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THE DESIGN, IMPLEMENTATION, AND ASSESSMENT OF A THREE YEAR RESEARCH PROGRAM AT THE HIGH SCHOOL LEVEL

By

Andrew John Moore

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ABSTRACT

THE DESIGN, IMPLEMENTATION, AND ASSESSMENT OF A THREE YEAR RESEARCH PROGRAM AT THE HIGH SCHOOL LEVEL

By

Andrew John Moore

Science education has seen many reforms in past years. The purpose of these reforms is to continually evolve and change to meet the changing needs of students. One of these needs is to learn how to "do" science, not just to memorize science facts and procedures. In this study, the author designed a three-year program in which students will be able to study an area of their own interest, learn experimentation skills, and ultimately design and perform a research project or their own design with the aid of a professional mentor. In the process of performing authentic research, students will gain valuable knowledge and skills, as well as participate in a process that will endear the student to the field of science and research.

Students in this program, sophomores and juniors, participated in many activities and procedures that enabled them to perform authentic research. Students were assessed by the creativity, usefulness, and complexity of their project design. This three year research program has specific goals of achievement, and each student was assessed as to the level of attainment of these goals.

The students participating in this research program all showed a significant change in many aspects of their scientific knowledge, maturity, work ethic, ability to "do" science, to convey scientific knowledge orally and in written form, and to participate in the scientific community.

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Problem Statement

During my third year of teaching, I had the opportunity to educate a particularly bright young student, who eventually went on to study mathematics at Yale University. During that third year of teaching, in which the student was a senior, I had an eye opening conversation with him. This student looked at me, and said: "I have taken every science class this school offers, every AP, every elective, and I still do not feel like I know anything at all about science." It became instantly clear that this student could take classes for the next couple of years, and still not know what science really is. Since that moment, I have spent enormous amounts of time sitting and thinking of a way that talented, bright students can learn how to "do" science.

While American scientists, as a whole, contribute more to new discoveries in math, science, and technology than any other nation, American high school students consistently rank below many underdeveloped countries in overall science literacy. Studies have shown that students lose interest in science drastically as they continue through the ranks of a traditional curriculum. While students in elementary school commonly list science as their favorite subject, science is chosen as a favorite by only a select few high school students. What is causing this "leaky pipeline," where bright and talented students are ending their high school careers with a perception that science is not their interest? Whatever the cause, it seems that there have been two avenues to fix the leaky pipeline. First, and most popular, is to seek out a commonality and increase the "fun" factor of science to appeal to all. The hope is to level the playing field for all, and end up with more students interested in science at the end of the pipeline, albeit with less individuality and more generality. Second is the theory of intellectual mining; identifying students who have a propensity for science early, plucking them out of the general population, and nurturing that talent on an individual basis. I believe that the idea of intellectual mining, the idea of picking out individuals identified as talented, and putting them on a different, science centered track, can help us decrease the gap between the general ability and science literacy of high school age students and the overall contribution that American scientists make to new discoveries in the world.

The problem that remains, however, is deciding what kind of program can adequately address the needs of bright, talented students who have shown a propensity for science. I believe there is no better way to strengthen student interest in science than by working on a research project in a laboratory or in the field under the mentorship of a professional scientist. It is there that students are able to undertake detailed investigations of challenging problems and participate in many dimensions of research. To facilitate this, I designed a three year research program that not only entices students to explore the field of science, but provides them with an authentic research experience. The purpose of this research project was to develop, implement, and assess the effectiveness of an independent science research program at the high school level. The program is directed to those students who wish to pursue excellence and progress into advanced areas of original research, while learning what actual research entails, with an emphasis on both laboratory and bibliographic research.

The five main goals of the research program are:

- Use methods of scientific inquiry: Students state a research problem, generate a hypothesis, state the hypothesis, and test the hypothesis by designing and executing an experiment culminating in the production of novel, useful knowledge. Students collect pertinent data. Students organize the data using graphs, charts, tables, and figures. Students store and analyze data by conducting statistical analyses. Students distinguish valid from invalid interpretations of data. Students draw conclusions based on data, indicating future research that the present completed research suggests.

- Conduct authentic experimentation: Students conduct experimentation which addresses the hypothesis, is reproducible, has appropriate controls, is complex, novel, and state of the art.
- Participate in the scientific community: Students locate and contact professors and professionals to serve as mentors, with the purpose of asking them to work with them on an authentic research project.
- Write a scientific paper: Students write a research abstract, using economy of language. Students write a scientific paper that includes the review of literature, statement of purpose (or hypothesis), methodology and materials, results, discussion of results, and conclusions.
- Present scientific data: Students present, at various times throughout the year, project progress and final presentations to the teacher, class, community, and to the scientific community at the final year symposia using PowerPoint slides and posters using a delivery of poise and literacy.

The goal of the research program is to foster the inspiration, excitement, and level of interest in science in a select few students that have shown prior scholastic aptitude through the implementation of an authentic research project. The goal of this research project is to assess the viability of the program developed by the author to achieve the goals that were set earlier in this introduction. Secondary to this primary goal is providing academic opportunities for students and an open-ended opportunity for science-loving students to pursue their passions.

The program was intended to span three years, from sophomore to senior years of high school, with each year advancing towards the program goals. It was assumed that in subsequent years, students will meet in mixed grade classes. The research program was designed to have students use external mentors, and to meet for one class section, held once a day for 47 minutes, as well as one-on-one with the teacher for biweekly conferences. This was a formal, exclusive, graded program in which students submitted an application that included transcripts, a parent signature, and an essay.

The first year of the program, the sophomore year, had two overall objectives: First, to help the student find an interest area, cultivate that interest well by reading of primary literature, and recruit a mentor who has done research in the students' interest area. A secondary goal was to teach basic research and experimentation methods.

The second year of the program, the junior year, had one overall objective: To design, and implement, an authentic research project. The junior year was spent reading and practicing research methods specific to his/her project objectives and methodology. At the end of the junior year, the student stated a hypothesis, completed a literature review, and wrote a methodology to test the hypothesis. This was all done with the assistance of a mentor and the instructor. The junior year culminated in the summer, a period of intense work when the student was performing the project that was designed in the previous school year.

The third year of the program, the senior year, has two overall objectives: First, students will write a formal paper based on their project. Secondly, the student will open up his/her project to public scientific scrutiny by submitting the paper to various scientific competitions. In addition to their entry into competitions, the students present their work both at school as well as at formal symposia.

This research program was designed and implemented at Grand Rapids Catholic Central High School (GRCCHS) in Grand Rapids, MI. A parochial school of approximately 700 students, the GRCCHS student body is 93% Caucasian. The research program revolves around the newly developed research class, which in this first year is comprised of ten sophomores and seven juniors, eleven of which are girls and six of which are boys.

What is science research?

In current science classes, students routinely follow the steps of the scientific method in conducting laboratory experiments, creating a "cookbook" type experience for students. Seldom is there opportunity for students to pursue extensive investigations based on individual interests that include both the learning of the scientific method and the science behind the project. Usually, students in a class follow identical procedures and share their results only with their lab partners and teacher. Science research provides an opportunity for students to become scientifically literate by reading journal articles, while learning concretely by executing their own experiment, and developing complex problem solving skills by having developed their own hypotheses and experimental design. Through various venues, such as scientific competitions and symposia, students then communicate their work and results to the scientific community. Students are supervised and receive feedback not only from a teacher and other students in their program, but also from a cooperating scientist/mentor. Students learn to communicate in writing and using e-mail with authors of scientific papers.

What are indicators that this research program is successful?

Achievement measures are highly variable, depending on both the target of assessment and the type of achievement. If student achievement is being used as an indicator of success, then how is student achievement defined?

Many schools, especially on the east coast, are adopting various types of research programs, and the success of these programs are measured solely on the number of students who reach the semifinal and final levels of science competitions. These allow the work of the student to be critically reviewed by a wide audience, including professional researchers. However, to define student achievement as producing winners in local, state, and national competitions is narrow and limited, and may overlook many pedagogical benefits of this program. In the experience of the author, it is evident that students lose interest in science as they progress through the traditional grade levels. Bright and motivated students begin to see upper level science courses as means to an end (to get into a good college) rather than a learning opportunity. Allowing students to investigate intellectual areas of their own choosing results in students that are motivated to learn. Students set their own goals and objectives, and rather than a teacher telling them what level of understanding they should reach, the students decide for themselves. To accomplish this, they have to work in a completely independent environment, which helps them with the working environment outside of a school classroom. Therefore, the success of this program should not be measured in the number of students winning regional and national competitions, but rather on the quality of individual work and improvement of experimental methods as the student progresses through the program. The success of the program should be measured by looking at students in an objective, individual fashion.

Students who do not win competitions still gain many valuable skills. These include: researching and understanding scientific literature; comprehending scientific results; interpreting data; reading charts and graphs; time management; problem solving; reasoning; creative thinking; effective use of technology; planning and organization of research; following the steps of the scientific method; real-life application of science; applied statistics; presentation of results; public speaking (communicating effectively orally); and technical writing (communicating effectively in writing). Therefore, it should not be the winning of competitions that dictates success, but rather the improvement in these areas.

Literature Review I: Justification of Methods

Introduction

In developing this pilot program, the author started out with the basic idea that students need a different venue in which to learn discovery science. To organize a program that would accomplish the original goals, an extensive literature review is necessary to establish a philosophy, and therefore methods, that would have a high likelihood of success. Authentic research is social constructivism in its purest form, and therefore an extensive review of previous work and study in the benefits of a constructivist approach is explored. Running a program that embodies authentic research requires a research instructor that can project his/her own perspectives gained through his/her experiences, and therefore the author will review of the role of the teacher in a constructivist setting, as well as characteristics that will make a teacher successful in such a setting.

While the teacher has a more generalized degree with a broad picture of a subject area, research scientists have a more specific expertise. The relationship between the student and a prospective mentor, benefits and effects, is extensively explored, culminating in a review of how such an environment would change how a student learns science, and the resulting benefits to the student. It is assumed by the author that this line of reasoning, through compilation of previous work, justifies the development of a research program at the high school level.

Science education should lead students to the shared values of scientists as well as developing positive attitudes toward learning science, mathematics, and technology (AAAS 1990). These attitudes include curiosity, openness to new ideas, and informed skepticism. The choice to pursue a research project demonstrates the first two attitudes and properly mentored experience leads to the third. Project 2061's <u>Science For All Americans</u> describes science as a blend of logic and imagination. Although there are a set of steps that one can follow, called the Scientific Method, some discoveries occur by accident, and it is knowledge and creative insight that create meaning in such a situation. Several principles stated in the book echo the original problem resulting in the need for a research setting in the high school. "Cognitive research is revealing that even with what is taken to be good instruction, many students, including academically talented ones, understand less than we think they do"(AAAS 1990, p.198). Also, science teachers should emphasize clear expression (oral and written) because the struggle for clarity often aids the understanding. Project 2061's <u>Benchmarks for Science Literacy</u> recommends "students working individually or in teams should design and carry out at least one major investigation. They should frame the question, design the approach, estimate the time and costs involved, calibrate the instruments, conduct trial runs, write a report, and finally, respond to criticism" (AAAS 1993, p. 9). Responding to criticism is also cited in the National Science Standard as a form of peer review. Conversations with peers can help to develop meaning and understanding (NRC 1996).

Constructivism: Performing Authentic Research

The authors of Breaking Ranks: Changing an American Institution make the recommendation that teachers be facilitators of learning so that students will be more actively engaged and involved in their learning (NAASP 1996). One of the analogies the National Association of Secondary School Principals draw is that athletic coaches would never hit or throw the ball *for* the student. Rather, a teacher who utilizes the Socratic method in coaching students in the classroom, "all the while providing information for the student to ponder, provokes the student to discover his or her own answer, pushing the student to the limits of his or her knowledge"(NAASP 1996, p. 23). What students are *already thinking* has an effect on how students interact with teaching (Hawkins 1994; Johnson and Gott 1996). To summarize Ausubel's (Ausubel 1968) work, a key factor in what students learn is what they already know. "Many students' views of learning and the learning process are limited in that they conceptualize learning as the transfer of prefabricated knowledge that then is stored in memory" (Duit and Treagust 1998, p. 6). For those students, science is essentially just an accumulation of facts. "Science instruction frequently is not designed for the science perspectives to be learned effectively" (Duit and Treagust 1998, p. 19). However, learning is defined within the constructivist view as the "the acquisition of knowledge by individuals through a process of construction that occurs as sensory data are given meaning in terms of prior knowledge" (Tobin, Kahle et al. 1990, p. 6).

