excellence had experience with research; either as a graduate student researcher, in an education science methods course, or as a high school student participating in the science fair. It may not be possible for every school to find a Ph.D. Chemist who wants to be a teacher but it is possible to add an independent research project to a science methods class for pre-service teachers. Teachers who have had experience doing science research are more likely to feel comfortable helping students do research (McComas, Clough, & Almazroa, 2002).

Another way to get hesitant teachers on board would be to have new teachers attend the state or international science fair as a co-chaperone with the students. I know for me personally it was this experience that helped cement for me the impact participating in a science fair can have on students.

### **Limitations of the Study**

There were certain limitations within this study. The study was limited because only five of the twelve identified schools were included in the research. Several of the schools with a longer history of participation in the science fair chose not to participate in the study and their information could have contributed to the richness of the research. All of the schools in the study were also self-selecting in some way. The results could have been seen as more generalizable by some if along with the two public schools who did participate one of the three traditional enrollment public schools identified as being excellent would have agreed to participate.

All schools were involved in different parts of the science fair process during the visit. This perhaps limited direct comparisons being made at the schools because the same process was not really seen at multiple schools. Kalamazoo Area Math and Science Center and Oregon

Episcopal School were both in the research stages, duPont Manual was in the presentation phase, Plano ISD was observed during the actual fair and Fairview had just competed in the regional fair and was preparing for the state fair. Not only was the same observational data not obtained from each school, but the surveys and interviews conducted at each school varied. Only two of the schools utilized the survey with a large number of students and only three of the schools gave the researcher access to parents. While the goal of the research was not to ascertain attitudes related to the science fair, since climate of the school became an identified essential element it could have helped triangulate the data at the other schools if additional data could have been obtained from these groups.

### **Areas for further Study**

One very interesting finding was the level at which the schools entered the science fair. Some schools were able to have their own fair and others had to compete with other schools. It would be interesting to look at the list of twelve identified schools and see at what level the other seven schools enter the competition at and what percent of their students are eligible for awards. While the level of research is still high at all schools, this entry point into the competition could be worthy of further study if interested in what projects make it to ISEF.

Another area of interest to the research is the elective science research study course. Examining how many other schools that do well at science fair offer this course, how the course is funded and how the course is taught would be interesting. It would be interesting to look at state approved courses and see how many offer a version of this elective research class. This data could also be used to see if there is any nationwide trend on regions where the course is approved.

Since the importance of mentorships was a reoccurring theme, contacting universities to see what their policies, procedures and current activities involving student researchers are would be another area of interest. Do universities want to work more closely with local schools or do legal and logistical issues get in the way?

Another area of related interest would be to see how money for STEM initiatives as designated by the White House is being allocated and if there are any grants specifically associated with science fairs or science research. All of the schools mentioned the amount of money needed to run a successful program. Grant money could be used to provide stipends for teachers, pay for research lab assistants, update school science labs or fund an elective research class. It would be interesting to see how the states that have been awarded 'educate to innovate' grants have used their funding and if it is even possible for it to be used for these resources.

Issues related to attitudes surrounding the science fair could also be used to add to the body of research. While some studies have been done, many teachers mentioned that the students did not see the benefits of the research until later. Conducting surveys of science majors or professors across campuses to determine how many participated in science fairs and what if any impact that had on their decision to pursue a career in science.

Attempting to determine the amount of exposure to science research that is beneficial for a student would also be an interesting area of study. Some students expressed frustration with having to do a project for multiple years in a row while other felt that they learned from each project. Is there a certain level of exposure that benefits a student but does not make them feel burnt out on the process?

Examining several science teacher education programs to see what if any elements of a science research project are included in the program would also be an interesting area of research. Are there colleges and universities that have this embedded in the teacher education program and if so does that translate into teachers making it a part of their classroom?

A final area of research that would be daunting but highly interesting to me would be to examine trends in participation both in numbers and regions. Is participation declining or increasing in science fairs across the country? What impact, if any, are programs like robotics competitions or Science Olympiads having on science fairs? There are still many areas of research to explore in relation to the science fair.

### **Final Thoughts**

This research has focused on exemplary practice in the realm of the science fair. The schools included in the study are examples of complex, dynamic institutions that have made a commitment to providing students authentic science research opportunities. The success of these programs is exhibited by the students excelling at the highest levels of competition. The awards and accolades that come from this success help to build pride in the school programs and thus predict future success.

The cycle of excellence had to begin at some point and all of these successful programs were started by passionate teachers who felt involving students in authentic practices could help plant a seed in a future scientist. These teachers felt the call to improve science instruction long before the president asked them to do so. A visit to any one of these schools would not make citizens worried about our national security. There is an amazing generation of scientists on the horizon using an old, but not outdated approach to begin changing the world. Hopefully this research will provide some insights into these exemplary schools that other educators will choose to emulate and it will create a positive impact on science education at their schools.

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## Appendix A Guiding Questions for Focus Areas

### Assigning of the project:

What students are involved in the science fair and how is this determined?

Is the science fair mandatory? Is it associated with a specific grade level or course?

What is the process for students selecting their topics?

Is anything done to encourage participation of minorities, low socio-economic, or female students?

### Implementation of the project:

What is the time allotment during the school day/year for students to work on the science fair project?

Does the school have any association with outside resources (research institutions, mentor programs, etc.)?

Does participation in the fair impact the student's grade in any way, if so how is this determined?

### Implementation of the science fair:

Who/whom is in charge of the fair and what do these duties include?

Does the school conduct their own fair or do they partner with another resource?

When is the fair held and what are the expectations for the students (dress code and oral presentation for example)?

How are science fair projects judged? Who are the judges and what are their responsibilities and training?

### The climate and attitude towards the science fair of the school, school district & community:

How is the science fair perceived by all the various stakeholders?

What is the motivation of the participants?

What percent of the school is involved in the fair and what is the perception towards the fair of those not involved?

What is the level and nature of support from various levels (department, school, district)?

## Questionnaire

Stakeholder group:	Questions:
Teachers	<ol style="list-style-type: none"> <li>1) What students are involved in the science fair and how was this decided?</li> <li>2) Is the science fair in anyway tied to a student's grade? If so, how?</li> <li>3) What time, if any, is allotted in the school calendar to work on the science fair?</li> <li>4) What is expected of the teacher(s) in relationship to the science fair?</li> <li>5) What support is provided to the teacher(s) involved in the science fair?</li> <li>6) How are expectations for the student, in regards to the science fair project, communicated?</li> <li>7) How are judges selected for the science fair and by whom?</li> <li>8) Where and when does the science fair take place? How is this decided and who is involved?</li> <li>9) Are changes/modifications made to the science fair process from year to year?</li> <li>10) Why do you think your school does so well at the science fair?</li> </ol>
Administrators	<ol style="list-style-type: none"> <li>1) What is expected from the teachers &amp; students in relationship to the science fair?</li> <li>2) What is the district involvement in the science fair?</li> <li>3) Does the science fair relate/connect to other school or district wide initiatives?</li> <li>4) What is the community involvement, if any, in relationship to the science fair and student research opportunities?</li> <li>5) What other academic competitions, if any, is the school involved in?</li> <li>6) Why do you think your school does so well at the science fair?</li> </ol>
Students	<ol style="list-style-type: none"> <li>1) How is it decided what students will participate in the science fair?</li> <li>2) What support is provided to the student(s) involved in the science fair?</li> <li>3) How are expectations for the SF communicated to the student?</li> <li>4) What is your commitment level to the science fair project during the school day? Outside of the school day?</li> <li>5) Are students encouraged to participate in the science fair more than one year? If so what is the level of encouragement or motivation?</li> </ol>

	<ul style="list-style-type: none"><li>6) Is the science fair project graded? If so how?</li><li>7) Why do you think your school does so well at the science fair?</li></ul>
Parents	<ul style="list-style-type: none"><li>1) What is the role of the parent in the science fair?</li><li>2) How are the expectations for the student, in regards to the science fair project, communicated to the parents?</li><li>3) Why do you think your school does so well at the science fair?</li></ul>

## Appendix B: School demographics

Name of School Location of School	School Type	School Pop.	Eligible for free & reduced lunch	Cauc.	African Amer.	Asian	Hispanic	Other
DuPont Manual High School, Louisville KY	Public magnet	1856 9-12	15%	69.6%	16.5%	10%	1.7%	2.2%
Fairview High School Boulder, CO	Public	2118 9-12	7.2%	75.5%	0.4%	10.1%	8.2%	5.8%
Kalamazoo Math & Science Center, Kalamazoo MI	Public charter	184 9-12	2.2%	76.1%	2.2%	19%	2.7%	
Oregon Episcopal School Portland, Oregon	Public	300 9-12	35%	30%	17%	4%	49%	
Plano ISD, Plano TX Plano East High School Plano West High School Plano High School	Public	2817 11-12 1948 11-12 2673 11-12	23% 8.9% 11%	48% 61% 62.5%	14.7% 10.6% 7.6%	15.2% 19.3% 19.5%	21.7% 8.3% 10.1%	0.4% 0.8% 0.3%

## Appendix C

### **duPont Manual, Louisville KY**

#### **Case of DuPont Manual High School**

DuPont Manual High School is one of many high schools included in the Jefferson County school district (JCPS, 2015) in Kentucky. The school district serves over 101,000 students in Jefferson County which includes the city of Louisville. The school district has twenty two high schools serving grades 9-12, with four magnet schools in operation. Jefferson County is a school choice district which means students can apply to attend schools outside their home school. The home school is based on residence and admittance to other schools depends on a variety of factors including, but not limited to; availability, demographics of school, ethnicity, gender or socioeconomic status of the applicant, and criteria assessments (JCPS, 2015).

#### **School History**

DuPont Manual, referred to by most students and staff as Manual, was the first all magnet school for the district opening in 1984 (DuPont Manual, 2015). The building has been open since 1934, originally serving as an all-girls school and merging with the all-male high school Manual in 1950 (Heavrin, 1992). The building is located in downtown Louisville adjacent to the University of Louisville campus. Due in part to the history of the school it was decided to turn it into a magnet school when the school in operation began experiencing a decline in academics and discipline (McDaniel, 2005). Manual has since gone from one of the lowest performing high schools in the district to the number one high school in Kentucky and one of the most challenging high schools in the country (Best Schools, 2013; US News and World Report, 2015). Students must apply during the 8<sup>th</sup> grade for one of the five magnet programs within the school. The Youth and Performing Arts magnet (YPAS) is the original magnet beginning prior to the school being officially designated as such. The other magnets are Journalism and Communication, Visual Arts, Math Science and Technology, and High School University. The

school operates on an A/B block schedule and enrolls close to 2,000 students (see Appendix C for detailed demographics) which are divided fairly evenly among the five magnets.

The Math, Science and Technology (MST) magnet was the primary focus for this research. Students in the MST magnet are grouped together to take their core math and science classes with designated MST teachers. Elective math and science classes are open to students in other magnets but enrollment priority generally is given to MST students (B. Barr, personal communication, January 26<sup>th</sup>, 2015). For example a teacher observed for this study taught three pure MST Biology classes, one pure MST Independent science research class and one mixed AP Environmental Science class. Students must complete an application packet which includes; transcripts showing grades and attendance, teacher recommendations, and response to a magnet specific essay (see Appendix D). Glen Zwanzig, MST science teacher and MST past applicant reviewer, says primary focus for the MST magnet is on the student's math scores due to the rigorous courses the students will be expected to take at Manual (personal communication, January 26<sup>th</sup>, 2015). According to Zwanzig the school acceptance rate fluctuates from year to year ranging from a quarter to half of the applicants being accepted. This year 1,100 students applied to Manual to fill the 475 available seats in all magnet programs, applicants are usually evenly dispersed among the five magnets (Konz, 2015). Students do not generally leave Manual, but if spots become available in later grades students may be admitted under exceptional situations (G. Zwanzig, personal communication, January 26,2015).

### **Program Set up**

The science fair started at Manual in 1984 and became a requirement for all MST students' in 9-11 grades, in 1990. "Our program didn't really have a focus.....to give us an identity we had to have something so I really pushed for the research side" said 33 year teacher veteran Glen "Skip" Zwanzig (personal communication January 26, 2015), MST science

teacher and science fair director since its inception at Manual. The program started with only the students in Mr. Zwanzig's classes participating and then grew to include all students in the MST magnet. Current students are introduced to research in the 9<sup>th</sup> grade, which is designated as integrated science by the state of Kentucky. During the first semester students are exposed to basic research techniques and how to write a research paper and also begin to discuss project ideas. The setup of the class is discussed in the quote by Skip Zwanzig below who created the course and has taught it multiple times.

I spent the first two months just doing little labs where they had to analyze data, analyze experiments; determine what makes a good hypothesis. How do you do a controlled experiment versus a non-controlled experiment? I would give them some basic statistics; chi square, t-tests...during that time they come in with project ideas and we sit down and talk about it, sometimes I sit with a kid for an hour going through magazines to get ideas.

(G. Zwanzig, personal communication, January 26, 2015)

Students are given deadlines related to the project and points for completion of the research and research paper which together account for approximately 20% of their total course grade. Some of the dates are flexible since students are conducting projects that may vary in time length, but all students are expected to have their research done by the end of January. Time is given in class to helping students with research ideas, paperwork and presentations, but the actual experiment is expected to be done outside of school. Teachers will order supplies and open labs after school or on weekends to help students conducting research they also sell presentation boards to make it more convenient and cheaper for the student, "we accommodate the kids the best we can" (G. Zwanzig, personal communication, January 26, 2015). The MST science teachers also hold a science fair night in the fall geared primarily at the freshman parents to introduce them to the science research component and the expectations for the students. In recent years some middle schools have started participating in the science fair so some students

may come in with more experience than others depending on their feeder school.

In the 10<sup>th</sup> grade students can take Chemistry or Physics and in the 11<sup>th</sup> grade students take Biology. The project requirements stay the same with less class time given specifically to science fair related information and students are not required to do a research project related to the course content, but there is an expectation that the projects will become more advanced. Science Independent Research is a course offered to students in 11<sup>th</sup> and 12<sup>th</sup> grade and students are only admitted with the approval of the instructor. In this course students are expected to work with a mentor in a research lab and are given release time from school to do so. The instructor will help a student find a mentor but many of the students arrange for these themselves according to Bob Barr current instructor.

About 50% off the class takes care of themselves, the other half of the class sort of works through us. I have a list of labs that have been taking students and usually consistently want them. I also have a list of labs that have not worked....the student's don't get enough reasonable support.

(B. Barr, personal communication, January 26, 2015)

There are currently 42 students enrolled in the class, due to the course being offered at the end of the day they only offer it for one period and try to limit the amount of students enrolled. Many students work in labs at the University of Louisville due to Manual's close proximity to the campus. It is important to note that many of the students, not just those in the independent research class, work with a mentor. Of the thirty or so presentations I observed in content science courses the majority appeared to have been done in a lab. There has been some discussion among the MST teachers to not allow students to work in labs until their sophomore year, but there has been some push back from the parents. One parent whose daughter started working in a lab in middle school said:

Our teachers try to tell us actually don't go to the lab in middle school....my own daughter has been going to the lab for two years because I can't keep her away from the lab, it's just what she wants to do, she loves hanging out at the lab.

(V. Rachivandra, personal communication, January 26, 2015)

There has also apparently been some recent discussion from the University of Louisville about the liability of allowing non-university students to work in a lab says Cindy Corbett parent of a MST student and University of Louisville Biology professor.

Because we are right across the street we get inundated every year with requests and projects to help with and a lot of students call us with really vague notions of what they want to do and I'm responsible for getting my undergraduates in labs and getting them research experiences and they're (the U of L) is starting to come down with some policies that make it harder to get minors into your labs.

(C. Corbett, personal communication, January 26, 2015)

While all students in the MST magnet are required to do a science research project, not all students are required to participate in a science research competition. All students must give a ten minute research presentation to their class, but most students are given the choice of participating in the science fair or other science competition like Kentucky Junior Science and Humanities Symposium. Some teachers offer extra credit for participation in a competition and it is a strongly recommended for students in the Independent Science Research class. Some students may be encouraged not to enter a competition if the teacher feels the project is not high quality, says Zwanzig "we don't want kids to embarrass themselves so we won't send those (with weak projects)" however if a student wishes to compete in the school fair they are allowed (G. Zwanzig, personal communication, January 26, 2015).

Manual students used to compete in the Louisville Regional Science fair (LRSF) and generally swept all of the categories. In 2002, partly at the request of the LRSF, Manual was

designated their own ISEF affiliated fair. Up until this year Manual and Louisville Regional would still co-host the fair together to share rental costs and judges; Manual usually had about 300 of the 360 high school projects. This year the Louisville Regional fair decided to move to a new venue and not work with Manual.