Shiland (Shiland 1997) came up with five propositions of constructivism. First, learning is an active process that requires mental effort or activity. Second, misconceptions and preconceptions may interfere with the ability to learn new material. Third, problems create dissatisfaction and learning. Fourth, learning has a social component. Finally, applications must be provided or found for learning to be retained. Regarding Shiland's third proposition, it was hypothesized that students' conceptual difficulties are, at least in part, due to concepts being introduced "without making explicit connections with students' previous conceptions, and without having students adequately compare and contrast unfamiliar scientific concepts with pre-existing notions" (Labudde 1988, p. 81). Regarding Shiland's fourth proposition, research (Carlsen 1993; Prophet and Rowell 1993) indicates that teachers tend to dominate classroom talk, particularly when teaching topics unfamiliar to students. However, use of "internalized-context" lessons (Rodrigues and Bell 1995) suggests that when students and the teacher share and collaborate, cognitive gains occur for the students.

A remarkably simple shift toward constructivism is realized when the teacher abandons his or her typical questioning style which Erickson (1998) refers to as 'traditional teacher questions' in which the teacher already knows the answer to the question and the students know the teacher knows. Erickson asserts that if the teacher and students slip back into their former 'known information' question, then the new constructivist curriculum was never truly implemented, and everyone simply 'went through the motions' (Erickson and Meyer 1998, p. 1156). Not knowing if an answer or a procedure is right can be intimidating for students and teachers.

"Learning is seen as construction of mental models. Knowledge then is something an individual possesses" (Duit and Treagust 1998, p. 8) As such, it is "imperative to provide an integrated, relevant context in which such knowledge and skills can be used, applied, and practiced in order to facilitate the development of cognitive links that are meaningful and coherent" (Berlin and White 1998, p. 505). Accordingly, the teacher's role changes from dispenser of knowledge to guide and facilitator (Tobin, Kahle et al. 1990; vonGlassersfeld 1988; Berlin and White 1998). It is better to guide side by side rather than lecture and watch.

Student attitudes as a consequence of implementing a constructivist approach in the classroom were studied over a four-year period (Hand, Treagust et al. 1997). Students reported that they were appreciative of the opportunity to use their own ideas and knowledge and also aware of the changing roles and responsibilities required of them. The association between locus of control and summative achievement was found to have a small positive relationship (Tobin and Capie 1982). "Higher rates of attending were associated with students with a greater internal locus of control" (Tobin and Capie 1982, p. 453).

Humans have the ability to have mental images of objects and actions on them "which allows us to reflect on our actions, consider multiple perspectives simultaneously, and to even think about our thinking" (Fosnot 1993, p. 1190). It is the reflection on the representations that may bring new insights, new constructions, and new possibilities.

Staver (1998) differentiates between radical constructivism and social constructivism. The difference is largely in the focus of the study, and Staver distinguishes radical constructivism as focusing on cognition and the individual, versus social constructivism focusing on language and the group. In social constructivism, "collective meaning making is achieved through language-based social interaction" (Staver 1998, p. 508)

"A crucial part of science education involves understanding the rationality that scientists employ in generating and validating knowledge claims" (Hodson and Hodson 1998, p. 35). An appreciation of the nature of scientific evidence and an understanding of the role of scientific knowledge are also involved in science education. Hodson and Hodson argue that a student 'constructing their own knowledge' does not constitute worthwhile science education. However, they do advocate a shift in emphasis toward social construction within the community of scientists and to a "view of learning as a process of enculturation" (p. 33). Teaching "comprises the activities associated with enabling the learner to participate effectively in the activities of the more expert, and learning is seen as enculturation via guided and modeled participation. Expert performance is modeled and learners are instructed and supported in their efforts to replicate expert practice" (p. 37).

Roth argues that to practice constructivism means to make an epistemological and methodological commitment that influences the day-to-day practice of science teaching (Roth 1993). An important task of science educators, according to Roth and Roychoudhury (1993) is to help students develop the thinking skills of scientists. It is also important to learn how students view scientific knowledge, in particular, the status of data and theories. Some students believe that data and observations drive the creation of theories exclusively, while others concede the role of the scientists' personal feelings (DeSautels and LaRochelle 1998). Students are generally aware that scientists work in teams and discuss the results of their research. However, many students feel that the underlying factors that lead a scientist to adopt a certain theory are the facts, the presentation of the facts, and the number of times the theory has been tested. The recommendation by Driver et al. is to "make these epistemological features an explicit focus of discourse and hence to socialize learners in a critical perspective on science as a way of knowing" which will necessarily develop a different relation to scientific knowledge (Driver, Asoko et al. 1994, p. 11). Essentially, knowledge about the world is viewed as human construction (Duit and Treagust 1998).

Schon (1983) described high school students who were not given instructions in science process skills yet were able to conduct experiments using open inquiry method. Roth and Roychoudhury (1993) used the open inquiry learning method in their study involving science students in 8th, 11th, and 12th grade. They provided a framework in their classrooms for students to take ownership of their studies. The students were assigned to do readings, weekly sets of problems (which came out of different textbooks and were selected by the students), reflective writing assignments and short notes on biographies of scientists and special topics not normally covered in the course. Student assessment was partially individual and partially as part of a group. One of the findings was that the pursuit of problems of genuine interest motivated students to generate new hypotheses and to focus questions for further experiments. Another finding was that "given the freedom to choose research topics and to design their own experiments, students became very adept in planning and carrying out the investigations" (Roth and Roychoudhury 1993, p. 141). In the case of some students, it may be that they are motivated toward minimizing effort rather than toward learning (Rennie 1990), so it is still necessary for the teacher to supervise the students' goals and progress.

Learning science involves being introduced to the "ways of seeing" of the scientific community and thus involves a socialization process (Driver and Scott 1996). Learning science is "related to students' and teachers' conceptions of science content, the nature of science conceptions, the aims of science instruction, the purpose of particular teaching events, and the nature of the learning process" (Duit and Treagust 1998, p. 5). After observing gender differences in science –related experiences based on socialization factors, Farenga and Joyce (1997) concluded that constructivist strategies should be employed to maximize students' prior knowledge and interest.

Another inquiry-oriented, laboratory-based instructional approach that is similar to constructivism is called the Learning Cycle Approach (Abraham 1998). Students were provided with an introductory laboratory activity and given the opportunity to construct knowledge from their own experience and apply that knowledge to new situations. With minimal modifications, Glasson and Lalik suggest that the learning cycle approach can be made more congruent with social constructivism (1993, as represented by Abraham, 1998).

Few would question the importance of having students actively involved with materials, but the connection between this 'experimental work' and the growth and development of students' scientific understanding is not readily apparent (Erickson and Meyer 1998). Several assumptions are made. First, any assessment project must identify what types of knowledge are being assessed by the instruments being used. Second, data from an assessment project can validate or refute claims about the growth and development of students' scientific understanding. Third, students' responses to a new situation will be based on an amalgam of their knowledge bases. Specifically, the students possess three general knowledge bases: general cognitive abilities; everyday science content knowledge; and school-related science knowledge (Erickson and Meyer 1998). In the school-related science knowledge base, there are three subcategories. These include specific language and concepts of science, practical techniques (such as measurement and observation) and inquiry skills (such as an understanding of uncertainty in measurements, use of a control in an experiment, and ability to replicate an experiment.)

Constructivism: Scientific Literacy

The goal of scientific literacy has been mentioned in several studies (Hodson and Hodson 1998; Kahle 1996; Jenkins 1990). An operational definition of scientific literacy includes the following: an appreciation of the nature of the scientific method; an appreciation for the possibilities and limits of technology; a general grounding in the language and key constructs in science; a basic group of interpreting data mathematically; and an idea of where and from whom to seek information and advice about matters relating to science and technology (Jenkins 1990).

Project 2061 recommends that "the presidents of all colleges and universities establish scientific literacy as an institution-wide priority" (AAAS 1990, p. 226). According to the *National Science Education Standards*, a scientifically literate society is defined by educated students who are able to:

"experience the richness and excitement of knowing about and understanding the natural world; use appropriate scientific processes and principles in making personal decisions; engage intelligently in public discourse and debate about matters of scientific and technological concern; and increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers" (National Research Council, 1996, p. 13).

Functional scientific literacy includes the specialized vocabulary terms of science and technology. This was the emphasis in science teaching for years (Bybee 1995). Conceptual and procedural scientific literacy has been under-emphasized, and should be demonstrated by an understanding of the parts (facts and information) and the whole (concepts and structure) of science (Bybee and Ben-Zvi 1998). The *National Science Education Standards* (NRC, 1995) and *Benchmarks for Science Literacy* (AAAS, 1993) provide clear and detailed definitions of scientific literacy. Scientific literacy is not guaranteed for those who pursue a science major in college. It is a lifelong pursuit (Koballa, Kemp et al. 1997). The value of scientific literacy is more important than the content; "whether or not persons can communicate in science is not the same as asking if they do so, will do so, or want to do so" (Koballa, Kemp et al. 1997, p. 30)

"Although there is no agreement on a single definition of scientific literacy, there is consensus that it encompasses three aspects of science. These aspects are product, process, and habits of mind. The product part of science is the information base of the life, physical, and earth/space sciences that also include knowledge of the nature of science, particularly its methods of investigation. The processes of science are the thinking skills used to solve problems and to conduct inquiries, whereas scientific habits of mind are the beliefs and attitudes that characterize the enterprise of science, such as respect for logic and longing to know."(Cothron, Giese et al. 1993, p. vii)

While inquiry is part of literacy, scientific inquiry should include processes of science and greater emphasis on cognitive abilities such as using logic and evidence to construct explanations (Baybee 1995). There has been confusion between an emphasis on knowing about the procedures of science and doing scientific investigations (Baybee and Ben-Zvi 1998). Inquiry should not be taught in isolation but as a tool for finding answers about the world (Baybee and Ben-Zvi 1998).

Role of the Teacher: Teaching Science

Science teachers "have a responsibility to provide a classroom environment in which necessary cognitive processing can occur" (Tobin, Capie et al. 1998, p.17). In order to engage students more actively, the researchers advocate that "individualized activities must be used" (p. 18). Realizing that "the old teaching methods are not producing true understanding, educators are beginning to examine what is really involved in achieving knowledge" (Lord 1998, p. 135). According to Ray Ann Deprisco Havasy, Professor of Science Education at the New York Institute of Technology, inquiry-based learning is "learning through which questions get answered and problems get solved via use of the best science investigation methods. Rather than encouraging students to memorize a lot of scientific facts, inquiry-based learning teaches students to ask questions and come up with a variety of ways to answer them" (Kaye 2001, p. 68). Havasy further suggests for science research students working with a mentor," The best thing mentors can do is not give students answers. Students who are the most successful are those with mentors who listen and validate what the students are saying, and then encourage further inquiry by asking questions, not answering them"(Kaye 2001, p. 68).

In the early 1990's, collaboration between high school teachers, university faculty and corporate leaders in Massachusetts led to a pilot program for 56 students from 14 different high schools. The participants had face-to-face meetings and utilized telecommunications through a statewide education network. Students had access to worldwide resources in order to facilitate a variety of enrichment activities. One of the goals of the program was to offer the enrichment (including a research project) that one might expect at a magnet high school without pulling talented students from their home high schools. A two-week Summer Institute provided hands-on experiences in academic and research areas in the sciences and mathematics. The outcome of "collaborative work skills, scientific research skills and discipline of mind that students learn by doing their own research" (Goodrich 1994, p. 75) was considered a more important outcome than the actual research projects completed by the students. Students learned by doing science in an active environment of their own volition, instead of existing in a passive, traditional setting.

An essential component of an individual and active learning environment must have constant self and peer assessment. Having students conduct peer assessments (Billington 1997) and self-assessments (Tobin, Capie et al. 1998) are crucial for developing complex understanding and improving learning. Self-assessment activities can include writing personal logs, portfolios for assessment and self-assessment sheets about academic and personal progress. These allow students to express what they know, what they are learning, and what challenges they have overcome or are still facing. More importantly, these allow students to become aware of their own progress and of the gaps in their understanding (Black and Atkin 1996). Students can perform these tasks in the short-term (self-assessment sheets being filled out) and the long-term (portfolio assessment.) Students develop the ability to reflect on their work (Schon, 1983) which makes them partners in the assessment process.

The authentic research approach goes back to the 1700's and Rousseau's discovery learning and the early 1900's and Dewey's project method which promoted real world experiences (Berlin and White 1998). In this approach, students actively work on their own problems and the teacher acts as facilitator. Many reformers are trying to make school science reflect to students what really happens when scientists and mathematicians are at work (Black and Atkin 1996). Black and Atkin discuss a tension in science education between pursuit or 'pure, high science' and 'science in action' dealing with messy everyday problems. When dealing with the latter, it is necessary that students have access to resources which meet their 'need to know' which will be different for each student and arise at different times. The science teacher has the responsibility to provide a wider range of types of learning (Black and Atkin 1996.)

Science teachers are representatives of the scientific community and as such, they have the opportunity to act as practitioners and to induct students into scientific practices. The best way to learn the professional standards, conventions, ethical values, and expectations of the science profession is believed to be through thesis advisers, research supervisors, and mentors (Bird 1996). Unfortunately, most faculty, thesis advisers, and research supervisors are not trained to be mentors, and "few are naturally good at it" (Bird 1996), so training of mentors is a vital component for research programs in which students will be conducting independent research. In order to have an authenticity at all, the learning environments need to share some fundamental characteristics with the everyday work of scientists including poorly defined problems and "predication of learning on current knowledge" (Roth 1998).

It is not uncommon for apprentices to have access to several masters (Collins, Brown et al. 1991) and the same premise works with students engaged in independent science research. Students can gain from their science teacher, from their primary mentor, a secondary mentor, and others (such as teachers of English). Since the ultimate aim is to give learners control over their learning processes, an apprenticeship with a competent and other person is desirable (Hennessy 1993). The apprenticeship may utilize modeling effective problem-solving strategies followed by fading and scaffolding as the student is able to engage more successfully. It is ironic that even when group work is apparently being encouraged, that an individualist perspective still dominates our educational system.

Students benefit from observing other learners with varying degrees of skill (Collins, Brown et al. 1991) and the classroom which combines sophomores through senior engaged in research enriches each level of student. The sophomores get a view of what is to come, and they can benchmark their progress against those further along. The juniors and seniors also benefit from benchmarking as they view where they started and how far they have come. The upper classmen especially have an opportunity to reflect on their learning, particularly as they answer questions from the younger students about their research.

It is important in school for students to be able to transfer what they learn, including processes. One challenge is to make the abstract tasks in a curriculum make sense to the students. The best ways to promote the development of expertise (Collins, Brown et al. 1991) is to first perform a task so that students can observe (modeling) and then observe and facilitate students performing a task (coaching) and provide support to students (scaffolding) and encourage students to verbalize their thinking (articulation). Encouraging students to evaluate their own performance (reflection) and to pose and solve new problems (exploration) complete the methods which Collins, Brown and Holum advocate.

Literature Review II: Impact on Students

Process Skills

Students conducting research improve communication skills, verbal or writing skills or both, coping with a high degree of uncertainty in the outcome, explaining the risks and probability of harm, estimating costs, and budgeting time (Cairns 1998). Having to present their research before others (whether via poster or oral presentation) motivates students to review their work more thoroughly (Cairns 1998).

One of the major problems of realizing the goal to increase process skills for all students is the ability (or inability) to assess the outcome. "Educators do not have nationally recognized, valid, reliable, and efficient (paper and pencil) instruments to assess all of the process skills that states have mandated be taught and tested" (Lipowich 1998, p. 1). Process and thinking skills include "classifying, collecting and organizing data, communicating, controlling variables, developing models, estimating, experimenting, graphing, inferring, interpreting data, making hypotheses, measuring, observing, recognizing patterns and predicting" (Berlin and White 1998, p. 503). Poster presentations utilize the student's ability to write brief and clear summaries and to identify and demonstrate the important points (Billington 1997) which are additional valuable process skills. In addition to these process skills, the Iowa Guide to Curriculum Development set as a goal that students will seek information and to carry out investigations to verify or generate information (Iowa 1986).

Students enrolled in a science research course enroll in one or more additional science classes each year. The students learn specific science process skills, generally from their mentor, which are necessary and appropriate for the chosen topic or field. It is important that the science process skills be explicitly taught since earlier research concluded that there is not a relationship between the number of science courses taken and integrated science process skills (Baird and Borich 1987), which implies that taking science courses does not enhance such skills.

Keeves (1998) refers to the processes of investigation and inquiry as 'Heurism'. Keeves argues that the heuristic processes of investigation, which are central to a scientist's work, need to be taught. These processes and skills are important not only in scientific research but also in learning in the modern world (Keeves 1998).

Communication skills include the ability to convey spatial information that may not be able to be conveyed by verbal means alone. The poster presentation is an ideal communication tool and can be an integral part of assessment. In one researcher's experience, students who presented well via poster tended to articulate poorly in an essay task, and vice-versa, leading to the conclusion that diversity of assessment is critical to assess students fairly (Billington 1997).

Learning Environments

A situation is a specific external environment that is turned into a context at a particular time by the mental activity of an individual or group. The four factors of a situation used for educational activity are: where it takes place; what the focus of the activity is; what the educational purposes are; and who is involved (Gilbert and Boulter

1998). According to Hennessy, "the environment is an essential resource which makes knowledge possible" (1993 in Gilbert and Boulter 1998, p. 56).

The Learning Environment Inventory (LEI) was developed by the Harvard Project Physics staff because it was not feasible to visit a national population of classrooms, so the "paper and pencil alternative was devised to determine students' perceptions of the classroom climate" (Whelch 1973, p. 367). Validity and reliability evidence have been provided as part of a Harvard University doctoral study (Anderson 1969). A different form of a learning environment instrument was proposed by Fraser et. al. (1992 in McRobbie, Fisher et al. 1998). This new form asked students for their personal perceptions of the learning environment of the class as a whole. The use of both the personal form and the class form is informative, and the researchers have conducted validation studies.

After conducting an investigation of learning environments, Tobin and Fraser advocate for the use of both qualitative and quanitative data in researching learning environments (Fraser1990; Tobin and Fraser 1998). Although it was asserted that students and teacher would differ in perceptions of the classroom environment (Fraser 1990), it was found that the student perceptions differed due to different learning environments that existed for different students within the same classroom. Fraser recommended use of both qualitative and quantitative data because "qualitative data may provide insights into aspects of the environment which are not captured quantitatively" (Fraser 1990, p. 218).

One of the initial pioneering studies performed to monitor the students' views of the learning environment was conducted by Roth (1997). Roth had students respond in the form of essays, class discussions, and with the "preferred form" of the CLES that consisted of four groups of seven Likert-type items. Interviews were also used by Roth to collect data. Autonomy of learning and integration of new and prior knowledge were shown to improve in the sample taken over two years, as reported by the students. However, those improvements were aggregate, and it was discussed that certain students sought the comfort of teacher-directed work and that small groups were arranged for those students who expressed a desire for more interaction with the teacher.

Research on learning environments in science classrooms has focused more on the socio-psychological characteristics (Fraser 1994) than on physical attributes of the environment. However, the physical setting may deserve some attention since a multi-functional space facilitates "science for all" courses and allows teacher flexibility to employ constructivist methods (Arzi 1998).

Students Discovering Science through Research

Student motivation to learn increases when work is challenging and related to students' interest, according to Brophy (Brophy 1983). Brophy further noted that given some autonomy over task involvement during activities, students effectively become more responsible for their own learning. *Benchmarks for Science Literacy* suggests that students do not typically participate in legitimate scientific investigations.

> "The usual high school 'experiment' is unlike the real thing: The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect, and how to organize the data are also decided by the teacher (or the lab manual); time is not made available for repetitions or, when things are not working out, for revising the experiment; the results are not presented to other investigators for criticism; and to top it off, the correct answer is known ahead of time"(AAAS 1993, p. 9).

Hodson and Hodson (1998) suggest that scientific inquiry has five distinct phases. The first is initiation, which is finding focus for the inquiry. The second phase is design and planning, in which the learner gathers information to address issues and questions raised in the first phase. The third phase is performance, and this involves literature and media based inquiries as well as laboratory-based investigations which may require technical skills to use a range of instruments to collect accurate data. The fourth phase is interpretation, which will involve manipulation of the data. The final phase is reporting and communicating. In the final phase, students learn about the "distinctive styles of communication adopted in textbooks, and logbooks and interactive journals" (Hodson and Hodson 1998, p. 39). The inquiry phases outlined above apply to the three-year Science Research program and the stages that students go through with the sort of scaffolding and mentoring that were mentioned earlier.

Researchers must reflect deliberately on the information they gather and learn (Erickson 1998). Researchers intending to answer questions must make certain that they have framed those questions as completely as possible. The source of the information they gather may come from interview, observation, or experimentation and ideally from a combination of all three. Erickson suggests that after gaining information from one method (such as by interview) that the research follow up and attempt to gain information through the other method (observation).

Some of the attributes of student research found by Tytler (Tytler 1992) were: interest and motivation, rather than intellectual capabilities; the home environment for cultivating and guiding interest and accomplishing the project; student commitment; and self-reliance in the pursuit of background knowledge or in the arrangement of experimental procedures (Tytler 1991 in Hofstein and Rosenfield 1996.) Because the projects vary in difficulty, scores tend to have "low reliability" (Boud et al. 1986 in

Hofstein and Rosenfield 1996) and there is a lack of valid criteria for assessment. However, validity is high and the opportunity for student learning is significant (Woolnough 1994).

The perspective of any student is a function of their experiences, and the environment of learning by authentic research could dramatically change the perspective of science by students. In a recent study (Rowsey 1997) university research scientists responded that junior high and high school science teachers had a positive influence on their vocational choice. Upon graduation from high school, 85% recognized a special interest in science and 34% had made the decision to become scientists. Hegarty-Hazel (1990) proposed that science education objectives can be subsumed under four broad classes, one of which is "attitudes." Attitudes include activities that aim to increase motivation, enjoyment, interest and attitudes toward science learning and choice of a science career (Hegarty-Hazel; Arzi 1998). Eichinger (1997) surveyed successful college students, both science and non-science majors, and found that although attitude toward science is relatively low during the junior high/middle school years, teacher's behavior and attitude and the use of active instructional techniques promote positive student attitudes. Eichinger reported that the high-ability students surveyed craved instructional activities that involved and challenged them, especially those activities that promoted personal discovery.

Literature Review III: Evaluation of Students, Program, and Impact of Program

The lack of adequate instruments to assess student performance can be a problem in putting new standards in place and modifying curriculum (CPRE 1995). The National Science Foundation (NSF) is attempting to bring together those who have identified the problems with those who have the resources and skills to help solve them (CPRE 1995). According to Gitomer and Duschl (1998), the practices of educational assessment are "very much in flux" (p. 791) and science education finds itself subject to debates regarding a move toward having classroom teachers carry out formative assessments of student learning.

The formative assessments have as their goal not only a valid measure of a student, but to provide exemplars of good pedagogical practice and clear expectations of desired competence. Student portfolios allow inferences to be made about the kinds of expectations that teachers have for their students and about social values (Gitomer and Duschl 1998). The development of performance assessments, according to Gitomer and Duschl, raises new generalizability issues. Although one may conclude from an outstanding portfolio that the student is an outstanding scientist, it may not be generalizable to other areas of science. For example, the student may have worked in the field of chemistry or biology and may not be able to demonstrate the same level of outstanding work in the field of physics. Performance assessments may not be generalizable across a range of conceptual domains, despite evidence of complex scientific reasoning in several domains. The most promising efforts in assessment reform, according to Gitomer and Duschl (1998) are those that "address directly the relationship of assessment and instruction, specifying precisely how assessment can be used to support improved instructional practice" (p. 803). However, Gitomer and Duschl caution that "claims that these models of assessment improve practice need to be validated" (p. 804)

The research literature is limited regarding information of the assessment of independent student research projects (Hofstein and Rosenfield 1996). The intended goal of the independent research project is to develop more independent learners. Students follow their interests and develop self-direction, self-respected and self-criticism (Kilpatrick 1951 in Hofstein and Rosenfield 1996).