They just divorced us this year and left us hanging. Even though I've been keeping them alive, kept them going all these years, they have about 60 high school projects but they have a big middle school component. ... there's been a lot of conflict. When we originally separated there was a lot of cooperation between us, because we were doing it to help them. But most of those people are gone and with the new people there's a bit of enmity there, but they pulled out on their own.

(G. Zwanzig, personal communication, January 26, 2015)

The Manual science fair is held in the commons area of the University of Louisville campus and is run by the Science Fair parent booster club initiated by Zwanzig many years ago, "I started that about 10 yrs. ago and it's been getting bigger and bigger, they took it out of my hands...sure was nice, because it took too many hours" (G. Zwanzig, personal communication, January 26, 2015). The teachers notify the parents how many projects there will be in each category and the parents arrange for the judges and prizes. The parents also raise money to help with the cost of the fair and of sending students to state and international competitions, "we're basically event planners" said Cindy Corbett(?) president of the booster club. Corbett says it can be challenging to get adequate judges, usually requiring "multiple rounds from every angle" (C.Corbett, personal communication, January 25, 2015.) The booster club is divided into several different committees to handle all aspects related to the fair helping to reduce the workload of the teachers.

## **Elements of success**

During the process of interviewing parents, teachers and students, observing classrooms and analyzing surveys three themes rise to the surface that help explain du Pont Manual's success at the science fair: school climate, student disposition and support systems. While there are also some challenges and negative connotations associated with each of these themes, the general overall effect is a competitive but positive school program that fosters an environment for high quality science fair projects.

### **School Climate**

Driving up to du Pont Manual it is easy to assume it is part of the University of Louisville campus, with its classical architecture and seemingly shared parking lots. As you enter the lobby you are greeted with banners extolling champions at various academic and athletic competitions dating back decades. Right away one is given a sense that this place has history and people are proud to be a part of its legacy. Even though the parquet classroom floors are scratched they add an element of class rather than one of dilapidation. Unfortunately that sense of dilapidation or age becomes apparent when looking at the resources available in the classrooms. Ironically the classrooms in the math, science and technology magnet, as well as all the other magnets, have very little technology and what is available is outdated and mismatched. One of the Biology classrooms is half of the old library, while it has great built-in bookshelves there is only one sink and no lab counters. This juxtaposition of reverence and neglect helps create an interesting climate for the school and its place in the district.

One would think that a district would be very proud to have a national high performing high school and would provide resources to aid that school into maintaining this status; apparently that is not the case in Jefferson County. "This school is not looked on highly by the board of education. They would shut us down in a heartbeat if they could." (G. Zwanzig, personal communication, January 26, 2015). According to Zwanzig there is a feeling among the

school district that Manual culls the best and brightest from the other high schools thus creating animosity towards the school. Zwanzig argues that many of the students would go to private school if they could not get in to Manual so the school district should be thankful that the students are staying in the district. His argument is given credibility when two of the parents interviewed mentioned, completely unprompted, that they would have sent their students to private school if Manual had not accepted them. This sense of embattlement with the district adds a little to the pride and perhaps slight elitism that is also part of the climate at Manual. Perhaps it is not that the school has wanted to separate itself but if others are going to view them differently then they will embrace it as well.

Manual does have a rigorous application process and this carries over into rigorous academic standards for its students. While many of the secondary schools in the Jefferson County school district have adopted a limited or no homework policy, Manual's students can have anywhere between two and six hours of homework a night. Says a Manual parent "they (the students) really understand what this place offers and they know what it's going to take for them to be successful here and they are ready". A part of this rigor for the MST students is the expectation of doing a science research project for at least three years. While this counts as twenty percent of their grade in science class, it is an added expectation on top of other content related assignments. Teachers, parents and students all agree that the requirement of the science research project and encouragement of entering the science fair is a main component of Manual's success at Intel and other science fairs.

Here we require it (science project) to be honest many of the kids would not do it if it wasn't required. I have kids coming back all the time and tell me they hated it when they were in high school, but because of what it's done for them they really appreciate it.

Skip Zwanzig

## Student Disposition

du Pont Manual is filled with the best students in Kentucky- the students who perform the best in mathematics, science, and technology participate in the science fair. People who want to grow up to be doctors, people who want to find cures for cancer, people who want to dedicate a major part of their lives to science and humanity. Manual Student

The students at du Pont Manual have taken an active interest in their education by merely completing the application process for the school. These are very high performing students, most of whom have already decided they would like to pursue a career in a STEM field. They are willing to tackle a rigorous curriculum and motivated to succeed. Some of them are functioning off pressure from parents but many are self-directed. One Manual parent told about her daughter wanting to start working in a research lab when she was in the 6<sup>th</sup> grade. Another young man pursued a partnership with the Wharton school of business last summer to help him patent the hearing aid he is developing after going to a doctor's visit with his grandfather in India and realizing how expensive one could be and how many people in developing countries are in need. These students are driven and very smart, they are still teenagers but you have to remind yourself of that when they are being kicked out of the library two hours after school is out.

Part of the drive is fueled by competition. Several students commented that it is a 'healthy' competition but a competition nonetheless. When observing presentations in the independent research class, it seemed students had a heightened interest in the projects that might be their direct competition. One young man even commented he did not want to be in a certain category because he knew he couldn't beat the other projects. Students are friendly to each other, but not necessarily respectful. Out of the three different teacher's classes that were observed one had the students make a compliment sandwich for the presenters; something good, something to improve on, something good. In the other two situations the students paid very little attention, except again when it was a friend or someone who was in their category, or the young man who

did very well at Intel last year. Students also commented on their surveys about the competitive drive not just of the MST magnet but the permeating culture of the whole school.

### **Support Systems**

The students at Manual are motivated and bright, but the support systems available to them help showcase these talents. As one may imagine students at an application based school are going to have parents who are supportive and involved in their education, because they were willing to merely assist in the application process. The case is the same at Manual with the parents being extremely involved in their children's education including their science fair projects. The morning I arrived at Manual a young lady was in the lobby with her parents talking to Mr. Zwanzig asking about her science project. Parents at Manual are not just involved in helping with their student's project; they actually help to organize the entire fair. A very unique feature of the science fair at Manual is it is put on entirely by the Science Fair Parent Booster club. Parents contact judges, solicit sponsors, organize the set up and break down, and complete all the scoring and present awards.

Another support provided to the Manual students is the close relationship the school has with the University of Louisville. While not every student works in a lab, or a lab at the university, teachers estimate approximately 200 students work in labs at the U of L. This is a huge number even for a large university. The relationship started slowly years ago with Zwanzig walking over to campus and approaching professors about opportunities for students. Now most students make their own connections, but the groundwork Zwanzig laid and the reputation of the program aids in the process. While there is some concern from teachers and professors about the set-up, the situation continues to flourish with students now working in labs across the county.

So you have to be a little creative if you're going to have high school students' work with you, the stuff I do in my lab is very expensive and I can't hand that stuff over to someone else, even an undergrad much less a high school student. So those are some of the

concerns that come up. I have seen several labs take in high school students and give them small manageable projects, usually under the supervision of graduate students, because that gives them mentoring experience as well but you just have to be creative.

(C. Corbett, personal communication, January 25, 2015)

The administration being willing to support the program by offering the independent research class is something not many schools may do. While there is very little money offered to teachers for their extra time (Zwanzig receives a \$300 stipend) there is time built in for the students to work off-campus in a lab. This offering helped elevate the level of the projects initially and helped build the relationship with the University.

#### **DuPont Manual Student Survey Analysis: 37 Students completed surveys**

Q1: How many years have you been involved in the science fair?

# of Years	1	2	3	4	5	6	7	8
# of Students		8	13	6	6	1	1	1

Q2: How are students encouraged to participate in the science fair?

Mandatory/Part of grade	100%	KS36 "The students are actually required to do science fair. This is not horrible but it is frustrating to do homework while doing this."
Winning prizes & awards. Attending prestigious competitions.	12%	
Extra Credit	10%	KS5 "Some teachers give extra credit if you enter competitions."
Competitive nature of students	10%	KS3 "For the most part, most students at my school are eager to participate! It is like being an outcast

		if you don't. But on the other hand, the cash prizes are a big influence.”
Future benefits/Scholarships	10%	KS30 “Mostly due to making science fair a grade. However, some are inspired by the previous winners and their future successes. Competitiveness too.”
Enjoyment/Interesting Experiments	6%	KS22 “teachers require them to do it, but that is more of a push. Once students start up a project, many get really into doing research.”

Q3: What support is provided to you during the science fair process?

From Teachers	Finding mentors	75%	KS8 “Each student can ask for help in finding a mentor but it is up to the student to call/email/meet the mentor to discuss the project”  KS27 “Our teachers are able to help us find mentors and are happy to let us use supplies they have, but most people try to find mentors on their own because it feels as if the mentors will appreciate you more if you go out yourselves to talk to them.”
	Providing materials <ul style="list-style-type: none"> <li>• Boards</li> <li>• Lab supplies</li> </ul>	22% 14%	KS31 “Teachers are willing to help you find whatever you need, helping you find a mentor or materials or reviewing your work.”  KS3 “the biology teachers are really supportive of helping you, on a personal level, find a mentor to work with, providing tri-fold boards and headboards, a workspace to use, all kinds of resources.”

	Guidelines & feedback	36%	<p>KS 36 “The teachers don’t provide a mentor or materials, but you can talk about your project with them.”</p> <p>KS3 “The two (biology) teachers really walk you through the process of how to enter science fair, how to give a good presentation, other local science fair information, etc.”</p> <p>KS10 “If you talk to teachers they could help set you up with a mentor or give strong advice or criticism for your science project.”</p>
	Provide Ideas	3%	KS4 “Teachers may help us find mentors, provide ideas, and proof read our research plan.”
	Little to no support or materials	12%	KS36 “The teachers don’t provide a mentor or materials but you can talk about your project with them.”
From University	Mentors/resources	8%	<p>KS20 “We are able to work with mentors at the University of Louisville. They even come to our school and give all of the students a safety procedure presentation before using a lab (at the U of L).”</p> <p>KS23 “Support from U of L by letting us use their facilities and professors.”</p> <p>KS30 “I found a mentor who helped me understand the research process.”</p>

Q4: How are you graded on your science project?

Presentation	56%	KS20 “Whether your project is simple or complex, as long as you are able to present your research in a knowledgeable way, you can get a good grade.”
Paper	53%	KS30 “Based on research paper for class. Based on ability to explain project for actual science fair.”

Participation/Quality	25%	KS2 “The teacher will grade on how much work and effort the student obviously put into their project.”
Research process	12%	KS31 “How much work you put into it and actually following the scientific process.”  KS7 “We are graded on our ability to answer a research question using the scientific method and are given extra credit based on performance in competitions if we choose to compete.”
Authenticity/Creativity	12%	
Participation in Science fairs	10%	
Variances reported based on teachers	10%	KS 36 “Presentation has nothing to do with your score”  KS2 “Grading styles change with every new teacher”  KS19 “Depending on the class, it could be on the presentation, the success or the paper.”

Q5: Are you given time during the school day to work on the science fair project?

No	36%	Yes (if you take the Independent Research class)	74%
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Q6: How do you know what is expected of you in regards to the science project?

Teacher guidelines	61%	KS9 “When we enrolled in the MST program we knew what we were getting ourselves into. Our teachers are very austere when it comes to research projects , so if we want a decent grade, we have to meet with the rigorous curriculum.”  KS12 “Science fair is taken very seriously at Manual...they call it research projects and these projects are expected to be high level projects that we
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		can learn from. When our teachers check on our topics, they make sure that they are projects that are challenging and are not from science buddies.”
Previous projects/Experiences	22%	KS3 “Now, as a sophomore I know that an authentic, interesting, important project is expected.”
Peers/Siblings	14%	KS25 “My brother was in this program and he set the standard for me.”  KS33 “we have peers that help set our standards high”
Don’t	3%	

Q7: Why do you think your school does so well at the science fair?

Motivated Students	61%	KS20 “People at my school, in my opinion are very curious. They tend to think outside the box and think of very amazing projects.”
School Environment	39%	KS28 “Our students are self-motivated, take pride in our magnet, enjoy intelligence and learning, and the competition between each other to be the best drives us.”
Required/Graded	28%	KS5 “There are many students attending which increases the chance that some of them will have very good projects.”
Teachers	23%	KS25 “The teachers and students both work really hard.”
Access to resources	14%	KS27 “Having U of L does help by giving us resources to create elaborate projects.”

Manual Parent Surveys: 13 total surveys

Q2: What is the role of the parent in the science fair?

Financial & moral support	8	KP9 “To buy all materials, drive the child to all meetings with his peers and to the science fair. To help in any way I can.”
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Help organize science fair	5	IKP “Really as parents were more even planners....we coordinate a lot of people.”
Feedback/guidance on project	5	KP10 “Making sure experiment is safe, otherwise assisting as requested with proofreading, listening to presentation, etc.”
Task master	2	KP13 “Help get materials and keep student on track.”
Find mentor/be a mentor	2	KP7 “Another key role is for the parent to network and get the kids access to technical mentors and labs.”  KP5 “The parent can offer ideas and suggestions for finding a mentor or where to go to get information or help. It is very important for the parent to not influence the project or it’s results.”

Q3: How are expectations for the student, in regards to the science fair, communicated to the parent(s)?

MST Open house & School meetings	6	KP5 “At the science fair open house all the particulars are related to the science fair are discussed.”
Emails	4	KP5 “..parents email addresses are entered into a data base that continually provides communication related to science fair initiatives, events, etc.”
Forms from teachers	3	KP10 “teacher send out rules of science fair along with list of deadlines...”
Student	2	KP3 “The student communicates deadlines to the parents.”
Not clearly stated	1	KP1 “The expectations were not clearly stated in the beginning. Students were basically on their own.”

Q4: Why do you think your student's school is so successful at the science fair?

Teachers/School support	9	KP8 "This school attracts the best teachers and has THE best science fair coordinator."
Students	7	KP1 "There are many dedicated and talented students that attend the school. Most are interested in science and technology related careers."
Parents	5	KP8 "Students attending this school have parents who cared enough to complete the application process and realize what an opportunity going to this school is."
Mentors/Resources	2	KP4 "The strong support from the parents and community, including University of Louisville faculties and administration."
Required	2	KP7 "Science fair is part of the research requirements in the curriculum. Hence all students need to do a project."

Additional Quotes:

KP8 "Without at least one dedicated teacher and a school administration that value STEM subjects, even the best students will not get much out of science fairs."

Emergent themes from Interviews and Observations

School climate	Research project required for all 9-11 MST students Presentation at Science fair big focus Rigorous application process	Chaotic classes Low quality equipment Undertones of negativity within district, creates a little bit of elitism (have and have nots)
Support systems	Parent involvement with booster club Some very dedicated teachers Close relationship with University of Louisville Strong verbal support from administration Strong feeder middle school program	Not all teachers willing to buy in Administration doesn't really support the program financially (give teacher a \$300 stipend)
Student climate	Academically strong Competitive students	Level of disrespect in some classes for teacher and other students

	Independent (find mentors, come up with projects, spend hours working on them) Pride of being a Manual student	Some students have attitude of elitism
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#### Science Fair Research Paper:

The pages included below are part of the documents provided to students at duPont Manual to communicate expectations related to the science fair research paper. It was decided to include these pages to exhibit the expectations of the students in regards to the scientific process skills that must be included in their research which will then be described in their paper.

### Laboratory Report/Science Fair Research Paper Format and Assessment

#### 1. Abstract (For science fair research paper only)(Up to 15 points)

This is a concise summary of your project that includes the problem, thesis, procedures, and principle results. Do not exceed 250 words. This section basically tells what you did, how you did it, and what your results were in 250 words or less.

#### 2. Introduction (Includes the title to the research paper or lab) (up to 20 points for the lab report and 50 points for the research paper). \*Note: the only label for this section should be the introduction. Each of the following parts is not labeled. I repeat, DO NOT make a separate section called background, problem, purpose, or hypothesis. \*The entire section is simply labeled "Introduction."\*

- A. Background - You will detail any background information that the reader might need to know to understand the problem. This should be written as though the reader is intelligent but not familiar with the subject. It might be a very good idea to tie the problem to some common real-life situation.
- B. Problem - The problem should be stated in simple language but should completely describe the need for the experiment.
- C. Purpose - What do you hope to learn?
- D. Hypothesis - What do you think will happen?
- E. For the Science Fair Research only- What have others done or said about things related to your topic? This is where your literature search comes in.