Of the programs the author investigated during the design phase of this study, the overwhelming majority of programs evaluate the success of the individual student by simply comparing the overall scientific ability of each student as a senior to their abilities and perspectives when the student started the program. If they increased the overall scientific literacy of a student, as well as contribute to the formation of a well rounded learner, then the program was deemed successful for that individual student.

A high school research teacher in Westchester County, New York, wrote an article entitled, "What students who drop the course learn" (Pavlica 1995). This article summarized important skills and knowledge gained by students who discontinue a three-year research program after one year. These include: knowing and internalizing the protocol of the scientific method; how to search on-line literature through research databases; how to search on-line author publications; how to prepare a scientific poster; how to make a public scientific presentation; how to establish timelines; the need to be a producer of information; the ability to isolate and narrow a topic of research; ability to plan individual work in short term (two weeks) and long term (10 weeks); ability to assess self-progress; respect for research and the work of others; how to maintain an organized lab notebook; use of a portfolio; and how to communicate with professionals in the field of science.

The Science Research Program (SRP) is a high school research program developed by Dr. Robert Pavlica of Byron Hills High School of Byron Hills, New York. Each year's formative evaluation of the Science Research Program (SRP) has documented perceptions of four areas: effectiveness of teacher and student recruitment and retention efforts; effectiveness of the teacher training component; process of program implementation during each year; and effectiveness of the program as defined by outcomes of each year. During the first year of the program, it was reported (Newman, O'Connell et al. 1997) that teachers utilized varying means of assessment of students (one-to-one conferences, peer evaluations of presentations, and portfolio review) and that students were reported to improve in knowledge of conducting scientific research and knowledge of science. Student portfolios were "highly variable" during the first year, and were therefore carefully reviewed over the next two years. Administrators perceived the SRP as meeting many of the criteria put forth in various initiatives from the state education department.

During the second year (Newman, Cardella et al. 1998), students were also found to have improved in making inferences, organizing and planning, solving problems, using technology effectively, time management, and interpreting data. Student portfolios were again reviewed, and 80% were found to be high level. System outcomes included administrators remarking that the skills in the program translate to all academic areas. Mentors offered suggestions for expansion of the SRP, and interactions between teachers and mentors became a focus for year three. Additionally, the evaluation team noted the willingness of teachers to voluntarily attend training and support group meetings and the unique opportunities for students to collaborate in science research that benefits the scientific community.

The Year Three Program Implementation (Newman, 1999) placed an emphasis on portfolio utilization by students and asked the question, "How do students use their portfolios to construct scientific knowledge?" Although the majority of students maintained high quality portfolios, the portfolios were seen as static collections of work and questions were posed to determine whether students examine one another's portfolios and how this would help students. Approximately a third of mentors who responded to surveys reported that they were unaware of the existence of the SRP, although these mentors were actually working with students, the mentors did not know that the students were a part of the SRP. The majority of administrators noted that "a highly motivated and committed teacher is instrumental to the program's success."

Another area that was assessed by the year one evaluation of the science research program (Newman, 1997) in order to assess the effectiveness of the program was "What are perceived changes to the educational system as a result of implementing the SRP?" (p.6). Respondents believed that the program helped to fulfill New York State Education Standards by meeting the research component of the standards and the Math, Science, Technology (MST) initiative. One administrator commented that the science research program "has the potential to foster greater respect and interest for science in the total body" (p. 23). Participants of the program reported that "the science research program expands the high school curriculum by adding a unique elective which addresses the often neglected research component" (p. 23).

Literature Review IV: Summary

Students learn better when they are actively engaged in constructing their own knowledge. It is not enough for students to be actively engaged in a 60-minute hands-on laboratory. Students do not get deeply involved in "explorations" in which the procedure is followed similarly to a cookbook recipe and for which the answer is already known by the instructor. In order to have students conducting scientific investigations, they must pose the problems to be studied and they must be involved in figuring out the steps to solve the problems.

The National Association of Secondary School Principals, the National Research Council, and the American Academy for the Advancement of Science have all recently published standards for science education which include new areas of emphasis over the traditional accumulation of facts. Some areas of emphasis include positive attitudes including curiosity, openness to new ideas, and informed skepticism. Carrying out an investigation includes framing a question, designing an appropriate approach, learning to use scientific tools, and instruments, conducting trial runs, gathering and organizing data, interpreting data and drawing conclusions, and communicating results to the scientific community. The premise of high school students conducting scientific research investigations is well rooted in the theories and literature of constructivism.

Another goal of encouraging students to pursue authentic research projects is to raise scientific literacy among the population. As students conduct their own review of the literature in preparation for their experimentation, students are exposed to more technical abstracts and reports containing specialized vocabulary and techniques with which they are unfamiliar. Teachers and mentors assist students to decipher and understand the facts, processes, and concepts of science. Scientific literacy is a lifelong pursuit and it is less intimidating to initiate at the high school level at which support is available to students.

New teaching methods emphasize mentoring, apprenticeships, and peer assessment. It is a natural human response to avoid rather than to embrace change. The changes required in order to facilitate more inquiry learning include covering less material in the same amount of time and empowering students (read: removing power from teachers) to conduct their own investigations. There has been considerable opposition to divesting content in favor of process. Alternative assessments are still unfamiliar to many veteran science teachers.

The literature has indicated that taking more science classes fails to enhance science process skills, but that these skills are enhanced through working with a mentor on a research process. Critical observations, resolving problems and making decisions (drawing inferences and conclusions) are the sort of intellectual skills that are valued by most, if not all, state education departments. Students should become adept in measuring, generating hypotheses, predicting, estimating, controlling variables and communicating their work. An idea of where and from whom to seek additional information regarding scientific studies is another set of process skills that are critical to students' successes in understanding science. The science process skills of carrying out investigations to verify or generate information are tested on the science laboratory activity of the Connecticut Academic Performance Test (CAPT) and appear in other state science education goals.

Chapter II: Implementation

The design of the program and the protocols utilized for the research questions were reviewed by experts, including University science education professors, scientists, and pre-college science educators. The design of the program continues to evolve as needed improvements become apparent, and peer review of design ideas continues, based on analysis of other programs and the needs of the students.

This three-year research program has many components, all of which contribute to overarching goals that will help the student in the development of an authentic research project. To progress from September to June in each year of the program, there are various processes and procedures for each student and the instructor.

The program is exclusive; only 17 applicants were accepted in the first year. The criteria used for submission include: Grades in science classes, overall grade point average, teacher recommendation, and an essay that shows the ability to work independently and to excel in the face of extreme difficulty. In subsequent years, the program will accept only 7 new incoming sophomores each year. Ten wireless laptop computers were purchased for the program, as well as a data projector and a scanner/photocopier.

Timeline

Starting with summer of freshman year, students are asked to choose an area of scientific interest. They are required to read ten articles on this interest from magazines, newspapers or books. From these articles, the student develops questions, which may evolve into avenues of research.

During the sophomore year, the students are required to continue to narrow and focus on their topic. They master skills of computer researching, locate and retrieve approximately 20 journal articles in their field of inquiry, and are required to read five journal articles per quarter. After reading appropriate articles, the sophomores are required to write, by the end of October, a statement of their intended research based upon their bibliographic research. Subsequently, they are to contact the authors of these articles by telephone (or by e-mail), engage them in a conversation about their own related topic, and establish a rapport with the professors that often (but not always) develops into a student/mentor relationship. It is astonishing how readily a professor will mentor students who have read their publications and show interest in doing research in the same field. Each sophomore is required to publicly present one article from the articles retrieved. The article is presented using PowerPoint and an overhead projector and must include:

1. A review of literature.
2. A statement of the hypothesis.
3. The methodology of the author.
4. A presentation of the data using graphs and charts.
5. A discussion of the data presented.
6. The conclusions of the research.

The student is assessed by his/her peers on two levels:

1. The presentation of the author's research using the scientific method (as outlined above).
2. The student's presentation itself (viz., eye contact, clarity, use of overhead, etc.).

During sophomore year, the student tries to locate a research facility (with the teacher's assistance) where he/she will be doing the actual research. This research facility is usually a local university, or a company's laboratory. However, many students' research projects occur in the school, backyard or the local community, with the research instructor acting as the mentor. During this year, the sophomore will have created five timelines which chart the research plan – one for each quarter, and one for the summer. At the end of sophomore year, the student will create a poster board which will outline the intended research and any results already obtained. During this year, the student will meet with the teacher every two weeks to ensure that all goals and objectives are reached. All student presentations explicitly follow the steps of the scientific method. At the end of the year, it is expected that the student will have obtained a mentor, as well as developed a preliminary project idea and plan.

During sophomore year, parallel to his/her independent work, students will perform three independent experiments under the guidance of the research instructor. Science I will take place in the first 10 weeks of school, Science II will take place in the second 10 weeks of school, and Science III will take place in the last 20 weeks of school. Also integrated into this year are many lessons in experimentation, wet-bench methods, survey procedures, and statistical analysis.

The students' sophomore summer, determined by family commitment, is research oriented. During this summer, the student begins to design the experiment with the aid of the mentor, and is in contact with the supervising teacher on an as-needed basis.

The junior year is a year of intense laboratory research. The student meets, calls or uses e-mail to communicate with the mentor at least twice a month, and is actively engaged in experimental bench research. The hypothesis is redefined as needed, based upon literature readings and new experimental directions. Journal readings progress at the rate of 20 per year. The student continues to meet with the teacher for one hour every two weeks to discuss the ongoing research. During this year, the student gives public presentations of research findings to the teacher, the class, and the school community in the form of sympsia. In these public presentations, the student is required to include:

1. A review of relevant literature.
2. A statement of the hypothesis.
3. A clear exposition of the research methodology.
4. A tabulated and/or graphical depiction of the data obtained.
5. A discussion of the data.
6. The conclusions obtained, and future research needed.

These presentations are based on the model developed in sophomore year and is followed explicitly in every student's presentation. At the end of junior year, the students are introduced to the computer statistical analyses programs that they may use to help present their results.

The junior summer is dedicated to bench research. The student attempts to complete the research project and is in constant physical contact with the mentor and the teacher on an as-needed basis.

At the start of the senior year, the student research is completed. The student continues to meet with the teacher every two weeks to ensure that all goals and objectives are reached. Thereafter, the student engages in a formal writing of the research and in the construction of a formal presentation. The paper is entirely written by the student, with the aid of the mentor, and modeled on the format of journal articles. The paper is reviewed and edited by the teacher and the mentor. In addition, senior students are taught how to write and effective and strong abstract, focusing on economy of language. Seniors create PowerPoint electronic slides to present their research.

Senior students are required to give presentations to:

1. The Class.
2. The student body.

3. The academic community including the Board of Education, research mentors, visiting professors from local colleges, scientists from industry, parents, and the press, at a local scientific symposium.

Furthermore, they are encouraged to enter local, state, national, and international scientific competitions. Finally, each senior is required to attempt to publish his/her research in a scientific journal (high school, or professional). During this year, the seniors establish four timelines.

Timeline Matrix

On the following page (*Figure 1)* is the 2006-2007 pilot year timeline laid out in a matrix format, with each year mapped out against the four quarters of the school year. This matrix does not include the summer assignment prior to the start of year one.

In addition to the activities that are listed in the matrix, students met with the instructor in one-on-one meetings every ten days. The purpose and format of these meetings, as well as all of the components seen in the matrix, will be explained in the implementation section immediately following the timeline table.

While reading the matrix, one can easily discern a key component of the research program: *modeling*. Each student in the research program learns to watch others who are advanced in their studies to model each individual skill. Students learn how the scientific method is applied in real science by reading scientific journals and discussing with others how a particular scientist, or group of scientists, solved a problem. Before any student is asked to demonstrate a specific skill, that skill is modeled for them at least twice by an upperclassmen that has already performed the task, or the instructor. For example, before a sophomore is expected to stand up in front of the class and give a presentation in PowerPoint, they have seen both juniors and seniors present already. At the beginning of the year, the instructor will present a PowerPoint presentation to give an exemplary model of a scientific presentation.

Matrix: Timeline for Research Seminar

	Quarter One	Quarter Two	Quarter Three	Quarter Four
Year One Sophomores	-Science I Project -Observe Juniors and Seniors -Exploration, readings -Finding interest area -After first meeting, write first 10 week plan	-Science II Project -10 Week Plan -Progress from general articles to primary literature ***End of Quarter:*** -Sophomore Mid-Term Paper -Written Article Dissection of potential mentor	-Science III Project -10 Week Plan -Initiate Mentor Recruitment -Present PowerPoint of Article dissection -Wet-bench exercises	-Complete Science III Project -Secure Mentor -Present Poster of Article Dissection -Summer Vision Paper -Initiate Project design
Year Two Juniors	-10 Week Plan -Written Article Dissection of Mentor -Junior Vision Paper -Project Design -Continue readings and required content for project	-10 Week Plan -Present PowerPoint of Article Dissection -Complete Review of Literature for project ***End of Quarter:*** -Present PowerPoint of Junior Mid-term paper	-10 Week Plan -Poster presentation of Junior Mid-term paper, including: Review of Literature, Objective, Methods, and Analysis Tools. -Initiate project (if ready)	-10 Week Plan -Organize Symposium -Complete Summer Vision paper with mentor -Prepare for summer research project -Review competition guidelines
Year Three Seniors	-10 Week Plan -Complete research project -Write final paper -Present PowerPoint of summer research, including all available stages of project.	-10 Week Plan -Poster Board presentation of research project -12 minute PowerPoint presentation of research project, in preparation for competition	-Complete Poster board of research project -Competitions -Mentor underclass students -Run wet-bench work for sophomores	-Research Symposium -Submit project for publication in annual Catholic Central Research Journal.

Figure 1: Timeline Matrix

Application Process

Budgeting and time constraints limited the amount of students who could be allowed into the program. The first step in starting the program is developing an application process whereas students with the highest propensity for success in an independent environment are identified. In this pilot year, 9 sophomore students and 7 junior students were invited to participate.

Before giving out the applications, the author visited the classrooms of all freshman students, and gave a ten minute presentation of the research program, in the spring. After that presentation, all freshman teachers were given access to applications to the Research Program [Appendix A].

At the due date of the application, the author gathered all applications and sorted them according to science and math teachers. In systematic fashion, the author talked to the science and math teachers of all applicants, to get verbal and on site feedback as to the capabilities of each applicant to excel in an independent environment. Students who remained in contention were then interviewed in a one on one meeting with the author [Appendix A].

After these interviews, the final class of individuals was determined. The author looked for students who had maturity, writing skills, curiosity, and an ability to work well independently by managing a time and a workload.

Students who were accepted were sent a letter of acceptance [Appendix A], while those denied admission were sent a letter encouraging them to apply next year.

Pre-Program: Summer Assignment

The first task of a researcher is to answer a fundamental question: "What am I interested in?" For students, this question can be especially daunting. The summer assignment [Appendix B] simply tries to get students to pay attention to what is catching their interest.

The summer assignment gives them a head start in preparing for meetings with the instructor, and puts them in the proper mindset for what lies ahead.

One on One Meetings

In one-on-one meetings, the teacher is able to concentrate solely on the needs and concerns of the student, and the student gets all of the attention. These meetings are important so that the teacher can review their progress, set new goals, and give assistance when needed (particularly with editing of scientific papers written by the student).

In this program, students meet individually with the teacher once very two weeks. These meetings are scheduled in advanced, and students must be prepared for them. Each student will have individualized needs that will need to be tended to, but their specific progress from the last meeting must also be checked.

When the first one on one meeting in year one commences, the first thing the author will ask the student is "What did you find over the summer?" and will simply listen to what the student has to say about the articles/stories that the student seized upon. This will allow the author to further assign readings, based on the subject areas that seem to come up in the articles the student picked over the summer.

At the opening of each meeting, the teacher will ask to see the 10-day Goals [Appendix C]. These are a set of goals that the student set at the conclusion of the previous meeting, with the idea that they would accomplish these goals between meetings. The teacher will review with the student the progress towards the completion of these goals.

After discussing what has been accomplished between the last meeting and this one, the meeting takes on a set agenda:

1. Ask for the duplicates out of the students' lab books [Appendix C]. In this lab book, students will have written down summaries of any and all readings that they have done prior to this meeting, as well as any experimental notes on any project that they have running presently.

2. Ask for the time log [Appendix C]. A research student who is diligent should put in at least nine hours of work per week, including in class research time. It is important for the teacher to check the time log against what is written in the lab book summaries for inconsistencies. At this time, the teacher can talk with the student about time management if needed, or if the student simply needs to be doing more work.

3. At this point, the meeting becomes individualized. Depending on the class of the student (sophomore, junior, etc.), the time of year, and level of readings, this time is spent on whatever needs the student has at this time.

4. Students produce the 10-Day Goal sheet. At the bottom, the student and teacher together set the goals for the student from now until the next meeting time.

5. At the conclusion of the meeting, the teacher will allow the student to assess his/her progress during the previous 10 days using an evaluation form

[Appendix C]. The teacher will discuss the assessment with the student, and the student and teacher together will give the student a value to assess the students' progress during the previous 10 days.

Finding an Interest Area/Readings

The first task of finding the interest area of a student is to talk to the students about paying attention to what they read when they thumb through newspapers and magazines, which starts off with the summer assignment. When the student participated in the first one-on-one meeting, the teacher first asked them to talk about what they found interesting; i.e., what articles did they summarize? As the student spoke, the teacher listened to try and glean ideas that are common to the readings. After the student completed their discussion about each article, the teacher then wrote down several topics that seem to be in conjunction with what interested the student about that particular article. Then, the teacher went through the extensive list of different topics that seemed to have come up while the student was describing the readings, and got oral feedback from the student. The teacher assigned further readings based on those topics. At the beginning of the year, this list of topic interests should be large and diverse. Every time the student meets with the teacher, this topic list should get more and more specific towards a certain topic area. Once a student has identified, with the guidance of the teacher, a definite topic area such as biomedical engineering, diabetes, child psychology, etc., the student then proceeds to read articles solely on that one topic. Again, students move progressively towards more and more specific interest areas until the student has found a specific interest area that he/she would like to spend the next two years working within.

As each student progressed through the ranks of finding a specific interest area, he/she also progressed in the level of reading difficulty. Students started off with newspaper articles and general magazine articles. Ultimately, students displayed the mastery needed to start reading primary literature. At this time, real learning occurred on multiple levels.

When students reach the level of reading scientific journal articles, they complete assignment called an Article Dissection [Appendix D], written by Dr. Robert Pavlica. This assignment enables the student to fully understand both the structure of the journal article and relative importance of the parts or the journal article. Students dissected a journal article, and presented this dissection to the class.

As anyone can attest, the reading of these articles is not a trivial exercise. Students can take months to read even one article. This is appropriate, because the student must show mastery not only of the structure of the article but of the content. Students ended up teaching themselves an enormous amount of material before they were done with a journal article.

Mentor Recruitment

While the student is reading primary literature about his/her interest area, they found that certain names kept showing up as leading contributors to the interest area of the student. This is the time in which the student will start to think about recruiting a mentor to help guide them in their independent research.

Mentors include college professors and industrial researchers. In most cases, potential mentors have had a positive influence of a mentor early in their careers and have the desire to respond in kind. These mentors understand the significant role they can play for a new generation of young scientists. While the teacher has a more generalized degree with a broad picture of the subject area, mentors have a more specific expertise.

The significant contributions of mentors to a student that is seeking to develop an authentic research project include the following: specific expertise matching a student's interest, a time commitment, access to equipment and a lab, access to scholarly journals and articles, a professional role model, and guidance to the student.

Ideally, a scientist that has written a journal article that the student has already taken a special interest in would be a primary target as a potential mentor. If the authors of the papers are not available because of either geography and/or policies of the institute, then the student would then scour local research universities to look for possible mentor candidates.

When looking for possible mentor candidates, students consider that the possible mentor is doing work that is specifically interesting to the student, that the work is current, and that the possible mentor is geographically possible.

The student then focuses solely on the work of the potential mentor. In the span of several months, the student will read every abstract of every study the possible mentor has published, whether or not it is in the interest area of the student. Then, the student will pick four journal articles authored by the possible mentor and read them, making sure that they understand both the structure of the study as well as the science behind it. At this time, they will write an e-mail to the prospective mentor, that will include a description of themselves, a description of the program, a description of what they have read, a description of what work of the prospective mentor they find most interesting and why, and a formal request to work with that researcher. Two examples of recruitment letters to potential mentors can be found in Appendix E. Students are provided models, and these letters are edited by both other students and the teacher before they are sent.

If the mentor does not respond within eight school days, then the teacher proceeds to make a personal phone call to assure that the scientist received the email, and if so, if the prospective mentor had any questions. If the mentor responded and gave a negative response, then the student wrote a polite letter of thanks, and started over again with another prospective mentor.

If the mentor responded with approval, then the student immediately wrote a letter of gratitude and requested a meeting to start the relationship. This meeting is attended by the student, the mentor, and the students' parents. At this meeting, the student outlined what his/her specific interests are, and where he/she believes his/her potential research is heading.

In the scope of the three year timeline of this program, students recruited the prospective mentors in early May of sophomore year, with the goal of having a mentor secured by the beginning of June. The summer between sophomore year and junior year will be spent furthering the relationship via email and periodic visits between the student and mentor, and continuing with readings.

Planning

One of the most important tools of successful researchers is the ability to plan, in both the short term and in the long term. One of the central ideas in this program is to set deadlines, abide by them, and arrange work schedules to meet that deadline. To do this, students must first what it means to plan. During the first couple of days of school, the teacher asked the students to plan a trip to Disney World. The teacher did not give them any parameters, except to say that it is a weekend trip to Disney World for the family of the student. When the assignment was due, the students all shared their plans in front of the class, for their first experience in peer review. As each student stood up and read through their plan, it was the task of every other student to find at least one aspect of the trip that was *not* planned. In this way, students learned very quickly that even the simplest of tasks requires the planning of many, many details that are often overlooked.

At any given time, students have three plans in place, from the long term to the short term. The long term plan is for an entire school year, and is called the Sophomore Mid-Year Plan [Appendix F] (for sophomores) or the Junior Vision Plan [Appendix F] (for juniors). Midway through the junior year, the juniors will also be asked to submit a Junior Mid-Year Plan [Appendix F] that will serve as a precursor for the summer research project. At the end of the sophomore year, students are asked to submit a Sophomore Summer Vision plan [Appendix F] that explains what they will accomplish over the summer.

Four times during the year, students will be asked to submit a Ten Week plan [Appendix F], which corresponds with the beginning of each marking period.

Finally, students will set goals and plans to achieve those goals on a 10 day period, from teacher and student meeting to another. These plans will be constantly monitored and reevaluated during the course of the year during the one-on-one to make sure that each plan is being followed, and if there are revisions, to be sure that they are made appropriately and for appropriate reasons.

Experimental Methodology

During the sophomore year, it is important to teach basic experimentation skills. As the students enter the research program, they have a basic idea of the scientific method. The experience of the student has been very clearly "cook book" type labs where the question is asked for them, the system is set up for them, and the expected data are explained. Students must be shown the importance of asking a testable question, setting up a system that can attempt to answer the testable question, how to take data that can be used to support and or not support a hypothesis, and how to use the data to write a sensible conclusion. Students also need instruction on how to learn the basic science behind their projects and ideas, as well as to constantly look out for ways to improve their system.

Particular, specific experimental procedures should be taught to the student by the mentor, in a specific individualized setting. However, basic methodologies can be taught to sophomores before starting out on their own self designed projects. This process involves a great deal of modeling and constant peer review.

Prior to starting any miniature projects that teach basic methodology, the students participate in three small assignments [Appendix G] that teach students how to set up a controlled experiment, and an appropriate system, and to determine the difference between causality and correlation in experimentation.

The sophomores next complete three extensive in house projects throughout their sophomore year. They are called Science I (an observational study), Science II (an experimental study), and Science III (student's choice).