The introduction answers the question, "Why did you study this phenomenon?" The introduction identifies the phenomenon you studied/tested and provides relevant background information. This will include information from other studies or documents, which must be properly cited like this. (Zwanzig, 2005) This includes the author's last name and the year it was published. The introduction should end with your hypothesis or goals and clearly state the question your experiment was designed to answer. ALL RESEARCH PAPERS WILL HAVE CITATIONS DISCUSSING RELATED RESEARCH.

REMEMBER, THE ONLY TITLE ON THIS SECTION IS "INTRODUCTION."

#### 3. Methodology (up to 20 points for lab report and 25 points for the research paper).

- A. In this section you will describe how and when you did your work, including experimental design, experimental apparatus/equipment, methods of gathering and analyzing data, and types of experimental control when needed. The procedures used in the experiment or research should be written in paragraph form. The procedure of the experiments will be described in enough detail that someone else can conduct the research and obtain similar results. If special procedures are to be utilized they must be described. DO NOT MAKE LISTS of your equipment. You only want to mention the equipment and/or materials that are necessary to repeat the experiment.

This section should be written in the past tense because you have already completed the experiment. It should not be written in the form of instructions or as a list of materials as in a laboratory manual. Instead, it must be written as a narrative, which describes in the active voice what you did. For example, "Six petri dishes were filled with 20 ml of tap water in each dish." Be sure to use metric measurements.

4. Results (up to 30 points for the lab report and 60 points for the research paper).

In this section you are going to summarize your data. You present your observations and data with no interpretations or conclusions about what they mean. This is where you tell what the data is (using graphs and charts) (i.e., the trends of the graphs; the minimum, maximum, and ranges of the data). In essence you are number crunching and putting the data into understandable pictures. This is also where you would do your analysis of data to check for significance. Use the past tense to describe your results.

When using tables and figures, each table and figure must be introduced within the text. All tables must be numbered and have self-explanatory titles so that the reader can understand their content without the text. For example, Table 1. Percent of red maple (*Acer rubrum*) seedlings exhibiting visible injury after exposure to water with a pH of 3.6. Assign numbers to tables and figures in the order they are mentioned in the text. Tables and figures are numbered independently of each other, for example, Table 1 and 2, and then Figure 1 and 2. Tables are labeled at the top and figures at the bottom. Tables are referred to as tables; all other items (graphs, photographs, drawings, diagrams, maps, etc.) are referred to as figures.

- A. The data collected in the experiment should be complete, labeled and detailed in the appropriate units and significance. All data is organized into charts and graphs with appropriate labels.
- B. You will need to organize the presentation of your data in an appropriate manner that will make it understandable and helpful. All graphs and charts need to be numbered and have a statement of relationship or explanation below them with references to them in the body of the paper.
- C. You do not need to show your calculations. You should, however, show the results of those calculations. These should be in table/chart form with proper labels. Your calculations need to be correct and recorded to the appropriate degree of significance and accuracy. This would be especially important when using statistics to analyze your data. You do not need significance tests for lab reports.

5. Discussion/Conclusion (up to 30 points for the lab report and 50 points for the research paper). In this section you tell why you got the results your data suggests. What does the data mean! You draw any conclusions about what your data suggests here, and you discuss the significance of the data. Describe patterns and relationships that emerged. It is also very important to explain how any changes to or problems with the experimental design/procedure may have affected the results.

## Appendix D

### **Fairview High School, Boulder CO**

#### **Fairview Case Study**

Nestled at the foothills of the Rocky Mountains, Fairview High School is one of fourteen high schools in the sprawling Boulder Valley School District. The district primarily serves students in Boulder, CO which is located about thirty minutes north of Denver. While many residents commute to Denver, Boulder has many entities itself that bolster this community. The University of Colorado, the National Oceanic and Atmospheric Association, the National Center for Atmospheric Research, and National Institute of Standards Testing are a few of the local employers. Fairview, a 9-12 high school serves approximately 2200 students on a sprawling campus perched over a lake with a view of the foothills from the library that can distract even the most serious student. Colorado is an open enrollment state which means students are allowed to request to attend a school for which they are not zoned (Colorado Dept. of Education, 2013), or they can attend their home school which is the school associated with their residence. For the majority of the students, about 1600, Fairview is considered their home school, the rest of the students request to attend FHS with some of them driving from over an hour away according to assistant principal Sarah DiGiacomo (personal communication, February 25, 2015).

Fairview operates on a modified eight period schedule; three days a week students meet with each class for fifty minutes and two days each week are allotted for a block class of an hour and thirty minutes allowing students to meet with each class for an extended amount of time. Like many of the schools in the Boulder Valley School District Fairview has an open campus policy with students only required to be on campus when they have class. Depending on the grade level of the student they are required to sign up for a certain number of classes. Freshman and sophomores are required to take seven periods a day and can schedule one free period each day, juniors and seniors only have to schedule five periods a day but many usually schedule

more. Many students at Fairview take three or four science classes, when only two years is recommended by the state (S. DiGiacomo, personal communication, February 26, 2015).

### **Science Research Seminar**

Schools in Boulder Valley have been involved in the Cordon Pharma Regional Science and Engineering Fair, an ISEF affiliated fair, for many years. About nineteen years ago the school district decided to set aside funds for a class specifically devoted to science research and helping students prepare and participate in the science fair. The feeling from some teachers and administrators looking back is the district felt, or with pressure from the community, was made to feel like BVSD was not having as much success as they should at the science fair considering the scientifically minded community housing the district. In response to this the school district set aside funds to create a course called Science Research Seminar (SRS) at each high school in the district. The funding is set up where each school is provided with .2 or 20% of a teacher's salary to offer the class. The administration initially earmarked the course with gifted and talented funds and so it remains under the GT umbrella today. While some of the funding has been cut to the schools, it is required that the SRS class period remains protected. How this is used or managed at each school is not closely regulated, only the designation of the class period in a teacher's schedule, "while some schools may not like it they do it" BVSD administrator.

Originally the SRS class was supposed to only have ten students in it to allow a better mentoring experience for the students. As funding has remained the same and interest has grown at Fairview this number is now open ended with the current teacher having twenty one students in the course this year. In the last ten years, or those encompassing this study, the SRS class has had three different teachers. Each teacher has had a slightly different approach to the program but the overall premise of the course has remained the same; students sign up for the course as an elective and are given release time from school to work at home or with a mentor at a research institution or university. Paul Strode, current teacher of the course has created more of an

intentional curriculum for the course (see Appendix B) and take a more rigorous approach according to Dr. Helen Petach the SRS teacher before Dr. Strode. “Paul I think has the most rigorous approach to doing SRS, he feels strongly about statistical analysis, proper hypothesis generation, a formal layout of the scientific process” (H. Petach, personal communication, February 10, 2015). For example, students have always been expected to write a paper, but Dr. Strode’s approach is to have the students write a scientific paper as if the students would be submitting it as a manuscript for a journal. To prepare them for this and for having a greater understanding of science research in general, he has students spend a great deal of time in class reading and discussing scientific research articles as well as working on statistical analysis. Students also write a Research Proposal that is due before they can begin any research. The RP is similar to what a student might write for a Master’s Thesis proposal, complete with a literature review in the introduction. Dr. Strode also has a meeting each spring to meet with interested students to ensure they understand what is expected from the course, below is the description from the course syllabus.

The objective of SRS is (i) for students to learn about the human endeavor of scientific research, (ii) to learn how statistics fit into scientific research, and (iii) to experience planning, performing, and communicating real, original research. The general class structure is more free form than a traditional class. Therefore, students must be self-disciplined and self-motivated.

SRS course syllabus, Dr. Paul Strode, Fairview HS

Along with reading a non-fiction science book over the summer, students are expected to secure a mentor. While students do not have to work with a mentor the majority of the students seem to do so, teachers will help students find mentors or act as a mentor for a student but projects are usually not done at school merely due to space. Not every student who participates in the science fair is enrolled in the SRS class, some students do not have room in their schedule

for the elective so they will work with Dr. Strode or another science teacher on ensuring their project is ready for entry into the fair, other students will take the class for multiple years which is fine with Dr. Strode “I like having students who have been in the class before, they are a great resource and motivation for the other students.” (personal communication February 11, 2015). During the 2014-2015 school year there were six students working on research projects who were not enrolled in the class. Of those six, four had previously taken the class.

There is some disagreement at Fairview about the impact of the course on the schools success at science fair. While all high schools in BVSD have the SRS class, Fairview is the only one out of fourteen high schools in BVSD who tends to have a high level of success at the state and International level of Science fair competition. This leads to the discussion of what are the elements that contribute to the excellence at Fairview in regards to the science fair? Two main components quickly rise to the surface; climate of the school and climate of the community.

### **Climate of the School: Relaxed Intensity**

“Way to go Science! Fairview rocks the science fair!”

(FHS science teacher Dan Knowles)

After being met at the office by Dr. Strode, who prefers to be called Paul, this is the greeting we receive as we walk into the science office. This sets the tone for the whole visit and gives me a small taste of the climate that is Fairview High School. The first impression is that teachers are excited to be here and supportive of each other, this feeling continues as numerous teachers volunteer their limited free time to talk to me and brag about their science department and colleagues. The caliber of teachers at Fairview seems to be very high and according to Dr. Strode the school had over 100 applicants for the last open science teaching position. Out of the 120 teachers at Fairview, 86 hold advanced degrees with seven of these being Ph.D.’s. One of the science teachers holds a DDS and three of the teachers with Ph.D.’s are science teachers who have intentionally chosen to teach high school over college. An example would be Dr. Helen

Petach, who has a Ph.D. in Chemistry and Physics from Cornell.

I left the university because I got the impression that students either became scientists or not scientists before they got to the university level and they had just made up their mind and it was very difficult to roll back the clock. At the high school level I feel like students are still incredibly open to what they do in the future and the experiences they have in high school have a dramatic impact on what they want to do in the future, so if you take the best and brightest and get them excited about science the best time to do that is when they are in high school and so I was pretty thrilled to be able to switch over and do that.

(H. Petach, personal communication, February 25, 2015)

The high caliber of the teachers is not just based on their advanced degrees but also on the attitude they seem to have of being true professionals. Many are actively involved in their professions outside of school: Paul Strode has a Ph.D. in Ecology and Environmental Science and regularly contributes to research journals and works with the Howard Hughes Medical Institute on creating and evaluating science curriculum. He also has taught courses at the University of Colorado. Dr. Tracey Clement is a former research scientist in Physics who worked in that field for twenty years before transitioning into teaching science at Fairview. Dr. Petach took a leave of absence last year to participate in a science fellowship with AAAS working on environment and health programs for the government. This level of professionalism is not just present in the science department, Paul and his wife Dr. Sarah Zerwin have a place in their family budget for travel to professional conferences and Dr. Zerwin has also taught courses at the University of Colorado.

The teachers are also professional in their collaborative demeanor with each other and their dedication to students. As a former science teacher she admits she may be a little biased but Assistant Principal Sarah DiGiacomo feels the science department is not the only strong department at Fairview but is certainly one of the best.

They're all awesome, they love what they do, they love working with each other, they actively collaborate, science is a collaborative field but how many science teachers are actually saying come watch me teach this, I want to make my advanced classes more student-centered how do I do that? They are actively looking at getting themselves to be better instructors, so then you just have this whole energy.

(S. DiGiacomo, personal communication, February 25, 2015)

This energy is palatable as students and teachers are in and out of classrooms and offices to ask questions and share ideas. Initially to an outsider, the open campus policy seems to translate into very little structure, yet there is no chaos because the environment is one of independent purpose not total freedom. The 'problems' that arise are too many students wanting to talk to a teacher, not enough room for everyone in the library, or having to tell a student they can't take eight AP classes because they need a break in their day to breathe and eat lunch. This independent atmosphere for the students lends the school a certain climate of relaxed intensity. There is no question the students will respect the limited boundaries they do have and so they do. I'm sure this climate was not created overnight but no one can remember when it was any different. While the students are bright, it is how they approach school that impacts the climate at Fairview. They are not just here to earn credits but to expect a quality education that has meaning for their life; they will give their best but expect the same from the administration and teachers.

An example of this attitude can be shown in what happened this past fall across BSVD. In November, 99% of seniors at Fairview did not take a new state test protesting the amount of classroom time that is devoted to standardized testing (Daily Camera, February 13, Amy Bounds). While several students in BVSD protested taking the test, the students at Fairview decided to hold a canned food drive while they were outside the school protesting. They also wrote a letter to the editor of the local paper where they had calculated how the money spent on the new test could be used in more valuable ways for education across the state of Colorado. This

speaks volumes to the activeness that these students take in their education.

There is no doubt that the students are not just citizen minded but are academically minded as well. The reputation for academics at Fairview is very high and the school has a very robust AP and IB program that draws students in the open enrollment process. The students are motivated to succeed and competitive with each other, when Dr. Strode was asked by one parent at the science fair “how do you get the students to do this high level?” he replied by saying, “I put them near each other and then get out of their way.”

According to IB Coordinator Darren Bessett 1600 of the 2200 students at Fairview are in at least one AP or IB class, approximately 600 students are taking three or more AP or IB classes. The school has intentionally grown the two programs together and tried to allow the benefits of the classes to permeate the whole school, “By design inquiry has trickled into the other classes, we have very few teachers who only teach AP or IB” (D. Bassett, personal communication, February 25<sup>th</sup>, 2015). This same idea of having high quality teachers work with lower levels of students was also mentioned by DiGiacomo when talking about the science department:

We get the best teachers and we put them with the kids who hate science and think they’re not good at science and they can’t do science and we really develop those classes.....you build all of them not just the high.

(personal communication, February 25, 2015).

This view of looking at the entire curriculum as being cohesive contributes to the climate of the school. Programs try to work together when possible such as the IB/AP supporting students in science research. Many students who make it to Intel ISEF are scheduled to take IB/AP exams during this time. AP will allow for a late test, but IB students must take their test at the competition. Students are supplied an IB testing ‘nanny’ as Basset calls the position, who will assist the students with taking exams at the alternate location.

One area of overlap that initially seemed to be beneficial has caused some problems in the last few years: the extended essay in IB and a science research/science fair project.

According to Basset “IB has inadvertently discouraged science fair for students. IB and ISEF ethical standards aren’t congruent” (personal communication, February 25, 2015). According to IB the extended essay project is supposed to be entirely unique to the student. If a student works in a lab with a mentor IB questions if that is truly the student’s independent work, a question that has been raised by others as well. Last year a student almost did not receive his IB diploma because he was accused of plagiarism related to the release by the lab he had been working in of the same data he used for his extended essay project. The student and researchers argument was the student had done his part independently but IB felt it did not show independent work and had to be convinced not to punish the student.

Another supportive aspect of the community at Fairview is the involvement of the parents. Each year, between fifty and seventy proctors are needed for the IB and AP tests and these are all parent volunteers. Parents also voluntarily staff the IB store and there is a waiting list to volunteer in the post graduate center. Many of the parents come from scientific backgrounds which may also help the students, but many are just willing to do what it takes to support their student’s school. One mother reached out to me and asked me to meet her at a coffee shop during her lunch break because she was so eager to talk about the science program at Fairview and help me with my research. With tears in her eyes she shared with me the story of how her son was the only student at the end of year assembly last year to receive a standing ovation. This was an assembly to recognize athletic and academic achievements and the ovation was started by football players standing up for her son, a sophomore, who had placed 2<sup>nd</sup> at ISEF Intel. This cycles back to the attitude of the students and the entire climate that exists at Fairview as cultivated by the teachers, administrators, students and parents.

“In Boulder we have a really unique situation, really knowledgeable parents and they care a lot and have a lot of trust in the educational system...” Sarah DiGiacomo

### **Climate of the Community: Contributing Partners**

The SRS program would not have come into existence without the support of the community and the Boulder Valley School district. While the climate at Fairview has helped to foster its success, continued support from the district and the scientific community of Boulder have also helped push the program to a level of excellence.

The district supports the science fair with the inclusion of the SRS class in the high schools and also by encouraging science fair participation at the middle school. The level of participation varies at each middle school with some offering it in conjunction with a class and other doing it as a club (BVSD administrator, personal communication, February 26, 2015.) Summit Middle school, a BVSD application based charter school, is one school that has fully embraced science research. All of the 8<sup>th</sup> grade students do a science research project. Originally the students did a project in 6<sup>th</sup> grade, but it was felt by teachers that perhaps this was a little too early for students to do quality research projects and it might be better to lay more of a research foundation before the actual implementation of the project (P. Teasdale, personal communication, February 26, 2015). Students now work on a history day project in 7<sup>th</sup> grade to learn research skills. The science classes also spend some time on basic statistics so the students are not unfamiliar with the topics in 8<sup>th</sup> grade. The students have a mentor teacher within the school to help with the initial research plan and some students, about 10%, will work with mentors in the community on their actual research. Students are not required to submit their project to the actual science fair but many do. Mr. Teasdale works diligently on providing his students a high quality science experience and he feels that science research is integral to this experience, “things that don’t have a practical impact I avoid like the plague.” (personal communication, February 26, 2015).