Science I involved an observational study of a river waterway system. Students were instructed to research what an observational study is, and the difference between an observational study and an experimental study. Students were then put in groups of four, and the class as a whole traveled to a nearby river with ready access. Students were given two hours to observe and take notes. The next class period, students were allowed to discuss possible study ideas. The next day, these ideas were shared amongst the class, and critiqued. Students had a week to develop a complete project plan, as well as an order list for supplies. Each project plan went through both a written and oral peer review, and students were given two weeks to run the experiment. After one week of taking data, one class period was used to give an update to the rest of the class as to the progress of projects. After collection of data was complete, students had one week to analyze the data, write a scientific paper, and present their project and results to the class in PowerPoint format. An example from a group of four can be found in Appendix G.

Science II is an experimental study that involved the science behind cooking, performed in groups of three. Students were required to purchase the book *Cookwise* by Shirley O. Corriher, which is a veritable textbook on the chemistry behind cooking. Students were required to do an extensive literature review on an area of research involving information contained in the book *Cookwise*, design and conduct an experiment, write up the experiment as a scientific paper, and present the project to the class as a Power Point presentation. The Science II project had the same time frame and peer review schedule as Science I. At this point, students become very aware of both the value and importance of peer review, and actively seek it out even when not scheduled. An example of a Science II project can be found in [Appendix G].

Science III is an individual year end project required for all sophomores. This project entailed the entire second semester (20 weeks), and the subject and type was of the individual choosing of the student. For Science I and II, all deadlines were set by the teacher. For Science III, sophomores scheduled their own deadlines for each stage of the project, including project ideas, literature reviews, design, materials ordering, performing the project, data collection, data analysis, scientific paper, and presentation. Students were also required to schedule peer review at all stages of development and implementation. Examples of Science III projects can be found in [Appendix G].

Institutional Review Board and Grant Board

In an effort to provide students with a research experience as realistic as possible, part of the research program involves the formation and use of an IRB and a Grant Board. An IRB (Institutional Review Board) is an appropriately constituted group that has been formally designated to review and monitor research involving human subjects. The purpose of IRB review is to assure, both in advance and by periodic review, that appropriate steps are taken to protect the rights and welfare of humans participating as subjects in the research. To accomplish this purpose, IRB's use a group process to review research protocols and related materials (e.g., informed consent documents and investigator procedures) to ensure protection of the rights and welfare of human subjects of research. The IRB at Grand Rapids Catholic Central consisted of four individuals: An established science teacher (not the research teacher), the assistant principal, the head of the religion department, and a parent who is a physician. When sophomore students are performing the Science III project, some of them may choose a project that involves using other students as subjects. If that is the case, the student is required to fill out an

IRB application. This application includes a vast amount of information to the review board, including the subject of the study, the procedure, the type of data collected, the procedure in which the data will be collected, the role of the experimental subject in the procedure, and what risks and or benefits are involved. The review determines if this project is indeed appropriate according to both school and civilized guidelines (borrowed from the IRB at Michigan State University and INTEL), and approves the project. The student must then write a consent form that must, after again being approved by the IRB, be signed by both the experimental subject and his/her parent. This gives the student invaluable experience in the real world workings of experimentation and research.

While performing Science I, II, and III, students need to order and purchase materials. Before being allowed to do this, students must justify the need for these materials to a Grant Board, made up of three individuals: The research teacher, a senior student that has been hand selected by the research teacher, and the assistant principal. Students must submit their project proposal in writing, as well as each individual material and cost. The Grant Board determines if the cost is justified, and if so, orders the materials. If the Grant Board determines that costs are not justified, then the proposal is sent back to the student for revision. This gives students invaluable practice in two key areas of practicality: First, students learn to work within a set, limited budget. Secondly, students learn to work to find the most cost effective way of achieving a task instead of simply ordering kits out of a catalog.

Science Thursdays

As a way for all students to keep abreast of what others are doing in their individual projects, we have a day of sharing every other Thursday. Elected students bring in food and drink, and the period is spent going around the room giving an update on the state of each individual student's research. This is especially useful with the modeling aspect of the class. Sophomores tend to hang on every word of the Juniors, learning where they are going to be at this time next year and what they can expect and where they should be in their own research. It is a key time for peer review of progress also; it is not uncommon for other students to question why a particular student has not progressed further since the last Science Thursday. Finally, this gives students in the class to hear interesting and up to date information on subject areas outside of their own.

Ethics

As students of research, it is important to spend time with students talking about the ethics that are involved with discovery science. As found in Appendix H, the teacher spent approximately one week working on ethical issues involved in research and how best to work with them.

Statistics

Five class periods are devoted to statistic lessons. During these five class periods, students travel to the classroom of the AP Statistic teacher, who teaches them basic statistics, statistical analysis, making and using graphs and charts using data sets, and using specific experimental situations to decipher proper statistical analysis. After getting feedback from mentors and professors, it is deemed not necessary to teach complex statistics. These skills will be learned on an individual basis with the mentor.

Presentations

A part of being scientifically literate is the ability to express oneself scientifically. When students complete a project, whether it be a Science I, II, or III, or an article dissection, they are expected to present this project to the class in a PowerPoint presentation, and in the case of a Junior Summer Vision paper, they are expected to also use a posterboard. The skill of being able to express oneself scientifically without simply reading your paper out loud is not only valuable but extremely difficult. For students to make the switch from learner of a particular topic to a teacher of this particular topic, to convey an appropriate amount of understanding, to give a meaningful presentation, is a skill that takes a lot of time, and practice, to learn. Students that give presentations are given feedback from their peers in all sections of the scientific method as well as the quality of the presentation itself [Appendix I].

Competitions

Several competitions exist for the sharing of research projects at the high school level. While entering competitions is not a goal of this research program, nor is winning a measure of success, entering competitions was encouraged. There are literally hundreds of competitions that exist nationwide that provide an avenue for a student to put his/her research project and subsequent paper up for a larger audience for peer review. Most students will enter the Intel Science and Engineering Talent Search. Some will find their particular project will fit more specifically in a competition that is geared more towards the subject area of their project.

Chapter III: Presentation and Analysis of Data

This research project set out to define and then assess the effectiveness of a research program designed by the author. This research program had five main goals: Use of the Scientific Method, write a scientific paper, present scientific data, participate in the scientific community, and to culminate into conducting an authentic research project.

The first year (2006-2007) of this pilot program involved both sophomores and juniors. At the end of the pilot year, the sophomores will have only just secured their mentor to start work, while the juniors will have started a project of their design. Therefore, the students in the class will be at different levels of attaining the ultimate goal: the design and implementation of an authentic research project. The results gleaned from students in this pilot year are organized into three sections. Part I, which assesses the competency in research skill areas. Part II, which assesses the change in attitude, perception, and ability over the course of the pilot year. And finally, Part III, which gives the exact descriptions of each project designed by students so that the reader can discern the impressive level of accomplishment.

Part I: Skill Self Assessment

Students were asked to self assess their competency in seven areas, which were expansions of the main five goals of the program, in both the beginning and end of the pilot year. These seven main areas are use of the Scientific Method, scientific thinking, conducting literature searches, conducting authentic experimentation, working with data, participating in the scientific community, and writing a scientific paper.

Students were given a questionnaire [Appendix J] in both August (Pre-Pilot Year) and June (Post-Pilot Year).

In Figures 2 and 3, each of the seven skills is treated independently. These data are gleaned from all 17 members of the pilot year of the research program. Each chart is representative of the average rating on a Likert scale of each of the seven skills from one (being the least proficient) to 5 (being the most proficient) both before and after the pilot year of the research program.

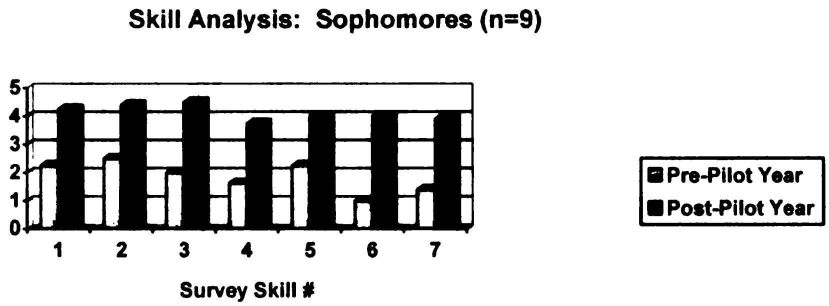

Fig. 2

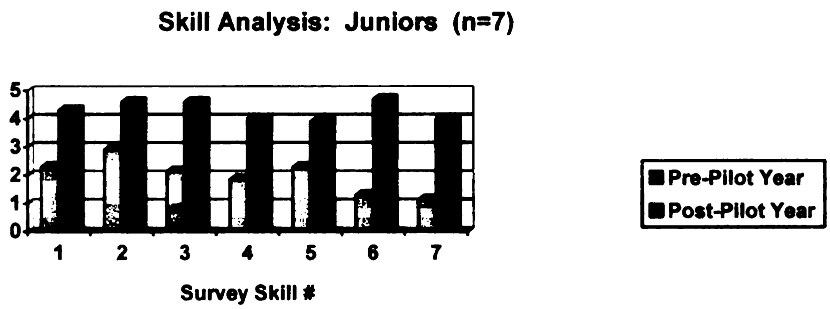

Fig. 3

Part I Analysis:

All students ranked a marked increase in their skill level for all seven goals. Not surprisingly, the most improvement came with the skills of working within the scientific community and writing a scientific paper, since anecdotal evidence showed no evidence of practice in either of these before the pilot year. Also, it is not surprising that goal five (use of statistical analysis) showed the least percentage of improvement, since this was the goal that was least addressed. The bulk of statistical education should be done on an individualized basis as relevant to the subject field and research project, and thus should be done with the mentor.

These data suggest that on average students in the research program improved at skills pertaining to the five goals of the research program over the span of the one pilot year. Further studies in future years can demonstrate further improvement and mastery of the goal skills.

Part II: Student Interviews

A technique common in field research is the interview. The value of asking students "real questions," ones to which the researcher is genuinely interested in the answer, rather than contrived questions designed to elicit data of a particular sort, is emphasized by Carol Gilligan (in Maxwell 1996, p. 74). In light of this, all students were also asked several questions pertaining to perspectives, methodology, and program design for Part II of the Results. This is particularly helpful to help ascertain whether the pilot program significantly altered attitudes and perspectives of students as pertaining to science and science discovery. Two sophomore and two junior students were randomly selected for complete reporting of these interviews. The responses for all students were then used to assess if each student has achieved the research program goals.

The second part of the assessment came in the form of a formal one-on-one interview using a specific set of questions [Appendix K]. The interviewer was the teacher and developer of the project. Each interview took approximately 20 minutes. The full transcripts of these four interviews can be found in Appendix K.

Figure 4 is a checklist to illustrate mastery at a certain level of goals in the areas of methodology, perspective, and skills. Figure 4 is based on a distillation of the interview questions found in the Appendix to simple yes or no responses to the following questions:

1. What year in the pilot program?
2. Has the student displayed a change in perspective in relation to science interest?
3. Has the student displayed a change in perspective in relation to what scientists do?
4. Has the student displayed an ability to describe a controlled experiment?
5. Has the student displayed an ability to adequately describe statistical analysis?
6. Has the student displayed an understanding of how science is discovered?
7. Has the student displayed an appreciation for planning towards a goal?
8. Is the student performing at a high level because of his/her own motivation, and *not* that of his/her research instructor or parents?
9. Has the student become a better scientist?
10. Has the student displayed the ability to follow the scientific method?

Question #	Student A	Student B	Student C	Student D
1	Junior	Junior	Sophomore	Sophomore
2	Yes	No	Yes	No
3	Yes	Yes	Yes	Yes
4	Yes	Yes	Yes	Yes
5	No	Yes	No	No
6	Yes	Yes	Yes	Yes
7	Yes	Yes	Yes	Yes
8	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes

Figure 4

Part II Analysis:

After comparing the results from the four randomly selected students to the rest of the students in the program, it is evident that the four students reflect the interview data of the entire section of 16 students. It is also evident that students in the pilot year of the research program showed a marked increase in the ability to "do" science and their interest in science. However, the class as a whole showed themselves to act as a state function: they all made it to the same level (sophomores with other sophomores, and juniors with other juniors) at the end of the pilot year, but all took very different paths with different setbacks to get to that level.

Student A exemplified the aspect of the program to instill in students an ability to use the scientific method, experimentally, in an environment of discovery science.

Student A started off the year with a very healthy interest in science, but with only limited experience with lab work. While starting out with a very diverse set of interests, this student soon started to focus in on psychology, and the effects of psychology on health. Soon, however, this student came across some research on how specific nutritional factors affect certain cancer growths, and this idea led to a very intense study of primary literature of how nutrition can be used to decrease the growth rate of colon cancer. At about this time, this student completed Science I, working on a study of coliform levels of a nearby river, and turned in a scientific paper of a very high level of complexity. Student A showed a very high level of ability to work in a discovery science environment early in the year, climbing a very steep learning curve very rapidly. Student A recruited a professor at Michigan State University, and the mentor was duly impressed with the level of knowledge and accomplishment that this student showed. This student immediately cultivated a working relationship with her mentor to design a project, and is currently working on a very interesting study involving a specific nutrient in beans and their effect on the growth of colon cancer cells. This is a student whose interest was only strengthened, not created. However, her skills and mastery in being able to work in a scientific environment as a researcher greatly improved throughout the pilot year.

Student B exemplified an aspect of the program that affords students the opportunity to appreciate the process of discovery, and the excitement that often accompanies it, rather than just the end results. Student B is quite possibly one of the most intelligent and driven students the author has ever been involved with as a teacher. This is a student who, as predicted, showed very little difference in any goal category before and after the pilot year. Student B progressed very quickly through the reading stages to primary literature, centering in very quickly on transcription factors. However, student B lacked a true understanding of what real science entails, and therefore lacked an appreciation for the value in going through the process. It was very evident, both in discussion and in interviews, that the primary goal of student B was not in the process, but in the level of accomplishment in the beginning of the pilot year. For example, the primary goal was not in the realm of having a rewarding experience, but to "get into MIT" or to "have an amazing mentor." Student B, without consideration of logistics, recruited a potential mentor that was a Nobel Prize winning scientist that worked at the Whitehead Institute at MIT. This recruitment was indicative that the thought process involved had more to do with names and accomplishments then the specific project work of student B. When the inevitable decline came from the potential mentor from MIT, student B moved on to another scientist at MIT, and also received rejection. These two rejections led to student B reevaluating the criteria that was being used to find a potential mentor, and led this student to a professor at Michigan State University. Presently, student B is working on a very involved, complex, and novel project with this mentor. Daily, I receive emails from this student that exude excitement over what she is learning and experiencing. This evidence of appreciating an experience without regard to accomplishment is very evident in both discussion with the student and with answers to interview questions. This growth is also evident in the difference in written expression from the beginning of the pilot year to the present.

Student C is a student that grew exponentially in this pilot year in two key areas. This student started out the year with little or no confidence and poor writing skills, despite an acute intellectual ability. When deciding on an interest area, this student wavered for over four months. Even when the student seemed to be locked in and very excited about automotive engineering, she came in the very next day and declared that automotive engineering probably was not what she wanted to study. After some discussion, she admitted that after going home excited about finally finding an interest area that was inspirational, the student's parents deadpanned the idea, and the student changed her mind immediately. During this time, student C was completing two projects, Science I and II. Both of these projects resulted in papers that were poorly written, with spelling mistakes, grammar missteps, and poorly communicated ideas and organization. Even the emails from this student read as if they were text messages to friends, barely understandable. At or around February, after much discussion and meetings, student C started to show a marked improvement in both areas of confidence and writing. Without prompting, this student found an area (biomedical engineering) and began a furious primary literature search to find out as much as possible about the subject. Student C then identified a scientist at the Cleveland Clinic that was working on the PediPump, an artificial heart for infants and children, and spent a great deal of time learning about the work of this potential mentor, and in the process, learning an enormous amount of content matter pertaining to biomedical engineering. After identifying this potential mentor, student C presented an article dissection based upon an article from this scientist. This written report, and subsequent presentation, was so impressive in written form that it will be used by the author as a model to other sophomores next year when they write an article dissection. This student then wrote an incredibly intelligent, well organized, and persuasive letter to the prospective mentor, and was invited down to Cleveland Clinic immediately to meet the scientist who readily agreed to mentor the student. This student now speaks and carries herself with conviction and confidence, and emails from this student are now a pleasure to read.

Student D started this pilot year with incredible intelligence, ability, and interest, but lacking the work ethic and time management skills needed to achieve full potential. In our first three meetings, student D varied in interest areas, ranging from cellular aging, psychological aspects of education, and then finally settling into studying how specific genes regulate the spread of different types of cancer. Initially, during these meetings, the student showed appropriate progress, but it was clearly evident that the student could be moving much faster and accomplish much more. As a result, the author was forced to constantly encourage the student to reach farther with the available ability. During Science I, in a group of four, the student showed interest and did strong work, but the empathy was still present. Thankfully, in January, the student broke through this mental barrier. Science III is completely independent, and this student welcomed the chance to work on a project that was completely of his own design, without having to negotiate any ideas with project teammates. At meetings that occurred during this project, student D expressed numerous times that he had been spending many late nights preparing for, and executing, this project. After this project was concluded, the student saw with experienced eyes what the result is of hard work and dedication. This student expressed to the author, both in verbal form and in interview form, that the satisfaction gained from the results of working harder than he had ever worked before was unmatched in any accomplishment in his life, including sporting events. This student is an all-state caliber athlete.

Part III: Junior Research Projects

In Part III of the Results, students that were ready to start their research projects were asked to submit a detailed description of the project, including the introduction, objective, literature review, methodology, and expected results. This is used to inform the reader that the junior in the pilot program did achieve the final goal of designing and running an authentic research project. It is left up to the reader to assess the level of usefulness, complexity, and creativity of each project.

In this section, the reader will see the final, and the most complete assessment of the research program developed by the author. If students are able to design and implement an authentic research project, with a mentor, then it is assumed that all five main goals of the research program have been fulfilled.

There were seven juniors in the pilot program, all of whom completed the necessary steps to implement their research project. The seven students, and their topic of work, are:

Student A will study how beans affect colon cancer at Michigan State University.
Student B will study a molecular regulator of transcription at Michigan State University.
Student C will study depression and mood disorders at the University of Michigan.
Student D will study meteorites at the Center of Cosmochemistry at the University of Chicago
Student E will conduct an exploratory study that researches the possibility of attorney assistance in the early diagnosis of Alzheimer's patients at St. Mary's Hospital Alzheimer's Institute.
Student F will study the benefits of using video to model behaviors for autistic children at Grand Valley State University.
Student G will study space propulsion and build a microgravity drop tower at Michigan State University.

At the end of the pilot year, before they were allowed to embark on their projects, each student submitted an introduction to their project. This introduction was to include: a preliminary abstract, an objective statement, a literature review, methodology, and a review of expected results. These introductions are reproduced here as a testament to the success of the pilot year of this program for these seven juniors. These papers, in essence, are descriptions of their projects in both detail and scientific expression. Please note, these are student submissions that are not edited or reformatted in any way.

Part III Analysis

When starting this pilot year of this program, I was not optimistic about the level of work that could be accomplished by the juniors in this program. After all, one has to consider that with this being the pilot year, juniors were forced to move through two years worth of work in less than one school year. With this in mind, I did not expect the cognitive level of projects designed by students to be advanced in any respect.

To my delight, I watched during the year as the juniors took this challenge and did not limit their expectations of themselves in any way. As the reader will undoubtedly see, the students exceeded any and all expectations with the overwhelmingly advanced level of research work being done. These projects are creative, useful, novel, and required vast amounts of background work.

In the following pages, you will find student examples of work. These papers are descriptions of their research projects that they are participating in while the author is writing this thesis. They include the objective, the literature review, the methodology, and expected results. Following these examples of student work, you will find the Conclusion chapter.

I am proud of these projects, and of the students who designed them.

Summer Vision Plan

Student A

Research Objectives:

Throughout this year, I have gained great knowledge through my research. My main focus has been on how nutrition affects cancer. I am honored to have the opportunity to work on a project that has the potential for some incredible results. My project for the summer deals with which part of the bean inhibits the growth of colon cancer. By feeding rats already diagnosed with colon cancer diets containing different parts of the bean, we can determine which part of the bean inhibits the growth of tumors in the colon. Over the summer, I want to truly experience an authentic research project. I will learn about research and my topic through experience and especially from working with my mentor, Dr. Maurice Bennink. At this point, I am excited and ready to begin.

Review of Literature:

When it comes to cancer, anyone can get the disease. It does not matter how old, what gender, or what color the person's skin is; cancer has a way of getting to anyone [1]. Cancer can be defined as a disease in which the cells grow out of control. Normal cells follow a certain reproduction pattern. Cancer cells have some sort of mutation, and cannot stop multiplying [2]. There is also not just one kind of cancer. There are over 100 different types of cancer found throughout the entire body [3]. Of the six different types, carcinomas are the most common. This type includes colon cancer. This type of cancer is the third most popular form of cancer in the United States. In 2001, there were over 45,000 new cases for men and over 52,000 new cases for women [4]. This is a serious type of cancer seeing as how it is the third most deadly cancer in both men and women [5].

Although there is no cure for cancer, many scientists and researchers have found ways to prevent and control the disease. One can have certain tests such as colonoscopies or genetic testing done to look for signs of cancer [6]. It has been found that 30-40% of any type of cancer can be prevented by one's diet [7]. More specifically, beans have been found to contain many characteristics which help in inhibiting and controlling cancer. Some of these characteristics include the possession of: saponins, protease inhibitors, and phytic acid. All three of these work to either slow the growth of tumors or prevent them in the first place. Also, with the high fiber content, beans also lower one's risk of getting cancer [8]. Beans have also been found to contain antioxidants, which play a major role in stopping cancer. Antioxidants are substances which protect the body from oxidation and have also been found to fight against cancer [9]. Beans have also been found to have large amounts of folate and a lower glycemic index [10]. These two properties are thought to play some role in the anti-cancer effects. Folate is simply a compound of vitamin B and the glycemic index is a scale that tells how much the blood glucose level's average rise after one eats a certain food.

There have been a few experiments whose results have directly supported the idea that beans help inhibit the growth of tumors. One experiment, Hughes et al., fed rats either pinto beans or a milk protein. The rats fed pinto beans reduced their number of tumors by half compared to those fed the protein. Also, the rats fed the beans had fewer tumors altogether than those fed the protein. A similar experiment was done by Dr. Maurice Bennink and Dr. Hangen. This experiment had three different groups: casein, black beans, and navy beans. The results agreed with the first experiment showing that the rats fed the beans had a significantly less amount of tumors than the other rats [11].

The part of the bean that inhibits the growth of cancer is still unknown and is the purpose of this experiment.

Hypothesis/Objective:

The purpose of this experiment is to determine precisely which part of the bean inhibits the growth of colon cancer. We hypothesize that after the bean is broken down into components, only a very small part of the bean will actually have an effect on the tumors.

Research Methods:

We begin by injecting the rats with the colon cancer. By doing this, we ensure that each rat will have cancer and tumors in the colon. After this, each rat will be fed a set diet containing a different part of the bean. The bean will be broken up by which part is either soluble or insoluble with ethanol, and the soluble will be broken up further for a total of four different parts of the bean. One group will either be fed the entire bean while another group is fed a control, similar to the casein from the other experiments, making a total of six groups.

After a set time, the rats will be sacrificed and then dissected. The dissection will be done in order to obtain the colons, which will be weighed and examined further. By weighing the colons, we can determine which part of the bean helps inhibit colon cancer the most. The smaller the tumors or the lighter the colon, the more effective the bean was in inhibiting the cancer.

Expected Research Results:

After running this experiment, my mentor and I expect certain results. First, we expect that the rats fed the entire bean will have significantly lighter tumors than those rats fed the different parts of the bean. Also, we expect to find which of the four parts of the bean actually inhibit the growth of the colon cancer tumors more than the other parts of the bean.

These results can play a big role in conducting future experiments. This topic started very general, just looking for what foods inhibited the growth of cancer. After concluding that beans do just this, our study focuses on different areas of the beans. Future experiments can include breaking apart this section of the bean. By continuing to zone in on the specific component of the bean which inhibits the growth of cancer, researchers can figure out the exact components needed to inhibit these type of cells. By knowing this, studies can be done to foods with similar structures to find more foods with this ability. This is a step in research which has major possibilities.