Middle school is not the first time students in BVSD are involved in science; students are exposed to science early with an intentional foundation of inquiry being laid. Beginning in kindergarten students receive what is equivalent to a half day of science instruction each week in part facilitated by the districts two FOSS specialists (S. Messier, personal communication, February 26, 2015). The FOSS program was adopted intentionally because of its alignment with the science curriculum goals of the district, according to the FOSS website:

The best way for students to appreciate the scientific enterprise, learn important scientific and engineering concepts, and develop the ability to think well is to actively participate in scientific practices through their own investigations and analyses. The FOSS Program was created specifically to provide students and teachers with meaningful experiences through engaging with this active participation in scientific practices.

(FOSS website, 2014)

By continuing to pay for a teacher of the SRS, encouraging middle school participation and promoting science as inquiry through the whole science curriculum, the Boulder Valley School District has helped to contribute to the excellent program at Fairview.

Another contributing community is the scientific-mindedness of the residents of Boulder. An important point that kept coming up during interviews is that Boulder is not just an educated community it is a scientifically educated community; this is an important distinction to make. There are many communities around the country who have parents that are involved in the schools, or where students have access to work in research environments. What makes this community different is many of these students have grown up around science. Lab environments are not unfamiliar to most, conversations about science are common around dinner tables and coffee shops (I overheard one myself related to a renewable energy start-up company). “We have this sphere of science families..... from a young age they already know what a cool experiment is....” says Dr. Petach (personal communication, February 26, 2015). Parents will

provide support for students working at home, in terms of guidance with a research plan or obtaining of equipment. Because of the value of science in the overall community it is usually not hard to find places for students to work with mentors according to Paul, “some mentors love it and will take a student every year” (personal communication, February 25, 2015). Due to the increasing number of students in the class it is helpful if students can find their own mentors and connections in the community certainly help.

Most departments at University of Colorado are very willing to help with mentors however there are some departments that are too busy managing their own undergraduates in research they cannot accommodate high school students also. Other support can be provided by the university such as the graduate assistant that was provided this year to help with the science research class at Fairview. Ryan Langendorf, a Ph.D. student in Computer Science was part of a National Science Foundation grant through the Computer Science Department called Engaging Computer Science in Traditional Education. Ryan spent one or two days a week in the SRS class, primarily helping students with their statistical analysis but also acting as a sounding board for ideas. Paul appreciates the continued support, “when I taught at Boulder High we were right next to campus, it has been harder over here (at Fairview) to stay connected” (personal communication, February 26, 2015).

The culture of high expectations and successful role models within the community make a huge difference in the success rate of this community. The students are raised with the perspective that they will be successful and can make a contribution if they work hard enough. (Fairview High School Teacher, personal communication)

The climate that has been created at Fairview High School is one of excellence that inspires teachers, students and visitors alike. There is no question Fairview is impacted by its environment but in being willing to give teachers and students the freedoms they request, Fairview has created its own environment of excellence. As district administrator Sam Messier

puts it “we just put the support systems in place and then get out of their way.”

**Fairview Student Analysis:** 34 Students complete surveys

Q1: How many years have you been involved in the science fair?

# of Years	1	2	3	4	5	6
# of Students	23	3	1	1	0	6

Q2: How are students encouraged to participate in the science fair?

Science Research Seminar/Science Teachers	70%	<p>CS15 “The main way that students are encouraged to participate in the science fair is through our Science Research Seminar class. The SRS’s reputation for being a good class is a large factor influencing students to sign up for it.”</p> <p>CS11 “I am in a class called Science Research Seminar. The science fair is part of the curriculum.”</p> <p>CS19 “Teachers in the science department encourage/recommend students participate in the SRS class.”</p>
Personal Motivation	33%	<p>CS24 “Students do it based on their own motivation.”</p> <p>CS30 “It is completely optional and students must take their own initiative to become involved.”</p>
Peers/School Culture	9%	<p>CS20 “For many I think it’s a peer driven thing. They see other successful kids doing it and they want to do it too.”</p> <p>CS3 “There is an atmosphere conducive to scientific progress.”</p>

Benefits	6%	<p>CS33 “With the IB program, science fair is encouraged to double as your Extended Essay.”</p> <p>CS12 “The incentives of having awards to put on college applications and the opportunity to be involved in the science community in order to make a decision about whether or not to have a future in science.</p>
Parents	6%	<p>CS23 “We are encouraged to participate in SRS and our parents encourage us to participate in the fair.”</p> <p>CS22 “Other than the general science-centric atmosphere of Fairview, generally the only thing that initially encourages students to go to the fair is themselves or their parents.</p>

Q3: What support is provided to you during the science fair process?

From SRS Teacher	Finding mentors	52%	<p>CS3 “Dr. Strode assists students in the process of finding a mentor.”</p> <p>CS “We are asked to find a mentor, but if we cannot then our teacher assists us.”</p>
	Talking and thinking Scientifically (?)	48%	<p>CS22 “Dr. Strode is incredibly supportive, providing a spring board for ideas, a foundation in proper scientific methods and a helpful critic.</p> <p>CS25 “Dr. Strode would teach us how to correctly read and analyze scientific articles as well as allow us to practice presenting and talking about science.”</p>

			CS26 “The SRS teacher is an excellent resource in regards to learning how to be scientifically literate...”
	Poster/Presentation	30%	CS8 “Through the SRS class, I received a huge amount of support from my teacher with preparing my research proposal and presentation.”  CS13 “My teacher gave me advice on my presentation skills.”  CS3 “He also helped us with the paperwork, instructed us in statistical analysis and critiqued our posters.”
	Statistics	27%	CS10 “There was a lot of help from the school with the poster and understanding on my statistics.”  CS19 “The class also teaches you about statistical tests and the process of writing a scientific paper.”  CS25 “We also learned a lot about statistics and how to apply them to a variety of studies.”
	Materials	15%	CS19 “The school also allows you to use/borrow materials, such as measurement equipment or the schools greenhouse.”  CS29 “The teacher of the independent study class (SRS) was always there as a source of info and help us find ways to get what we needed for our projects.”
From Mentors	Resources	9%	CS11 “...there are also many resources available through the University of Colorado if any of us need materials that would only be available through a lab or expert opinion.”

			CS3 “These mentors are generally members of a university or research center so that materials are available in the lab setting.”
	Expertise	6%	CS27 “Mentoring on how to go about creating a scientifically sound study.”  CS23 “the process was facilitated by our mentors to understand how we can test our ideas and present our conclusions effectively.”
From Peers	Feedback	6%	CS18 “The research seminar course provides a supportive community which assists through critiquing presentations.”
	Experience	6%	CS22 “The other and more important support that we get is from our fellow students. As a community, those who have participated in lab-based or fair science help those who are new to the experience.”

Q4: How are you graded on your science project?

Participation (In class and science fair)	52%	CS23 “There is a lot of group work that influences our grade, but our grades are based off of our communication with our teacher and our contribution to the class environment.”  CS26 “Essentially it is a pass/fail system. As long as students participate in the practice presentations and provide feedback for other students they receive an A.”
Growth	15%	CS5 “If I can show learning and growth then I will get an A”  CS22 “At the end of each semester we discuss how we thought we improved ourselves, and participated with the class over the semester.”

Quality of science	15%	CS3 “Our research proposals and final research papers were graded for SRS with regards to quality of writing and analysis.”  CS12 “How your study was put together and your scientific knowledge of your scientific area. How you present your results and whether you talk in a scientific manner.”
No Grades in Class	18%	CS2 “We don’t have any grades in our course.”  CS24 “We don’t get grades on any work we do in class. At the end of the semester we argue and provide evidence for what grade we think we earned and our teacher agrees or disagrees and gives us a grade.”

Q5: Are you given time during the school day to work on the science fair project?

No	9%
Yes (if you take Science Research seminar class)	91%

Q6: How do you know what is expected of you in regards to the science project?

Previous projects/Experiences	39%	CS2 “Our teacher provided examples of well-done posters in addition to poorly constructed posters and showed us how to construct the best poster and best experiment possible.”  CS6 “Seeing what everyone else is doing. Fairview usually has a strong contingent of returning elite researchers who set the standards for everyone else.”
Expected to do good science	33%	CS15 “We are forced to understand and conduct the scientific process like real researchers.”  CS8 “We aren’t expected to do well at the science fair, but we are expected to do ‘good’ science.”

Guidelines/Feedback	30%	CS1 “The instructor outlines his/her expectations by providing grading rubrics as well as performing grading exercises with feedback to be able to succeed.”
Mentors	6%	CS23 “Our mentors explain what they expect of us to present at the fair.”

Q7: Why do you think your school does so well at the science fair?

SRS course design/Teacher	58%	CS25 “Dr. Strode did not teach us in order to win the science fair. He taught us how to DO science, as adults. By treating us as adults, giving us independence in our research but also teaching us valuable techniques actual scientists need to do, he prepared us not only for the fair but gave us knowledge that we could actually use in the future in college, graduate school and beyond.”
School Culture	38%	CS6 “...culture of both competition and collaboration at our high school. Everyone wants to do well, but we want to do well as a community as well.”
Community Resources	27%	CS9 “We live in a town with a ton of resources. Students have mentors at NCAR, the university and NIST. Many students have parents who are scientists and who have the socioeconomic means to aid the student to the fullest.”
Motivation of students participating	24%	CS12 “All of the students are participating because they are scientifically minded and want to be there.”

CO Parent Surveys: 11 parents completed surveys

Q2: What is the role of the parent in the science fair?

Emotional Support	37%	P1 Encouraged her efforts and positive self-concepts, attended the fair to share in her experience.
Project Guidance/Feedback	32%	P8 Offer feedback on scope of research and data collection, and encourage further

		research through in-depth questioning about research results.
Financial Support	21%	P2 We give support such as paying for poster printing.
Mentors	11%	P10 to help locate a suitable mentor

Q3: How are the expectations for the student, in regards to the science fair, communicated to the parent(s)?

Through the student	58%	P11 As high school students, I expect that the students take responsibility. The school and science fair also does an excellent job of teaching the students that it's their responsibility.
Through the teacher	42%	P1 A syllabus is provided upon enrolling in the class. Child-specific information is exchanged through parent/teacher conferences held each semester. The class instructor maintains a website for the SRS class and all associated expectations and assignments.

Q4: Why do you think your student's school is so successful at the science fair?

Instructor(s)	48%	P2 Dr. Paul Strode, the Science Research Seminar teacher, has high expectations but also provides ample room to experiment and learn from failures. His passion for science research has helped to make my son passionate about research.
Strong Academic Climate of School	30%	P1 Public opinion classifies Fairview as the strongest academic school in Boulder and it attracts the intellectual kids from around the area
Scientific Community	22%	P3 Boulder is a very highly educated community with many professional scientists that strongly support education in general and science education in particular

Fairview Emergent Themes from Interviews and Observations

Climate of the School	High Caliber of Teachers
	High Quality Curriculum
	Highly Motivated Students
	High level of Parent Involvement
Climate of the Community	Scientific Community
	Supportive School District

## Science Research Seminar Documents

The following documents are handouts related to the Science Research Seminar class at Fairview High School. The first document is a letter that Dr. Strode (SRS teacher) gives to students interested in enrolling in the class. The letter is provided in the spring for those who would enroll the following fall. The second document is the general course syllabus for the Science Research Seminar class that Dr. Strode provides to students enrolled in the class and highlights the guidelines that the course is operated under. The documents are included here to show the expectations for the course and to show the commitment that Dr. Strode expects from the students.

### Science Research Seminar

Dear Student Interested in Science Research Seminar (SRS) 2014/2015:

I am excited that you have signed up for the SRS course. This course will be incredibly demanding yet can be incredibly fulfilling if you approach the course with the right mindset. You have chosen this course for several reasons, among them are:

- you are interested in science as a college focus and perhaps a career
- you are self-motivated and can accomplish complex tasks with little assistance
- you want to seek out and learn from a professional scientist
- you want to continue to develop and hone your skills as a researcher
- you want to improve your scientific literacy and learn how to effectively communicate the knowledge of science to others in various ways
- you are excited about presenting your work in a public setting such as the Cordon-Pharma Colorado Regional Science and Engineering Fair in February next year
- you are committed to the SRS course for both Semesters I and II
- you have not chosen this class strictly as a vehicle for your IB Diploma Extended Essay

In order to be successful in this course you must lay some groundwork this summer. This will include:

1. Read a nonfiction book on science during the summer. Below are some great choices:
  - *The Canon: a Whirligig Tour of the Beautiful Basics of Science* by Natalie Angier
  - *Race for the Double Helix* by James Watson
  - *The Golem: What You Should Know About Science* by Collins and Pinch
  - *Why Evolution Works (and Creationism Fails)* by Young and Strode
  - *The Girls of Atomic City* by Denise Kiernan
  - *The Believing Brain* by Michael Shermer
  - *The Beginning of Infinity* by David Deutsch

- *Lucy's Legacy: The Quest for Human Origins* by Donald C. Johanson
  - *Deadly Choices: How the Anti-Vaccine Movement Threatens Us All* by Paul Offit
  - *Physics of the Future* by Michio Kaku
  - *Gulp* by Mary Roach
  - *Salt Sugar Fat* by Michael Moss
  - *The New Digital Age* by Eric Schmidt and Jared Cohen.
  - *Big Data* by Viktor Mayer-Schönberger and Kenneth Cukier
  - *The Immortal Life of Henrietta Lacks* by Rebecca Skloot
2. Email me and let me know which book you will be reading.
  3. Begin writing a one-page response essay for the book you choose.
  4. Work through your connections with friends and family to secure a scientist as a mentor for the development, initiation, and implementation of a research project that you will conduct next fall.
  5. Read through ALL of the Intel ISEF *Rules and Guidelines Booklet* (found here <http://www.societyforscience.org/isef/document>).

*NOTE – you **MAY NOT** begin experimentation until you have written an acceptable research proposal and that proposal has been approved by your mentor, your parent(s), and your SRS teacher. You may begin in the summer if you have fulfilled the research proposal and ISEF paperwork requirement.*

To discuss the summer and the course, I need you to attend a meeting on Wednesday, May 28<sup>th</sup>, at 10:40 AM during the first half of the lunch break between the Period 2 and Period 7 final exam periods. The meeting will be held in Room 411.

If attending this meeting is an impossible hardship for you, please see Dr. Strode.

Good luck on final exams and I will see you next week!

## FAIRVIEW HIGH SCHOOL SCIENCE RESEARCH SEMINAR General Course Syllabus

Dr. Paul K. Strode

Summer Reading and Essay. Essay directions will be provided on the first day of school and essay will be written during the first weekend of the school year.

“Textbook” – Sullivan, Michael 2004. *Statistics: Informed Decisions Using Data*. Pearson Education, Upper Saddle River, NJ.

- I will be using examples from this book later in 1<sup>st</sup> Semester when we talk about analyzing data. I will not require you to purchase this book, but it is a user friendly reference.
- Available used (really cheap!) or new from any online bookseller. Here is the Amazon site for the book: [http://www.amazon.com/Statistics-Informed-Decisions-Using-Data/dp/0130618640/ref=sr\\_1\\_1?s=books&ie=UTF8&qid=1313174796&sr=1-1](http://www.amazon.com/Statistics-Informed-Decisions-Using-Data/dp/0130618640/ref=sr_1_1?s=books&ie=UTF8&qid=1313174796&sr=1-1)

**Student Expectations:** The objective of SRS is (i) for students to learn about the human endeavor of scientific research, (ii) to learn how statistics fit into scientific research, and (iii) to experience planning, performing, and communicating real, original research. The general class structure is more free form than a traditional class. Therefore, students must be self-disciplined and self-motivated. We will meet daily as a group during the scheduled period for most of Semester 1. Then, as your mentors are secured and research begins, we will meet formally twice per week as a group to report about your progress and discuss the nuts and bolts of your experiences.

The specific expectations of all students are as follows:

- Complete the summer reading and write a response essay (posted on course website)
- Research about and find an adult sponsor for your research project
- Convey an understanding of the structure of primary research articles and learn how to interpret and evaluate them
- Participate freely and fairly in class discussions
- Learn how to use Norlin Library at CU (if you haven't already) to find primary research articles, or learn to use Google Scholar (<http://scholar.google.com>) to find research articles
- Design a rigorous research project under the guidance of the Research Seminar teacher and the student's adult sponsor (qualified scientist and designated supervisor, if necessary)
- Write a properly constructed research proposal that is deemed acceptable by both the Research Seminar teacher and the student's adult sponsor (see posted model research proposal)
- Complete the statistics homework problem sets on time (usually a weekly task)

- Present your research proposal as a Power Point talk to the rest of the class during Sem. I Finals
- Keep a carefully detailed lab notebook and recording of lab hours
- Complete the research project by the Regional Science and Engineering Fair
- Attend at least one symposium talk at CU within your general area of interest and write and present a response essay
- Create a scientific poster of the research project results and present it at the Regional Science and Engineering Fair (end of February - CU)
- Create a Power Point presentation of the research project and results and give the Power Point talk at the District Science Research Seminar Symposium (April)
- Write a properly constructed, publishable manuscript of a research paper in a scientific style appropriate to the nature of the research paradigm (see posted model manuscript)

### Assessment

<b>Semester One</b>
Response Essay (Last Week of August)
CU Symposium Response Essay (end of October)
Written Research Proposal (Mid October)
Research Proposal Power Point Talk (Final Exam)
Statistics Problems
Student Lab Notebook and Work Log
Participation (group discussions, attendance, communication with teacher)
<b>Semester Two</b>
Poster of Results for Regional Science Fair (end of Feb)
BVSD Symposium Power Point Presentation (end of April) or science class presentation
Research Paper (Spring, but by mid-May at the latest)
Participation (group discussions, attendance, communication with teacher)

## Appendix E

### **Kalamazoo Area Math and Science Center, Kalamazoo MI**

#### **Kalamazoo Math & Science Center Case**

The Kalamazoo Area Math and Science Center (KAMSC) is an example of what can happen when business, politics and education can cooperate and work in partnership to benefit a large community. The math and science center began in 1985 in Kalamazoo County, Michigan with an endowment of 2 million dollars from the Upjohn Company. Upjohn, now known as Pfizer, is a pharmaceutical company that created the endowment as a way to enhance the math and science education of students in Kalamazoo County (KAMSC website). The partnership thrives today and the school is currently funded based on the per-pupil money received from the state of Michigan, with additional money coming from the original endowment and supporting school districts. Director Michael Tarnoff emphasizes the importance of the partnership between KAMSC and the twelve school districts in Kalamazoo County.

Kalamazoo County is one of the most educational friendly school districts in the state..... there is actually an agreement between all the school districts in the county and KAMSC and they actually pay us added costs (per student). It's money they could use for a different purpose but yet they give it to us and support us.

(M. Tarnoff, personal communication, January 28, 2015)

A copy of the proclamation of this agreement is prominently on display in the hallway at KAMSC to show their appreciation and awareness of the larger system they belong to. The school is housed in downtown Kalamazoo on the fourth floor of a historic education building. The building was built in 1925 and was the second home of Central High School, which began in 1858 and was the first public high school in the state of Michigan. While the outside hallways and downstairs auditorium still retain historical charm, the KAMSC area was updated with computer and science labs to better fit its namesake.

### **Student selection and scheduling**

In order to attend KAMSC a student must reside in Kalamazoo County, many students apply not only from public school but also private, parochial and home schools. Students apply during their 8<sup>th</sup> grade year to be accepted as incoming freshman and the school serves approximately 300 students in the 9<sup>th</sup>-12<sup>th</sup> grades. The first step in the application process is to take an entrance exam. The entrance exam was designed by teacher and research director Dr. John Goudie and focuses on critical thinking skills along with math and science knowledge. Students receive their results on the exam along with information about what the scores mean, students are then given the choice to continue the application process. An independent selection panel of twenty to thirty community members reviews all submitted applications looking at academic achievement, test scores, teacher recommendations and student essays. No distinction is given to home school district, ethnicity or gender. Seventy five students are accepted each year for the freshman class.

Once accepted a student will spend half a day at KAMSC taking math, science and computer classes and half a day at their home school taking all other courses. Freshman and sophomore students come in the morning from 8-10:30 and juniors and seniors attend in the afternoon from 11:30-2:00 with the option to take an additional class from 2:10-3:00. School districts provide transportation for students to and from their home schools. The school operates on a unique schedule that allows three different lengths of class time; 45 minutes two days a week, ninety minutes once a week and 180 minutes once a month. The school also has open lab night most Wednesdays from 6-7:30 where students can come and work on homework or research. The school has one administrator, seven teachers, a research director, and a 1/3 time counselor (called a student advocate). KAMSC is also a founding member of the National Consortium for Specialized Schools of Mathematics, Science and Technology.

## Science Research at KAMSC

### Research Science

Research Science is a course all students at KAMSC are required to take which is embedded in their other core science courses. Students in the 9<sup>th</sup>, 10<sup>th</sup> and 11<sup>th</sup> grade complete the requirements for Research Science as part of their Biology, Chemistry and Physics courses. At the end of their junior year, students take an exam and if they pass with an 80% or above and have completed the requirements from the following three years, they are given credit for Research Science on their diploma. The Research Science course takes a scaffolding approach with the knowledge acquired each year building off the previous content.

Research director Dr. John Goudie spends time in the 9<sup>th</sup> grade Biology classes introducing basic aspects of research. The primary focus of the 9<sup>th</sup> grade component is on developing good library research skills, which is one of the three areas of focus for the course. Students take a field trip to the Western Michigan University library to learn how to use the library's online computer system and learn how to access other databases, indices, and libraries which are available for research. Students also look at scientific journal articles and abstracts to begin to get an understanding of what science research looks like. Students also receive some training in basic statistics in the 9<sup>th</sup> grade, from labs they are doing in their Biology class and from information presented by Dr. Goudie. All students select a topic to research and come up with a specific research question for an independent research project. Dr. Goudie provides some main subject areas of research and will help students narrow down projects if needed. For example in the 2014-2015 school year a main subject area was Biomedical Engineering with biophotonics listed as a possible specific area of research. One student selected biophotonics and her specific research question became "what is the effect of gold nano-particles on the advancement of biophotonics and medical applications?" (KAMSC document 3, Appendix C). For this 9<sup>th</sup> grade project the student does not actually work in a lab but does a review of the

research literature available to best answer their question. The student is given various grades during the spring semester to ensure progress is being made in the research and also to test the students' knowledge of science research and process skills. All students make a brief presentation to the class sharing what they learned from their research and a final research paper is submitted to Dr. Goudie. Students also participate in a school wide project day where all projects are displayed for parents, teachers and community members to view.

In the 10<sup>th</sup> grade Chemistry class, students work on a lab-based research project with a group. The topic is generally something students can research using the school's resources and involvement of mentors outside of school is not encouraged. Students are also given more information related to statistics, again often incorporated into labs being done in class. Research Science is "committed to the integration of subject matter content" (from Research Science Course Description) and the science courses are very lab focused, hence the fluctuating schedule to allow for longer periods of class time and intense labs. Students at this level also participate in the school wide project day, but do not compete at the regional science fair.

Physics is taught in the 11<sup>th</sup> grade and the student has a choice at this level to do a reading research based project or an experiment driven project. Group projects are usually not allowed and again the use of outside mentors is discouraged. Dr. Goudie and the Physics teachers are still available for assistance and mentorship, but the student is now primarily reliant on the research skills have they gained from the two previous projects. These students also participate in the school wide project day, but generally do not compete in the regional science fair. Students in elective course such as AP Biology or Astronomy will also have an independent research project, but this is not part of the Research Science course and the guidelines may vary depending on the teacher.

## Research Team

If these student projects are not entered into the regional fair then where do the KAMSC projects come from? In addition to the required Research Science course students can sign up for a science research based elective. The Research Team and independent research courses are semester course generally taken in tandem by juniors and seniors. Students taking the class are expected to complete the research project for any core course they are taking in addition to the project for Research Team. Students must apply to be in the class and Dr. Goudie is in charge of enrollment. Interested students meet with Dr. Goudie the spring semester prior to enrollment in the course to discuss research ideas and expectations. Students on the Research Team are paired with a mentor and given some class time to work in an off-campus lab. Students can work with a partner but this may be challenging due to potential scheduling conflicts. Dr. Goudie helps pair students with mentors based on research interest and students generally do not assist in the process. The number of students enrolled in this course ranges from year to year, generally between forty and sixty; forty seven students were enrolled for the 2014-2015 school year. Students are allowed to take the course two years in a row and can either work on a continuation project or develop a new research question.

The research projects carried out by students on the research team are entered into the regional science fair hosted and primarily attended by KAMSC. While the regional fair represents four counties, KAMSC is usually the only school present according to Dr. Goudie “schools can’t do this, they just don’t do this, it’s not feasible for them.....they are not in tuned to science fair” (personal communication, January 28, 2015). Projects from the Research Team will also be entered into the Junior Science Humanities Symposium, but interestingly those that are eligible will not enter into the Michigan state science fair citing too much time away from school as a reason. The primary focus is on the research, not the competition.

## **Elements of Excellence**

It would be very easy to say that Dr. Goudie is the reason for the excellent science fair representation that KAMSC has. This seasoned educator who has spent forty nine years in the classroom has been dedicated to science research at KAMSC since the doors were opened. This passionate educator who just as easily shows student research posters as he does drawings from his granddaughter would shy away from taking all of the credit for the schools success at the science fair. Indeed there are other pieces to the puzzle, with Dr. Goudie currently being the glue that holds it all together. The high level of students, the high expectations of mentorship, and the high amount of research exposure are all components that contribute to KAMSC's excellence in regards to the science fair.

## **High Level of Students**

Students involved in the Research Team at Kalamazoo Area Math and Science Center are the cream of the cream of the crop of math and science students in Kalamazoo County. These students had to be initially selected for admittance into KAMSC and they then had to be admitted onto the Research Team. These students are not only highly intelligent, passing the rigorous admittance standards to KAMSC, but they are also highly motivated because they willingly chose to apply for a school where the standards would be higher and more would be expected of them. One senior I talked to had the following to say when asked why she applied to KAMSC.

I wanted a challenge and I wanted the rigorous course work.....I heard amazing things about KAMSC and the amazing opportunities you had..... and how much more rigorous it is and I definitely wanted that especially with the science based stuff because I knew that was what I wanted to do.

(KAMSC senior, personal communication, January 28, 2015)

Many of these students are the top academic students in their home districts and are thankful for the opportunities provided at KAMSC that perhaps their smaller home district could

not provide. In addition to the excellent science courses offered there is a very robust Computer Science program with students also participating and excelling at a competition level. Students take advantage of the opportunities the school affords them and are passionate and excited about their education. During my research visit I was able to attend an open lab night and even with the threat of a winter storm approaching, about eighty students showed up to work on research projects, get help with homework or prepare for upcoming exams. The halls and classrooms did not have a study hall feel to them on this cold Wednesday night, but more like that of a festive lock-in. As I walked around, even though the atmosphere was very relaxed, students were actually working on homework and projects and ten of the twelve teachers were present and engaging with students.

These bright, motivated students may be inspired by competition but it is not the driving force behind their involvement in the Research Team. “When I first started working last year I didn’t know there was any type of competition so I just went in purely to get experience, and then I guess the competitions and the awards were just icing on the cake” says a senior KAMSC student another senior student says “I did it because I wanted to do research, that was my driving force.” These students genuinely love doing research and their eyes light up as they tell me about their different projects. When I asked one young man about the amount of time spent on his project out of school he replied “it does take a hit to your free time, but if you do something you enjoy it might be work, but at least you enjoy it. You don’t have unstructured time as much as you have time doing things you enjoy.” (personal communication, January 28, 2015).

### **High Expectations of Mentorship**

Another key piece of KAMSC’s success is the excellent students are paired with excellent mentors to enter into a research partnership. Dr. Goudie takes the idea of mentors very seriously and strongly disagrees with placing students in research labs before their junior year. While exceptions have been made, he believes no matter how bright a student is a certain level of

maturity should be present before students are allowed to enter into this mentoring partnership. He does this just as much for the student as the professor, wanting it to be a positive experience for both. Through the years Dr. Goudie has built relationships with many professors and research scientists which make the process of pairing a student with a mentor a little bit easier. The partnership with the Upjohn company, now Pfizer, helped to build the program. “The Upjohn company gave me a badge, so I always went to try to talk to scientists to see if there was a lab I could use with students and I pilfered equipment” (J. Goudie, personal communication, January 28, 2015). From the initial days of taking leftover equipment Dr. Goudie has created a mentoring partnership with Pfizer along with Western Michigan University, Kellogg Biological station and a new animal genetics company Zooetis just to name a few.

Students are not expected or even encouraged to find their own mentor. When the student initially meets with Dr. Goudie to discuss their research ideas he begins the search for the right mentor. Once the student begins the program in the fall Dr. Goudie will go with the student to tour the research facility and to meet with the prospective mentor. Dr. Goudie describes a little of the process in the following quote.

They (the student) come and they sign up and we talk, have an interview, to kind of see what they would like to do research in. So if they say medicine, or Biology or Chemistry, I have contacts in the community and will call them and say will you take a student in your lab, and then we'll make an appointment and I will take the student to the facility and we will have a discussion about what the student might do....and we'll see if it's a good fit. I want a good fit.

(J. Goudie, personal communication, January 28, 2015)

Dr. Goudie has also created a ten page brochure he gives to prospective mentors which clearly describes the course, and the expectations for the student and mentor. Dr. Goudie will also meet with students and their mentors throughout the course of the year to ensure the

partnership is progressing and to assist in troubleshooting. The weekend prior to my visit he had spent two hours in a coffee shop with two young ladies and their mentor trying to help them work through a technology problem.

As desire to be on the Research Team has grown the challenge to find compatible mentors has grown, according to students Dr. Goudie does a good job of trying to get you into a lab where you have an interest but sometimes the actual project may not be of your own choosing. When asked about the criticism that working in a lab means a student may not be doing their own project both Dr. Goudie and students I talked to were very adamant that no matter the research topic, the research experience from working in a ‘real’ lab was incredibly valuable. Says one KAMSC student who was working with a professor at the Kellogg Biological Station “I had to come up with the procedure and just to master all that took a while and it took a lot of problem solving and when it finally did (work) it was an amazing feeling.” Her fellow student echoed this when he said “even if you’re not choosing your own subject matter it’s the errors that you encounter, at least for me is, learning different ways to overcome them and tackle the problem.” (personal communications, January 28, 2015).

Several students said that working in a research lab had an impact on their understanding of science processes and content as well as helping them get into and decide where to go to college; “I was shocked at how many opportunities it has opened up and how familiar people are to with the research I am working with” (KAMSC senior, personal communication, January 28<sup>th</sup>, 2015). The high level of expectation for both student and mentor surrounding the partnership seems to ensure value and enjoyment for both sides. Most mentors want to stay involved in the program year after year and students seem to value the experience for years to come. The first morning of my visit Dr. Goudie received a card and an email from former students expressing to him how impactful involvement in Research Team had been for their college and career choices.

## High Level of Research Exposure

Every kid is getting a taste of either working by themselves or working in a group, designing a question, gathering materials...get data, analyze data.

(Dr. Goudie on the research class)

Perhaps another reason the mentoring partnerships are generally so successful is the students have been well prepared for entering a research lab. While the students may be unfamiliar with certain equipment or procedures, they have been thoroughly exposed to the process of research and have experiences in lab settings. This allows the students to participate in very advanced research and compete on a high level at the science fair.

KAMSC is unique in its approach to have a research course within but yet separate from the core curriculum. The research director and the teachers have to work closely together to ensure this “well-oiled machine” as KAMC director Dr. Tarnoff calls it, stays running so smoothly with the goal being to give students a ‘research experience (that) can help students develop a meaningful understanding of science concepts and phenomenon and apply them to real world problems’ (from Research Science: Introduction and Objectives). Students and teachers feel that the embedded research element is instrumental to the school’s success at science fair. “....it really introduces the idea of research so it’s not as foreign as it might be to a lot of people. And so when you see research team you’re not as worried about it and you actually think you might aspire to do it” (KAMSC student, personal communication, January 28<sup>th</sup>, 2015). Director Dr. Tarnoff is proud of his school for giving students the opportunity to see what it actually means to participate in science and students feel the same way, “right from the beginning we do really intensive research that we would not get at our home schools and that definitely helps...” (KAMSC senior, personal communication, January 28, 2015).

Within the Research Science course students are given the chance to participate in research and are also expected to understand a variety of components related to the process. As

referenced earlier the course has three main areas of focus; library skills, statistical tools and linguistic skills. There are ten items related to library skills, examples include 3) Be familiar with types of literature: primary vs. secondary and 9) Understand the basic format of journal articles (Appendix C). In regards to statistical tools fourteen items of desired understand are listed and these are prefaced by the importance statistical tools have in science research.

If you know what statistics can and cannot do, you may appreciate more fully the role of statistics as a tool of research and to see that it is logical, systematic, and reasonable, and not a hurdle in your path.....In the broadest sense the goal of statistical analysis is to draw conclusions and understand more about sources of or data. More specifically, the major roles of statistical analysis are data reduction, inference, and identification of relationships.

(from Research Science course outcomes, Appendix C)

To teach these important statistical tools students implement them in labs they do in class as well as broaching the topic of things like probability and central tendency in math courses. Reading scientific articles also helps familiarize students with statistical tests in a practical application format.

The third focus of the course is on linguistic skills, more specifically the practice of science talk and presenting the results of your research: there are four items specified under this topic on the Course Outcome document. Again the exposure to scientific articles plays a role here along with students presenting research findings in class as well as other seminar settings. Students have presented their science research via Skype to students in KAMSC's sister school in Hiroshima, Japan. The open lab nights also helps facilitate a student's comfort level with 'science talk' allowing time to discuss their project with teachers and students and assist in trouble shooting or clarifying of presentation of material. Participating in the school wide project day also gives students a chance to interact with members of the community in a low pressure

environment; by the time a student is actually involved in competition they have had practice presenting in front of others several times.

The Kalamazoo Area Math and Science Center is an example of how collaboration instead of competition can create a resource that develops amazing young scientists and takes what was a small spark of interest or desire and cultivates it into a burning passion to be the great minds of tomorrow, success at the Intel ISEF is just icing on the cake.

#### KAMSC Documents:

In the next five pages are documents that have been created by Dr. John Goudie in support of the science research program at Kalamazoo Area Math and Science Center. The first three pages (located on pages 158-160) are the beginning of the course syllabus for the embedded research class. This was included to present the scope and structure of the research class as designed by Dr. Goudie. The next two pages (located on pages 161-162) are pages from the mentorship booklet that is provided to students and mentors who participate in the research science team at KAMSC. The entire booklet is ten pages and only part of it was included here to give the reader an idea of the expectations and preparations that are part of KAMSC's approach to mentorship.

## Research Science: Introduction and Objectives

Science can be distinguished from other fields of endeavor by two main features. Obviously, it differs in its content – the type of organized knowledge with which it is concerned. A more important difference, however, lies in the procedure of science – its strictly empirical approach to problems. Science deals with rational beliefs that can be verified or disproved by observations or experimentation.

Skills in accurate and reliable observations; use of scientific literature, understanding experimental design and analysis require training and practice. This proposed course is committed to the integration of subject matter content, with research and design skills and experiences to help teachers help students organize their thought processes in a way most likely to lead to results.

Using research is but one instructional strategy that can be used to teach a packed curriculum. The research approach helps integrate scientific facts and problem-solving, which are the essence of science. A research experience can help students develop a meaningful understanding of science concepts and phenomenon and apply them to real world problems. This approach will also allow students to construct their knowledge by being engaged in solving authentic problems, in working with others and building solutions; in other words, it is an approach that teaches students "about" science by "doing science."

Like any course, performance objectives, and expected outcomes help to focus teacher efforts to train and teach. They also set up goals for students to attain. The following are proposed exit outcomes, research program outcomes, and course specific outcomes. These outcomes need not be completed in a single year but are suggested over a three-year period.

### Exit outcomes

(What we want all students to demonstrate when they leave our school.)

Your students:

1...will be self-directed learners capable of setting priorities and achieving mathematical and scientific goals; capable of monitoring and evaluating their progress; Will be able to create options for themselves to achieve their goals; Will be able to assume responsibilities for their actions; and will be able to create a positive, a healthy image for themselves and their future.

2...will be collaborative workers; able to monitor their own behavior as a team member; able to assess and manage themselves in a group effort; demonstrate interactive mathematical and scientific communication with clear consideration for individual differences.

3...will be complex thinkers capable of using a variety of strategies and higher-order thinking skills appropriate for the resolution of solving complex mathematical and scientific issues; they will be capable of accessing and using topic-relevant knowledge.

4...will be able to create products that achieve their purpose, products appropriate to their intended audience by using appropriate mathematical and scientific resources and technology.

5...will be a community contributor, demonstrating a cultural knowledge and real-world mathematical and scientific application about his/her diverse communities; capable of taking actions in those communities to be a significant contributor and member of that community.

#### Research Program Outcomes

(What students must show they know, are able to do, and are like when they finish the  
your research unit or course.)

Your students:

1...will possess an ability to ask questions of data by looking at data from an "experiment", scrutinizing, interpreting, and using existing data.

2...will possess an ability to get answers by being able to look at data and create new data.

3...will possess an ability to make logical arguments being able to spell out the rationale assumptions behind their things.

4...will possess an ability to make logical arguments supported by data including use of the scientific method as a technique to organize their thoughts in a way that will lead to results.

5...will possess an ability to search for and analyze scientific literature; possess an ability to communicate complex and technological issues in both a written and oral form.

6...will possess an ability to use statistical techniques to foster scientific inquiry skills that can be transferred to other spheres of problem solving.

7...will be a community contributor by participating/attending scientific conferences, workshops, seminars, and fostering mentorship relationships as demonstrated by a Student Portfolio.

Course Outcomes – content specific  
The Tools of Research

Research is a systematic quest for undiscovered truth. It is the search for an answer to an unresolved and perplexing question. In the pursuit for an answer, it is necessary to rely on a number of tools to help you. The basic tools include: library tools, statistical tools, linguistic tools, and mentoring skills.

### Library Skills

Students should be self-sufficient in the library. The following basic library skills will be discussed with students who are expected to become proficient with them.

#### I. Be familiar with a library search process:

- a. Initiating a research assignment: comprehension of assignment, relate to prior experience and learning, browse in a library, consider topics, brainstorm, discuss possible topics in class or with others.
- b. Selecting a topic: get an overview, make a decision
- c. Evaluating information sources: identifying keywords, define topic, keep log or source log
- d. Making a decision on a topic
- e. Collecting information (strategies for searching)
- f. Preparing to present: understanding the audience, organizing notes, outlining, quoting, paraphrasing, and summarizing

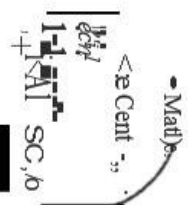
#### 2. Understand the Library of Congress Classification System

#### 3. Be familiar with types of literature: primary vs. secondary

#### 4. Learn the library's on-line computer system for searching books (These have replaced Card Catalogues)

#### 5. Be knowledgeable of the library's other data retrieval systems including BRS, InfoTrac, Dialog, WalsOnline, Newsbank, Science Citation Index, etc.

## Kalamazoo Area Mathematics & Science Center



### The KAMSC Science Mentorship

#### Course Description

The KAMSC Science Mentorship provides opportunities for students to participate in research or engineering projects under the direction of mentors in the local scientific and engineering communities. These opportunities provide students with valuable experiences as well as professional contacts that enhance their academic profile as they seek to enter challenging programs at major colleges and universities throughout the country.

#### Course expectations:

Expectations are high for students entering into a research relationship with local mentors. Students accepting this challenge are expected to develop a set of research skills and to demonstrate the maturity and behaviors that are characteristic of scientific professionals. The following is an example of some of these expectations.

1. Students will be self-directed learners capable of setting priorities and achieving mathematical and scientific goals.
2. They will be collaborative workers demonstrating interactive mathematical and scientific communication with clear consideration for individual differences.

3. They will become complex thinkers capable of using a variety of strategies and high-order thinking skills appropriate to the resolution of solving complex problems.

4. They will be able to create products (e.g., engineered designs, research paper, or computer programs).

5. They will share knowledge gained through presentations at symposia, science fair competitions and other research competitions.

#### What is KAMSC about?

The program at KAMSC draws talented students from area high schools, public and private, throughout Kalamazoo County and parts of the surrounding counties. The students in this program are selected from the top of applicants on the basis of academic achievement, test scores, essays, and teacher recommendations. The selection panels are made up of community leaders, local scientists, engineers, and business people. The 300 students attending KAMSC (75 in each class) spend half of their day at the Center and the other half at their home schools.

The program is an accelerated sequence of math, science, and computer courses taught by teachers with proven track records in teaching gifted and talented students. Many of the KAMSC courses taught are at the college level. There is a strong emphasis on student research, and students wishing to go to the next level are offered the opportunity to work with researchers in the community. Many of these mentored research projects have resulted in publications in scientific journals with our students as co-authors.

#### Who are KAMSC Research Mentorship students?

KAMSC Research Mentorship students are juniors or seniors who have the desire and motivation to participate in a real-world research experience. They possess the following basic laboratory and personal skills:

#### •Basic Laboratory Skills

- Measurement
- Math Skills
- Conversion between units
- Knowledge of the metric system

What is a mentor?

*"...every scientific mentor will help to shape the lives of his/her students, moving them ever closer to using the full measure of their often unrealized abilities."*

*-Rolie Otto, Ph.D.*

### What are Ideal Expectations of a Mentor?

- Committed availability -- mentorships are time consuming
- Mentor must have a vested interest in student's research
- Mentor doesn't give researcher too much help
- Mentor is open to guiding research
- Mentor exposes students to higher-level techniques within the research -- "tools of the trade"
- Mentor recognizes the skill level of the student and guides appropriately
- Mentor determines a deliverable evaluation of experience and an assessment of a student researcher's skills
- Mentor must spend time in communication with students and must ask probing questions
- Mentor must demonstrate passion for research
- Mentor should aid in writing reports
- Mentor should be aware of and open to different formats of report writing
- Mentor must explicitly deliver safety rules before using a lab
- Mentor and researcher should discuss ethics of scientific research -- observation, collection, and reporting of data
- There must be open communication between KAMSC and mentor about the progress of the student
- Inspires the student researcher to set and reach new academic heights and goals
- Provides guidance, direction, and support with the student's required research proposal, abstract, paper, poster visual display, and oral defense
- Provides opportunities for the student researcher to develop valuable research skills
- Keeps the student "on-track"! The student should be held accountable for his/her time and quality of work and effort

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- Reports to KAMSC's Research Facilitator any needs or concerns regarding the student or the progress of the research
- Makes an arrangement to have a responsible colleague act as a proxy mentor to the student researcher, if the designated mentor is unavailable for more than two consecutive weeks
- Provides an open learning environment where the student feels comfortable in approaching and asking the mentor questions

### Expectations of a Mentor

- Mentors should be an active source of expertise and encouragement for their students.
- Mentor should not be the sole source of information utilized by the students.
- Mentors should cooperate with students in devising and executing projects, and should not simply plug a student into pre-existing ongoing research projects.
- Mentor should not initiate direct personal contact with the students, and may not invite mentored students for personal visits at any location.

### Expectations of the Projects

- Projects will involve practical research and independent work by the student.
- While a search of the relevant literature is an essential starting point to all research projects, projects will not be limited to library research.

### Expectations of the Mentoring Relationship

- The relationship between mentor and student should be strictly professional. Both mentor and student should remember that the relationship is that of a professional scientist to a student, as well as an adult to a minor.
- Students and mentors should e-mail the Research Facilitator at the conclusion of the mentoring relationship. This letter should include both the quality of the mentoring relationship as well as any suggestions for improvements to the Science Mentorship Program.

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## Appendix F

### Oregon Episcopal School, Beaverton OR

#### **Oregon Episcopal School Case:**

Oregon Episcopal School (OES) is a private school located on over fifty acres in the Portland suburb of Beaverton. The school serves over 800 students from kindergarten to twelfth grade. A boarding option is provided for 9<sup>th</sup>-12<sup>th</sup> grade students, but the majority of the students are day commuters. The school was originally established as a boarding school for girls in 1869 with a boys hall being added in 1962, in 1972 the two halls were emerged into the existing OES. Tuition to OES varies depending on grade level, beginning at \$24,100 a year for kindergarten and increasing to \$29,300 for 9<sup>th</sup> -12<sup>th</sup> grade, financial aid and scholarships are available and the fee is increased for boarding students. The school is divided into a lower, middle and upper school. The lower school consists of grades K-5, middle school is 6-8, and upper school is 9-12. Of the six science faculty at the upper school four have Ph.D.'s, one has an MD and one has a master's degree. Three of the four science faculty at the middle school have a master's degree.

#### **Science Curriculum and Science Research**

While not advertised specifically as a math and science school, science is a very big focus of the Oregon Episcopal School and inquiry based teaching is something emphasized in all subject areas. Science is not taught in the lower school as an isolated course, but there is a science specialist who teaches or assists teachers in the lower school classes once or twice a week and introduces inquiry based projects to the students. In the 6<sup>th</sup> grade OES students have science for the first time as a subject and this is also when students begin their involvement with the science research program which will continue through their 11<sup>th</sup> grade year.

The science research program began about thirty years ago with Dr. Bill Lamb. Dr. Lamb, who has a Ph.D. in science education, was dedicated to the idea of inquiry and helped shape the science program at OES around this important concept according to Jordan Elliott head

of the Upper School “(he) really helped us make this commitment to inquiry and this understanding that the kids were going to have a better experience learning about science if they were hands on with it and even better if they were designing and implementing a project” (personal communication, January 6, 2015). Dr. Lamb was known for his creative and demonstrative ways of teaching and when the science building was recently remodeled a two story drop zone was specifically created for Physics experiments, complete with sand pit, in honor of and named after Dr. Lamb.

Dr. Lamb, who retired in 2012, left not only his legacy in the science program at OES but also on the Portland area. Unable to find a place for his students to display their projects, Dr. Lamb founded the Northwest Science Expo in the mid 1980’s (Owen, 2012); Portland State University has now taken over the Expo and it is housed under the Intel Northwest Expo System; involving many schools, grade levels and science fairs in the Portland area (Intel Northwest Expo System, 2015). The research program has grown so large at OES that they now have their own ISEF affiliated fair called the Aardvark Expo and only submit limited projects to the Northwest Science Expo (C. Mader, personal communication, January 6, 2015).

Conducting an independent research project is a required part of core science classes in the 6<sup>th</sup> through the 11<sup>th</sup> grades, accounting for about a quarter of a student’s grade. Some class time is devoted to the research process but what is done during this time may vary depending on teacher or grade level. In the upper school, time is usually not spent on experimentation but instead on helping students with items related to writing and preparation, “because of the huge diversity of projects that we have, the class time for experimentation doesn’t help pay for most projects.” B. Daglan, science teacher and lab director, (personal communication, January 6<sup>th</sup>, 2015). Students in the middle school are given class time to work on actual experimentation and have a smaller research window than those in the upper school, four to six weeks versus twelve. Another difference in the middle school is that students in the 6<sup>th</sup> grade do not participate in the

Aardvark Science Expo, the school fair for OES; instead they have a science showcase night which allows students to practice communicating their findings to others but takes the pressure of competition away from the novice researchers. Taking the 6<sup>th</sup> graders out of the competition also allows for experimentation to start later in the year, when students have more fundamental knowledge of science process skills and also when they do not have to compete with the 7<sup>th</sup> and 8<sup>th</sup> graders for resources such as equipment and space. Benno Lyon, 6<sup>th</sup> grade teacher, advocated for changing the process for 6<sup>th</sup> graders several years ago:

A lot of kids were just lost in the process; it was just too soon for them. I had a lot of support in the school when I started bringing it up, like pedagogically does this make sense? Like swimming lessons, you don't just throw the kids in the pool and say swim you give them some waders and let them figure it out.

(B. Lyon, personal communication, January 6, 2015)

An additional advantage of the change has been 6<sup>th</sup> graders get to see the completed projects of their slightly older peers and so are provided with good and bad examples to draw from before completing and presenting their own projects.

For all other students, science research begins the first day of class with idea generation. Some students have already started research over the summer, with OES teacher approval, but many others are still searching for ideas. There is some push for students to do projects related to the course they are in, for example students in 9<sup>th</sup> grade Physics should try to do Physics related projects.

As much as I can I steer my students to do Physics related projects because then I have rabbits when those units come up later in the year and I get a dividend..... I figure if I'm investing Physics curriculum time in this I want to get something back if I can.

(R. Orr, personal communication, January 6, 2015)

Overall, teachers try to encourage students to do something related to an area of interest recognizing if a student has a deep interest in something they will be more motivated and have a more valuable experience also these students will more than likely require less energy from the teacher which is important to consider when you have forty projects to manage. For those who struggle with generating an idea the teachers are willing to help out if necessary.

A lot of our (topic) diversity just comes from students hearing things outside of class, there's been a lot of NPR stories that they listen to with their parents on the way into town...we also come up with ideas over the summer and we bring them in and we're all excited and try to sell them to the students.

(B. Daglan, personal communication, January 6, 2015)

Once students have identified an area of interest they have about four weeks to come up with a research plan and get it approved by the teachers. The twelve week experimentation/data collection window begins for the upper school in October and ends in January. Labs are available after school and some weekends and holidays for students to conduct their experiments. The school has two dedicated research directors who share responsibilities related to the science fair and science research in addition to some teaching duties. These teachers, along with others, supervise the students during open lab time. The school has a lab that is dedicated solely to independent student projects and can be viewed through a large glass window from the shared science teacher office. Students sign up for lab time to help manage resources and to ensure supervision is available. Other labs can be used for independent research if necessary. After the data collection window closes, students have six weeks for analysis and write-up.

Many grades are given along the way and tare sheets are collected to ensure students are progressing in their research. Due to the diversity of research projects and extenuating circumstances most teachers remain flexible, like Physics teacher Rob Orr "we have 1<sup>st</sup> data points due, but an engineering project isn't going to have a data point so.....we have to have

some flexibility in this” (personal communication, January 6, 2015). Teachers vary not only in their strict adherence to deadlines but also in group structure, some teachers allowing students to work in groups and others requiring all students work alone. Students are not necessarily encouraged or discouraged to work with mentors outside of school but very few do. In the 2014-2015 school year less than 20% of the upper school students were working with outside mentors.

### **Elements of Excellence**

It could be easy to assume that any element of excellence has to do with the mere fact that Oregon Episcopal School is an exclusive, private school. While it is probably true that the availability of resources is a contributing factor to science fair success, there are other elements present: embedding science research in the curriculum and creating a collegial community for teachers and students.

### **Resources**

Entering the OES campus it is immediately obvious that the school does not suffer from a lack of financial resources. Sitting on over fifty acres in the upscale Portland suburb of Beaverton, the lush campus greets visitors with a half mile long tree-lined driveway showcasing the natural laboratory space available to the students who attend here. Several of the buildings have been recently updated and most of the science labs boast equipment not normally seen in most high schools. To be fair the scanning electron microscope is on extended loan, but the available resources are very impressive. One space specifically designed with the research program in mind is the dedicated research lab that is not attached to any classroom. This allows students to leave projects out without worry that they will be tampered with by a distracted student or pushed aside to make room for a class Chemistry experiment. This dedicated space also helps to foster the collegial community that exists at OES which will be discussed later. The 7<sup>th</sup> and 8<sup>th</sup> grade science rooms were also redesigned to all some lab space to help with the

sophistication and storage of those projects.

A wealth of resources not only means students at OES have access to up to date equipment along with plenty of space to work but students are also provided any needed materials for their experiments. Students submit a request to one of the research directors, Tanya Horvat, who is responsible for ordering any additional supplies or organisms students may need for their research project. While many of the students who attend OES most likely have parents who could afford to spend money on a project, the fact that it is centralized through the school helps the teachers stay connected to the students and the projects.

The school also spends funds on student posters, purchasing a large standard format printer several years ago to print student projects. The original motivation was to eliminate the amount of time students were spending on the creation of a poster and ease tensions across campus. According to Jordan Elliott “there was a strong perception among the faculty that the science department had a big impact on student time, so over the last eight years we’ve taken away the things that are demands on time that aren’t elements of the research” (personal communication, January 6, 2015). Instead of spending time cutting and pasting, students upload information into a power point type template and the school prints the large poster which would normally cost the student around a hundred dollars. An unforeseen benefit of this has been a clearer picture of research for evaluation purposes. As teacher Rob Orr puts it “the playing field is leveled really nicely, everyone can produce polished good looking work and you get to base it off of what the science was” (personal communication, January 6, 2015).

The students and faculty should also be considered resources that add to the school’s success at science fair. Attending OES does not come cheap and while scholarships are available many of the students attending have parents who are involved in one of the many science or technology related industries that call Portland home. Sometimes referred to as the ‘Silicon Forest’, Portland is home to many technology companies including ISEF sponsor Intel along

with the science education software company Vernier. While these parents are encouraged to be hands-off in regards to their science research projects, one must take into account the impact having science minded parents has on a student.

The science faculty at OES are also excellent resources, often specifically recruited for their research expertise. Jordan Elliott, head of the Upper School describes an ideal science teacher at OES, “we have to go out and find people who have done research who understand research and have demonstrated experience and also want to be teachers who want to work with kids.” Teacher Rob Orr supports this statement saying having research experience was what helped him get a job at OES. Students working in the labs after school have the experience of Bevin Daglan, who earned her PhD in Chemistry, to help them and if Dr. Daglan is unavailable co-director Tanya Horvat, who is an MD, would be the available back up.

### **Embedded Curriculum**

An important part of the success of OES is the embedding of science research into the curriculum and more broadly a school-wide focus on inquiry. The importance of this focus is shown in the following statement found on the schools website under Inquiry-based learning:

At OES, learning from day one is active, not passive. Students don’t just study science – they do it. They don’t just read great writers, they write – and write, and write. They don’t just listen to teachers, they ask questions. Each experience leads to the next one, always driven primarily by the passion and persistence of the student who serves, in effect, as the architect of his or her education.

(Oregon Episcopal School website, 2015)

Students are not only exposed to inquiry by doing an independent research project, but most of the labs they do in science class are geared towards an inquiry approach and instruction in other core classes takes this approach, helping make students comfortable with teachers not always providing answers. “Teachers have done a good job of making students and parents

understand it's about the question. " (S. Herdister, personal communication, January 6, 2015).

Designing and carrying out an independent research project is a requirement for every student at OES from the 6<sup>th</sup> through the 11<sup>th</sup> grade. While admittedly not every student is excited about this, even those who participate begrudgingly admit their projects get better year after year. Two young ladies who are quick to tell me they will not do a project their senior year (when it is an elective choice), are still excited to tell me how they have improved on their project with sunscreen toxicity from last year. Another student who placed at Intel last year explained to me how he was improving his project from last year based on judges critiques "they told me my clean up solution (for an oil spill) wasn't as environmentally friendly as it could be, so I am trying this year to create a better product" (OES student, personal communication, January 6<sup>th</sup>, 2015). This same young man becomes very animated when telling about his trip last year to Los Angeles for the competition and other students working in the lab begin asking a few questions about the trip. By providing a research opportunity multiple years for students, OES is allowing students to improve their research skills and designs, but it also affords the opportunity for students to share their experiences regarding the awards and social component of the competition and has created a climate of science is cool. Speaking from the parent perspective Scott Herdister, says "My kids are not enthusiastic scientists, that's not their passion. But they'll get pretty into it, they'll spend the whole Saturday doing science research, and there's a social piece to that to..." (personal communication, January 6, 2015).

Administrators admit the intensity and duration of the research program has positive and negative effects. Thanks in large part to the success of the students at Intel and other competitions; OES now has a reputation in this competitive private school community as a strong math and science school. In 2010 two OES juniors won the Siemen's competition, along with it's \$100,000 prize and just last year two young ladies won best in fair in the life sciences division at Intel and went onto win 3<sup>rd</sup> place in a National Institutes of Health competition

gaining publicity even in the Wall Street Journal (Reddy, 2014). This is great publicity for the science programs at OES and helps to attract students interested in science which in turn helps to feed the program. For those students not as interested in science it may cause some students to switch to other schools in the 8<sup>th</sup> grade, “to be quite frank we probably lose a couple of kids in the 8<sup>th</sup> grade because they cannot imagine doing three more years of science research.” (S. Herdister, personal communication, January 6, 2015). There has even been some discussion about expanding the research opportunities to other areas in order to appeal to the interests of more students and the school does have excellent programs in other areas but it is harder to publicize that in the community.

The accolades in science are so developed and well publicized through ISEF and Siemen’s, Westinghouse, whatever, there’s so many things that are associated with that that are tangible that’s it’s easy for people to associate with that kind of a school. We’ve actually been trying to build up (the) kind of fairs that are communities that our students want to be a part of, like English and history and the arts and there’s nothing like what happens in science in the structure so building up perception of what happens on the other end is just not as easy.

(J. Elliott, personal communication, January 6, 2015)

Interestingly enough, even with the large emphasis on science research, teachers are hesitant to label OES a math and science school and instead want to think of it as an inquiry school, pointing out collaborative projects that are done across areas and stressing the emphasis on inquiry in all subject areas. Even alumni do not connect OES’s strength areas with the science program. In a recent alumni survey respondents said preparation for writing and making analysis were things OES was the strongest at, which Jordan Elliott is quick to point out are a big part of the science research project (J. Elliott, personal communication, January 6, 2015).

Teachers and administrators also point out the emphasis of the OES curriculum is on science research and not science content and this again provides benefits and obstacles for the students. The benefits to students are the experience with research can help interested science majors on college applications as well as providing research opportunities at the undergraduate level. Working on an independent research project can foster skills that will help all students not just those pursuing science careers. Jordan Elliott, who is not only head of the Upper School but also an OES alumnus, felt the experience influenced other academic areas.

I was actually talking to a friend yesterday and he was an English major and I was a religion major in college and the skills that we learned in science research were directly applicable to doing work in a different field. Just how do you find your sources, how do you have a project, how do you manage your timeline....I believe that learning science is best done through an inquiry approach and there's a huge benefit to a students' academic skills from doing that project.

(J. Elliott, personal communication, January 6, 2015)

Because of the amount of time spent on labs and independent research, the amount of time for content is reduced. OES has tried to mitigate some of this by offering science elective classes in focused areas that may not be given as much time in a content course. For example, Physics is offered in the 9<sup>th</sup> grade at OES and is Algebra based; a Calculus based advanced mechanics class is now offered for seniors in response to student concern about taking Physics in college. Rob Orr says teachers are constantly asking for alumni feedback and the students responsive is usually positive, "they say I was two chapters behind everybody else but I was the first person selected for laboratory research assistant, that's not bad; two chapters they can do in a summer". This sentiment was echoed by student I overheard talking to a teacher while I was waiting in the lobby. The student was home on Christmas break and stopped by to visit with some teachers, he was telling his Chemistry teacher how easy the lab had been for him at his

university and how that translated into him doing well in the lecture because of his grasp of the concepts in lab. Even with student support and award winning science projects, there is still some concern from parents that OES does not offer advanced placement courses for science but the school administration has no plans to alter the curriculum to accommodate those programs.

### **Collegial Community**

The final component that contributes to the success of the science fair at Oregon Episcopal School is the incredibly collegial community that exists, palatable among the science department, but also present across the whole campus.

As I drove up to OES I admittedly had pre-conceived expectations of what I would find regarding the culture of an expensive, religiously founded school. I was anticipating starched uniforms, quiet hallways and subdued students and teachers; I could not have been more wrong in my perception. Immediately upon walking into the bright, modern lobby I saw casually dressed students engaged in conversations with teachers, often referring to them on a first name basis. I was greeted warmly and offered coffee (which I believe was required being in the Northwest) and as I sat and waited for my host I saw several former students eagerly sharing with former teachers the trials and joys from their first semester of college. The warm, welcoming atmosphere continued as I toured the campus with the carpeted hallways, bright windows and generous open green spaces. Students were friendly and greeted most teachers, usually using first names.

As I entered the science office I was amazed at the wall of glass windows providing a full view into the research lab. All of the upper school teachers are housed in the same large office and many of them expressly said this is a contributing factor to the success of the science program at OES, “this office space matters a lot” says Rob Orr, says Peter Langely “everybody is aware what everyone else is doing and able to help if necessary”. Indeed it is in this space where

science fair collaboration first begins when teachers meet as the review board for student projects. Projects are approved or rejected with notes made for the students on how to improve the project and who in the department might be a good resource. As Rob Orr puts it “the networking is hugely beneficial for the students and wonderful collegial building for the teachers because I think in a lot of cases if I was just going to a school to start a science fair it would be Rob on an island.” (personal communication, January 6, 2015).

The teachers also see helping with the lab as a group effort even though technically it is assigned to the lab and research director. On a day I am there to observe three additional teachers stay after school to assist students with projects; many teachers also volunteer time over holiday breaks to assist the lab director and keep the lab open more hours for students.

Being available for students is very important to the teachers and in fact my interviews were interrupted several times by students coming in to ask questions about research or see if they could work in the lab. The science door office is always open and students are encouraged to seek out help whenever they need it, according to Bevin Daglan this is a key component of the culture at OES “you are strongly encouraged and almost forced to advocate for yourself and talk to teachers.....being able to engage the adult community is a huge part of their success. And that comes from the whole (OES) community, we’re always chatting them up and their like, okay I’ll talk to you” (personal communication, January 6, 2015). The shared lab and office space not only provides students the opportunity to engage in discussions about research with teachers but also with each other;

They’re not at home in their garage, they’re in her with a dozen other people and their waiting for their stuff to boil and so their like ‘hey what are you doing over there?’ so they discuss their research together....they’re explaining their research. It’s like this is how science happens.

(B. Daglan, personal communication, January 6, 20105)

The resources, embedded curriculum and collegial community that exist at Oregon Episcopal School are key components to the schools success at science research and thereby science fairs. It is hard to say what the lynch pin is, did the curriculum drive the resources thus creating the communities, but what is most important is the dedication of the school to continue to do all they can to foster the success of the students and the school.

## Appendix G

### **Plano Independent School District, Plano TX**

#### **Plano ISD Case**

Plano Independent School District serves residents in southwest Collin County, encompassing the city of Plano a large northern suburb of Dallas, TX. The school district reports having a pre K-12 total enrollment of 54,839 students in the 2014-2015 school year (Plano ISD website, 2014) divided among 72 campuses. The grade configuration for the secondary students is as follows; 6-8 is considered middle school, 9-10 is high school and 11-12 is senior high school. There are 13 middle schools, 6 high schools and 3 senior high schools and one academy school which serves students 9-12. The majority of the students are Caucasian with high minority populations of Asian and Hispanic students. Interesting to note large numbers of Indian students were seen at the Science fair but the demographic data provided does not represent this population in anyway (see Appendix A).

#### **History and structure of Program**

Plano ISD's science fair program began in 1984 when science teacher Becky Wussow and husband Dr. Jim Wussow (now an assistant superintendent) decided to start a science based research club for students, "I thought that getting kids doing research was important" (J. Wussow, personal communication, February 11, 2015). The LASER club (Learning About Science and Engineering Research) quickly spread to other high schools in Plano ISD. Says Karen Shepherd former science teacher who is now the science coordinator for the district, "once I heard they were going to do it at Shepton, I wanted one at my school" (K. Shepherd, personal communication, February 10, 2015). The first science fair was hosted in 1985 by Clark High School and included 40 projects. From the LASER club the program has spread to create opportunities for students to be involved in science fair from kindergarten to the 12<sup>th</sup> grade. The requirement of when students are expected to do a project is similar throughout the district and

the parameters are listed below:

- All students in honors science classes in grades 7<sup>th</sup> & 8<sup>th</sup> are required to do a science research project.
- Students in honors science classes in 9<sup>th</sup> and 10<sup>th</sup> grades can either do a science project or an alternative project.
- All high schools and senior high schools offer an advanced science research course; a certain number of students must be interested in the course and space must be available in the schedule for it to actually be offered at the school.

Currently out of the three schools serving senior high school students (11-12), two of them have a class. Out of the six high schools (9-10), four offer the science research class.

- All high school and senior high schools offer a LASER club for students to be involved in.

(K. Shepherd, personal communication, February 10, 2015; Plano ISD website, 2014)

Additionally at some campuses, elementary students carry out a science fair or extended research type project. This may be an all school requirement or a requirement for those in gifted and talented programs, but again is not a district mandate.

To help teachers and students organize a science fair project the district has created handbooks that they provide students at the beginning of the year; there is a K-6 handbook and a 7-12 handbook. The K-6 handbook is 16 pages and covers topics related to the science fair such as how to come up with a project and creating a display board. The handbook for 7-12 covers the same topics and many more in much greater detail, it is about 45 pages; the handbook for the teachers is 48 pages and covers the same topics as the students' with some additional explanations and examples. The handbooks were initially created by Karen Shepherd and another teacher for their high school teachers and students; eventually these were shared throughout the district. The initial authors also helped expand the handbooks to include all grade

levels. Changes are made from year to year to include correct dates for school and regional fairs and any change or update in ISEF rules. For example this year ISEF has changed from seventeen categories to twenty so that may require a change in the category description section of the handbook. Teachers and students in the middle school use the handbook as part of their curriculum and spend every Friday on some topic related to the science fair. Students are not generally provided any class time for experimentation but time is spent on helping students come up with a project and helping them understand information related to identifying variables and writing a hypothesis. One teacher explained how she worked with the librarian to help students come up with a topic. The librarian will have science related magazines out on the tables in the library with stacks of different colored sticky notes. The students are told to use one color just going through and marking anything that seems interesting. After scanning they are told to go back through and look a little more closely at the articles that first caught their attention, marking two or three that they are really interested in with the other color sticky note. The librarian then makes copies of the articles to share with the classroom teacher and they use them to derive student projects from them.

Each school is responsible for conducting their own science fair and grading of projects. Some schools have a LASER club sponsor responsible for this or a science fair coordinator, and some schools rely on parent volunteers. Karen Shepherd and two other district employees look at the paperwork for every student. For the 2014-2015 school year, the state implemented an online program called Oracle to help manage the over 4,000 projects. Karen Shepherd will also help teachers if they need judges. Different schools have different methods of grading projects and conducting fairs. Some schools will begin mentioning the science fair to parents at back to school night and other parents said they only learned about it through students. Teachers I talked to at one school said they do not divide students into categories at the school; they just select the top projects across the board. Another school divides the students into categories and awards

prizes based on judge's scores. In another school the teachers select the top projects from their classes to compete at the school fair so there is less work for the judges.

The amount of projects each school is allowed to send forward to the regional fair is 2% of the campus enrollment. This means the smaller percent of the school's population that is competing in the fair, the more students that can move onto district; hence the seemingly ambiguity from some schools on how they select projects to move forward. If a school has 400 projects out of 400 students, 2% would be significantly less than top winners in every category, but significantly more than only grand prize winners.

The district conducts its own fair bringing together all the winners from the different schools into a dress rehearsal for the regional fair. Prizes are awarded and feedback is provided, but every student at the district fair is already eligible to participate in regional, and winning the district fair does not immediately send you to state. Teachers say they like the idea of giving students a chance to practice their 'elevator speech' and experience the feeling of being in the higher pressure environment. The judges are encouraged to provide good feedback and constructive criticism that will help the students at the regional fair. In meeting with the judges on the morning of the fair Karen Shepherd mentions a project from last year that did not place at the district fair but due to judge's feedback the student was able to improve and won an award at Intel ISEF.

Each awarded project receives a pink ribbon prior to the award ceremony. This indicates to the students that they have placed but not specifics on their ranking. It was interesting to watch the reaction of parents and students checking to see if they had a pink ribbon, again all of these students were already eligible for regionals but the pride and disappointment was evident as they searched for the pink ribbon.

### **Elements of Success**

This expectation and excitement for winning relates to the culture of success surrounding the science fair that Plano ISD has created over the last thirty years. The tradition of science fair is woven into the fabric of the school and community and has grown along with the school district. The continued success would not be possible if there was not support from the district and the community and if dedicated teachers and administrators were not so passionate about providing this opportunity to students.

### **Tradition of High Expectations and Involvement**

**From the school.** Over the last thirty years Plano ISD has been able to not only create students who excel at science fair but they have made conducting science research a backbone of the entire science curriculum and school culture. Starting with a small club in 1985, every student in the district is now exposed to science research for multiple years; students even have the opportunity to letter in science fair just as they do in football or band. In a school district this size there are bound to be some differences in actual implementation of the project, but the basic expectation of an extended research project of some kind is present across several grade levels. While gifted or honors students may be the more targeted audience the opportunity and expectation is there and accessible for every student. “Experience gets them excited, if they don’t have a chance to do research how will they ever know” Plano parent (personal communication, February 10, 2015).

In talking to several teachers, students and parents there are commonalities but not always consistency among the schools, again a challenge caused by the number of school in the district. There is some inconsistency at the high school level in regards to what types of alternative projects are offered and how students are given grades for the different projects. For example when talking to two young ladies from different schools one said she was being given extra credit for doing the science fair and the other said it was a part of her grade. This student

went on to say her teacher told her if she didn't place out of the school science fair she would have been given an automatic 75%. There is also some inconsistency at the middle school level on requiring a science project or allowing for an alternative type of assessment. One teacher I spoke with said she allowed her students in 8<sup>th</sup> grade the option of doing a science project or they could do a research paper, build a webpage, create a video or create a fictional story around a research related topic. A senior high school teacher said he is seeing more teachers at that level offer the projects as an optional assignment with fewer of the students taking up the offer. More than one teacher commented on the empty spaces on some of the tables, saying the convention room where the district fair is held used to be filled.

While the expectations of doing a project may fluctuate some and there may be a small decline in projects at the senior high level, the expectation of Plano dominating Texas in science fair is alive and well. When I mentioned to one teacher how surprised I was to see students disappointed for not receiving an award at this dress rehearsal fair she commented that they were upset because they knew the Plano projects were probably their greatest competition and the awards here reflected how they would do at the regional fair. This might have proven to be true, Plano captured 3 of the 4 junior division Grand Prizes and 4 of the 4 Senior Division Grand Prizes plus all the ISEF qualifying spots went to Plano kids at the district fair. In addition Plano seniors took 47% of the 1 and 2 places at the Texas State Science and Engineering fair (Dallas Morning News, February 21, 2015).

**From the students.** Performing well at various competitions is one motivation and seemingly expectation from students. "Plano has a big reputation at science fair so you feel confident walking into state" says one Plano student. Students also have an expectation that being involved in the science fair will be helpful to them later in life. Even a 6<sup>th</sup> grader I talked to told me "it's hard work but it totally pays off, and I know it will pay off for my future" (personal communication, February 11, 2015). One young lady said she decided to do the science fair over

the option of a research paper because she heard from older students it was good for your interviewing skills. This same benefit was also extolled by one parent who, an engineer himself, said he encourages his daughters to do science fair because “I don’t want them to be awkward engineers like so many people I work with, I want them to have experience talking to people.”

Exemplifying these traditions of excellence past award winners are well known and the young man who won ISEF last year is greeted almost like a rock star. He is not participating this year but does tell me how his experience with science fair helped him with college scholarships and interviews. “Science fair gave me something to be proud of; it was a good talking point in interviews” (Plano SHS student, personal communication, February 11, 2015). According to the student the schools were not just impressed with his awards but with his dedication to be involved with research:

The Harvard interviewer said when I talked about how I researched my initial idea and then reached out to find a place to research it that it showed tenaciousness and that was one thing they were looking for in their students.

(Personal communication, February 11, 2015)

Another young man who won ISWEEP, another science research competition, talks about the importance of mentoring that is built into the program, not just from research mentors but from older students, “I’m giving back by being a mentor because others mentored me” (Plano HS student, personal communication, February 11, 2015). This young man has taken this mentoring outside of the Plano school district by creating a non-profit organization focused on tutoring for disadvantaged students. His mother comments on how much being involved in the science fair has changed both of her sons, “science fair has given them so much confidence, they both started with bad projects and they have not just learned but have grown as people” (Plano parent, personal communication, February 11, 2015). Another parent echoes the science fair as a growing experience for his daughter, “science fair has changed my daughter’s life, she did an

experiment with acid on pig parts, (she) used to hate blood now wants to go into biomedical engineering” (personal communication, February 11, 2015). Being a part of the tradition of science fair and being expected to participate at a high level has significantly changed these students’ lives.

### **Support systems**

To create and maintain a program of this size multiple support systems have to be in place. The primary support in Plano is coming from the school district but this is bolstered by support from the community. Financial support, social supports and time commitments are both provided by the district and community and have a huge impact in helping keep Plano at the top of the Texas science fair heap.

**District.** I was amazed thinking about the resources the school district provided for the district fair, again when it was seemingly just a dress rehearsal. The cost of renting the convention center, giving teacher’s release time, providing buses, paying for awards, providing lunch for seventy judges, all of this does not come without a large price tag. This is just the tip of the iceberg in regards to funds the district allocates for items related to the science fair. The printing of the handbooks for teachers and students would also be significant along with the stipends paid to LASER club sponsors or science fair coordinators at each school. Funds are also provided to help send teachers and students to the state and international fair. While there is some funding provided by outside sources, the majority of this falls to the school district.

By providing financial support the district shows it places a value on the experience of science research that culminates in the science fair. The district also shows this by dedicating instructional time in the classroom for learning about science research. In a heavy testing environment like Texas I was surprised to see such a large district allocating class time to focus on science fair, seemingly unrelated to typically content heavy tests. When asked about this, one high school teacher said “science fair and science research teaches the science process that is

related to what they are expected to know on the test” (Plano MS teacher, personal communication February 10, 2015). While it is obvious the district deems science important some parents feel the district could do better about celebrating the success of the science fair students and highlighting its importance in the curriculum. “The back to school day principals message shows what they care about most, last year they marched out the football coach whose team had done well, but not the science fair coordinator” (Plano parent, personal communication, February 11 2015). While parents express some frustration with the principals and wish they would add science fair to newsletters, marquees and pep rallies there are no complaints about the districts science fair head cheerleader.

The constant at the top is Karen, schools change a little, admin changes, but if you have some consistency at the top keeping it in focus it is good. (Parent quote, personal communication February 11, 2015).

Karen is the districts personnel support provided in the 6 ft. tall package of secondary science coordinator Karen Shepherd, or Mama Shep as she is called by many students. This dynamo former Texas teacher of the year and Siemen’s Founder award winner projects enthusiasm for science fair and science research on teachers, parents and students alike. When I first contacted her about including Plano in the research study she was leery of my intentions but once she realized my objective she could not stop gushing about the Plano ISD program. Along with her other duties to the district, she reviews all the paperwork for every fair in the district, organizes the district fair and contacts judges, sometimes three or four times, to ensure their commitment. She provides judges at the district fair with a binder including instructions and grading rubrics. She also makes sure the schedule is kept to as closely as possible showing the judges she values their time. She provides parents, teachers and students her cell phone number in case they have questions related to the science fair and encourages students to rub her frog bracelet for good luck before the judging. She refers to students as future scientists and reminds

the judges to provide constructive feedback, helping to foster a student's scientific mindset, not a judge's agenda, "how do we all grow, we grow through feedback" (K. Shepherd, personal communication February 11, 2015). She says more than once "it is not about the awards, it is about the students".

Talking to her daughter, who was serving as a judge, she shares stories about the many students who stay in contact with her mom after they have graduated, some from when she was a classroom teacher, but many who know her only from competing in science fairs. Students who have gone to state or International in the past talk about the fun things she plans for them on the trips to help bring them together as a group and also to lighten up the stress of the competition. One student and his parent talk about the hours she spent last year at Intel ISEF helping him study for his IB exam. Mama Shep is eager to share her students' successes and encourages students to enter as many competitions as possible, maximizing their learning opportunities and earning potential. She intentionally helps cultivate mentoring relationships among students so that the spark will be carried on from year to year. Many students mention hearing about and learning from other students successes as motivation to compete in the science fair.

Again with a large district it is challenging for Mama Shep to shepherd everyone but she does her best to work with principals and teachers to ensure science fair stays valued at every school. She is one of the original authors of both the teacher and student handbooks and works to update it every year and ensure teachers across the district have access to the same information. She also facilitates informal communication by bringing in science teachers from various schools to help set up the fair and secures funds for release time to help with preparing the fair and awards.

Karen Shepherd is not the only human resource the district has supporting the fair, there are many teachers (both current and retired), along with principals and other administrative staff that share her passion for science fair. As I am walking around looking at projects I notice four

teachers seemingly grading a project together, as I begin to eavesdrop I realized that two of the teachers are retired and are walking through some of the projects with two new teachers helping them identify good and bad things about the projects. The new teachers seem very thankful for the help and one verbalizes regretting not talking to the retired teachers earlier. The retired teachers offer to come to the schools in the fall to help the teachers get started and answer any more questions they may have. One new teacher says she had no idea the science fair would be this much work and the other one says doing the science fair was never even mentioned in her interview. Both teachers comment on lack of support from other teachers at their respective schools. The retired teachers encourage the new teachers to celebrate student success as a way to get others involved and to want to have a stake in the process.

When your kids win tonight celebrate it like they are the Dallas Cowboys winning the Super Bowl, advertise, advertise, they need to be treated as well as athletes, in reality these kids are going to be the ones that run the world.

(Retired teacher, personal communication, February 11, 2015)

Referencing teacher support highlighted again some complications from being in such a large district. In talking to several parents and students there was a lack of agreement about the helpfulness of the classroom teacher. For every person who would say the middle school teachers were very supportive there was another who would say they weren't supportive at all. This was true for the high school and senior high teachers as well. While most middle school teachers said they knew from their interview the importance science fair would have in their jobs, a few said it was not mentioned at all in the interview. Again, while there are some challenges in keeping such a large district in science fair sync, the district provides resources for this to happen to the best of its ability. Mama Shep and many other dedicated teachers also work tirelessly to ensure science research has a significant place in the curriculum.

Support from the community also seems to be an element that adds to the success of the Plano ISD science fair. Many people I spoke with mentioned the climate of the community in Plano as being one that values not only education, but specifically STEM field endeavors. One judge from a local university even said he was encouraged by his department chair to participate and is seen as a possible research tool. He said he feels as if the university has a stake in “wanting to help grow domestic STEM students” (Plano Judge, personal communication, February 11, 2015). He was one of over seventy judges who gave up time from their jobs at various business entities, research universities and government agencies. The judges were very excited about the projects and encouraging to the students, many offering very specific feedback. One judge said he specifically looked for a good hypothesis, wanting to ensure good design and experimentation. Another judge commented while the student had a lot of technical information there was no practical application. More than one judge echoed this sentiment saying they liked to know the story behind the idea. Some of the judges became involved in connection with their students but many were there only to support future scientists. People I talked to commented that Plano has just created a climate of “this is what we do” in regards to the science fair. One judge, with no affiliation to the fair said “the risk of not doing science fair is much greater than the cost of doing it”.

The parent support and excitement for science they share with their students is another type of important community support for the science fair. I ended up being able to talk to several parent/student combos independently of each other and it was interesting to hear them tell the same stories of excitement and opportunity that have come about because of the science fair. All of the parents seem to have different ways they had supported their students, from driving them to collect data to making sure they didn’t oversleep on Saturday when they needed to work on their project. In a community of science related industry some of the students did have parents in related fields, but most parents claim they only helped their students understand the research

process not actually help the students with research. For example, one brother and sister team talked about how their dad told them they needed to have pictures of their planarian for their board but they had to research how to use their iPhone to take a picture from the microscope. One parent of a now successful science fair participant commented on the first few bad projects her son did, but how she encouraged him to learn a little bit from each one and emphasized that was what was most important. Another parent who happened to be an engineer said “I would rather them fail at this level than later when the consequences are greater” (personal communication, February 11, 2015). He then went on to say how he likes his daughters learning there is value in a ‘failed’ experiment, saying “there is a representation of real engineering in that, learning your prototype doesn’t work, realizing you missed some step.”

“Life is about doing projects, communicating findings, analyzing information. Science fair is the best way to practice and implement all these things” Plano parent and judge Bred out of a desire to involve students in science research, Plano ISD now has a reputation for breeding young scientists. The level of involvement and support for the science fair is unparalleled in most districts across the country. While there are challenges with keeping this large district focused on science fair, there are many parents, teachers, students and administrators who are fiercely dedicated to the cause.

Plano ISD documents:

Included below is a photo of the table of contents from the secondary science fair handbook that Plano provides to all students and teachers. The next picture is a page from the judges handbook, the entire judges handbook was twenty pages and only this page was included because it was created by science teachers at Plano ISD.

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# Helpful Reminders

## Suggested Questions

- How did you come up with the idea for your project?
- Does your experiment confirm or reject your hypothesis? Explain
- How can you apply the results to real life?
- How did error affect your project?
- What would you do differently if you repeated the experiment?
- How could you improve your experiment?
- What is the meaning of your data?
- What have you learned?
- If you did a second year project, how would you expand it?
- What was the most surprising thing you discovered during your experiment?

## Judging "Don'ts"

- ✓ ask parent's occupations
- ✓ ask what school attended
- ✓ judge someone you know
- ✓ fill out forms in front of students

## Stick to the Timeline:

- Complete student interviews by 11:30
- Lunch – take a lunch break between 11:30 and 1:00
- All paperwork and decisions completed by 1:30
- Grand Prize Judging to begin by 1:30
- Grand Prize Judging completed by 2:30



Office of Research Compliance  
Institutional Review Board

December 22, 2014

MEMORANDUM

TO: Kimberly Murie  
William McComas

FROM: Ro Windwalker  
IRB Coordinator

RE: New Protocol Approval

IRB Protocol #: 14-11-226

Protocol Title: *A Cross Case Study of Science Fair Excellence*

Review Type: ☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB

Approved Project Period: Start Date: 12/22/2014 Expiration Date: 11/20/2015

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (<https://vpred.uark.edu/units/rscp/index.php>). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

**This protocol has been approved for 600 participants.** If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or [irb@uark.edu](mailto:irb@uark.edu).

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