Expected Conclusions:

From this experiment, many different conclusions can be made. First of all, by knowing which part of the bean inhibits the growth of colon cancer, we can start to test for the effects on other types of cancer. Also, we can look for the same characteristics in other foods to determine if they too inhibit the growth of these tumors. By finding out which part of the bean inhibits the growth of tumors, scientists and researchers are one step closer to finding a solid way to prevent and control cancer.

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Junior Summer Vision Paper

STUDENT B

C/EBPγ is a member of the CCAAT/enhancer-binding protein family of transcription factors that is shown to have a cell-specific activating role when heterodimerized with C/EBPβ, regulating proinflammatory genes such as TNFα. While C/EBPγ's activating role has been demonstrated in a variety of cell types and promoters, little work has been done on the TNFα gene. In this experiment, we demonstrate that the re-introduction of C/EBPγ into C/EBPγ KO mouse embryonic fibroblasts is sufficient to rescue transcription of said gene through the subsequent formation of C/EBPγ-C/EBPβ heterodimers. Thus, we can conclude that C/EBPγ has an activating role the transcription of TNFα in MEFs.

Review of Literature

CCAAT/enhancer-binding proteins (C/EBPs) are a family of transcription factors characterized by a highly conserved, basic leucine zipper (bZIP) domain which allows for dimerization and DNA binding [1-2]. This bZIP domain allows for homodimerization and heterodimerization between family members [3-5], which then serves as a means of increasing regulatory diversity [6-9].

Members of this family play an important role in a variety of inflammatory products, such as IL-6, IL-8, and TNFα [10-13]. Specific to this study, C/EBPβ is a key regulator of TNFα transcription [12]. However, contrary to the activity at the promoters of a variety of other genes such as IL-6 and IL-8, C/EBPβ does not exhibit synergistic behavior with NF-κB at the TNFα promoter [14-16, 17]

In general, C/EBPβ is predominantly found in heterodimers with C/EBPγ, a ubiquitously expressed member of the C/EBP family commonly found in heterodimers

[18-20]; the primary result of this relationship appears to be repression of C/EBPβ mediated transcription [21]. However, this inhibitory role appears to be cell-specific. In one study, while C/EBPγ did in fact repress transcription in L cell fibroblasts, it failed to do so in HepG2 cells despite the formation of C/EBPβ:γ heterodimers [18]. Additionally, C/EBPγ has been shown to activate transcription in immunoglobulin heavy chain promoters [22-23]. In another study, C/EBPγ was shown to augment C/EBP activity at the IL-6 and IL-8 promoters in a B lymphoblast cell line, but not in a macrophage cell line [24]. Thus, C/EBPγ appears to have both a cell-type and promoter specific role in transcription; further study on its effect on different genes in various cell types is warranted.

In this study, we investigate the role of C/EBPγ in the transcription of TNFα in mouse embryonic fibroblasts; while previous work has shown it to have no influence in a B lymphoblast cell line [24], C/EBPγ's cell-type specificity raises the need to study its activity in a variety of cells. Here, we demonstrated that C/EBPγ does in fact play an activating role and does so through the formation of C/EBPβ:γ heterodimers.

Research Objectives

This project was sparked by Gao et al., who commented that "it will be worthwhile to evaluate whether C/EBPγ can stimulate target genes that are known to be positively regulated by C/EBPβ in these cell-types and tissues." As one of these target genes, TNFα deserves further investigation.

Methodology

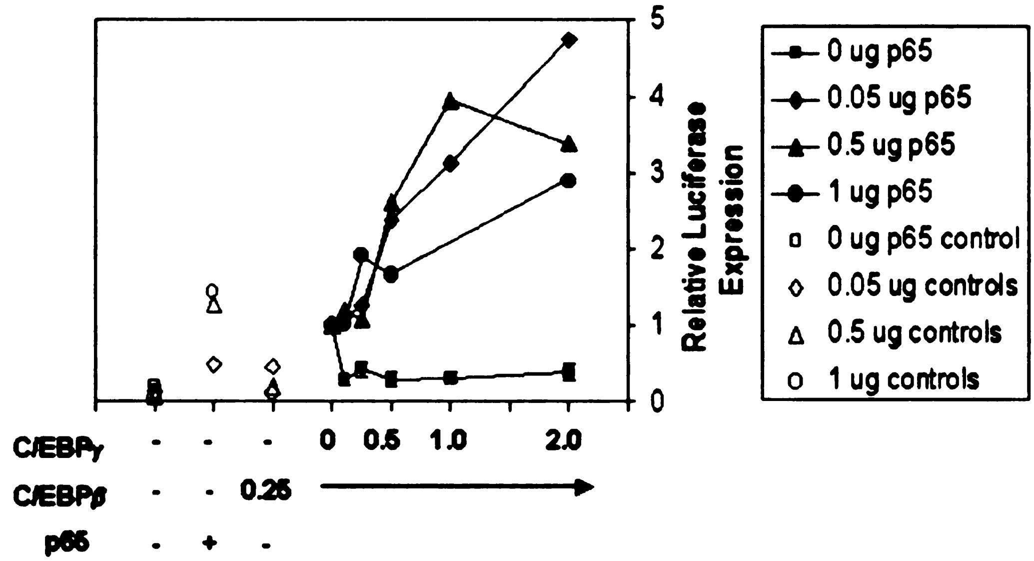
For this experiment, I will be using both WT mouse embryonic fibroblasts, or MEFs, and C/EBPγ KO MEFs [25]. I will prepare plasmids for TNFα-luc WT, C/EBPγ, C/EBPβ, and p65 (a form of NF-κB), and then transiently transfect the cells with the plasmids in combinations as follows. This will occur both with and without LPS treatment, which typically induces an inflammatory response by increasing the production of C/EBPβ [26]:

		TNFα reporter gene	C/EBPγ	C/EBPβ	NF-κB p65
1	*control*	-	-	-	-
2	*baseline TNFα expression*	+	-	-	-
3	*baseline γ activity*	+	+	-	-
4	*baseline β activity*	+	-	+	-
5	*baseline p65 reading*	+	-	-	+
6		+	+	+	-
7		+	-	+	+
8		+	+	+	+

After 4 hours of LPS exposure time, the amount of TNFα produced will be quantified by measuring the amount of light given off by the luciferase using a Luciferase Reporter Gene Assay Kit and photometer.

Expected Results/Conclusions

In order to support my hypothesis that reintroduction of C/EBPγ into the fibroblasts will restore transcription of the TNFα reporter gene, readings 3 and 6 ought to display the highest amounts of luciferase. Additionally, the reading at C/EBPβ and p65 (7) should not vary significantly from the reading at C/EBPβ (4) as I do not expect β and NF-κB to exhibit synergy; however, this reading was included to account for the possibility that this synergistic relationship only fails to occur in macrophages, as previously discussed [17]. Because NF-κB does activate the TNFα gene independently, though, as further discussed in the Liu et al. paper, I do expect some degree of luciferase production at reading 5. Reading 8 will ultimately depend on the results of the proceeding tests.



A figure from Gao et al., similar to those that will be found in my own paper later this year!

****This is an example of student work. The above Figure is a part of the work of the student, and not part of the body of this thesis.**

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Student C

Mr. Moore

Research Seminar

May 29, 2007

Summer Vision Plan

Research Objectives

The project I will be working on with Dr. McInnis and Dr. Saunders focuses on identifying illness patterns in those with bipolar disorder. The goal of this study is to identify clinical, neurocognitive, environmental, and genetic variables that may be predictors of disease patterns. To narrow down my specific involvement in this study I hope to find a relationship between those diagnosed with bipolar disorder and their personality types. Hopefully in finding a connection in the personality types of subjects with bipolar disorder it will be easier to diagnose the disease. The main objective for my study is to minimize the amount of misdiagnoses of bipolar disorder by discovering a common personality of those with the disease. A common factor related to bipolar disorder will serve as a predictor for the condition therefore proving to be a clue for determining if someone does in fact have the disease.

Introduction

In order to achieve the goal of identifying a predictor of bipolar disorder 400 subjects with bipolar disorder will be evaluated. 150 of those 400 subjects have a recent onset of bipolar disorder and 250 subjects have a recent onset of bipolar disorder along with depression. 400 healthy control subjects will also be analyzed. Patients will be followed over a period of time in a clinical setting filling out questionnaires and undergoing examination. Evaluations of personality and cognition will also be taken. Assessments will occur at regular intervals. The hypothesis of this study is to identify gene patterns that may be used to predict disease outcomes. I will be analyzing personality relationships of subjects with bipolar disorder. I will be closely following answers to the DIGS questionnaire, which is directly used for evaluating symptoms of Anxiety Disorders, specifically in my research Obsessive Compulsive Disorder. I hypothesize that there will be a relationship between bipolar disorder and the personality traits of Obsessive Compulsive Disorder. With this information it will be easier to identify and diagnose bipolar disorder. A new predictor of the disease will eliminate the amount of misdiagnoses for bipolar disorder and hopefully allow agreeable terms for diagnosing the disorder.

Literature Review

Mental disorders are psychological illnesses caused by chemical imbalances in the brain that effect thought or emotion of an individual. According to the National Institute of Mental Health mental disorders affect an estimated 26.2 percent of Americans ages 18 and older (1). Mental disorders often go unrecognized but early detection and intervention, specifically in mood disorders, can reduce the severity of symptoms, lower suicide rates, and lead to quicker recovery (2). Bipolar disorder strikes one in seven individuals is the most commonly misdiagnosed mental disorder due to its broad characteristics (wild mood swings) that have not yet been fully identified (3). In a study done by Bowden, in a group of subjects with bipolar disorder 40 percent had previously received an incorrect diagnosis (4). The majority of these patients were initially diagnosed with major depression, schizophrenia, or anxiety disorders. Bipolar disorder is considered to be multifactorially inherited, and the heterogeneity of the disease leads to confusion in diagnosis and treatment (5,6). Current studies have proven that both bipolar disorder and personality are highly heritable (6). A study done my Hoch proposed a relationship between a withdrawn, detached personality type and the development of schizophrenia (7). The concept of the endophenotype of personality to mental disorders was introduced to psychiatry by Gottesman and Shields (8). In a more recent study done by Brodsky et al. impulsivity was the only characteristic of personality disorder that was associated with previous suicide attempts (9). Therefore, impulsivity is a potential target therapeutically for prevention of future suicide attempts. Obsessive compulsive disorder is a personality/anxiety disorder that affects more than 2 percent of the population and is characterized by unwanted ideas or impulses that repeatedly well up in the mind (10). Other studies have shown that obsessive compulsive disorder is sometimes brought on by depression (11), which gives us the link between this personality/anxiety disorder and mental disorders. It is unclear whether specific personality traits co-segregate with individuals with bipolar disorder, and these temperaments have yet to be identified (8). A study done by Stone states that it is more likely for a group of borderline personality patients to develop bipolar disorder than a group of bipolar patients to develop borderline personality (12). This information proves the idea that there is a connection between personality and bipolar disorder but the link it yet to be found. In finding a connection between bipolar disorder and the personality traits of obsessive compulsive disorder (impulsivity, anxiety), heritable variable will be identified and diagnoses will hopefully be made easier.

Research Methods

The research methods to complete this study involved an interview with the Diagnostic Interview for Genetic Studies and a NEO PI-R will be conducted. In order to obtain the information needed to support my hypothesis I will be working on data entry for this study. Exposure to questionnaire results will allow me to closely analyze the answers to the questions given to the subjects. I will look through the information I can obtain to find agreeing details for my study.

Expected Research Results

From this study I expect to discover a relationship between bipolar disorder and the traits of the personality disorder of Obsessive Compulsive Disorder. I do not expect to have age as a factor in my study. I expect that bipolar subjects have the characteristics of anxious and controlling personalities.

Expected Conclusions

I expect to conclude that personality is a heritable trait that is passed on along with bipolar disorder. Hopefully by the end of my study I will have identified a common trait among bipolar subjects that will lead to quicker diagnosis. In a more general conclusion a single personality type will be identified from this study. More specifically I conclude that personality traits of obsessive compulsive disorder are common in those with bipolar disorder.

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Student D

Junior Summer Vision Plan

Abstract/Introduction

Although studies of star-forming regions have yielded insights into the evolution of molecular clouds, the processes relating to the formation of the inner regions of our solar system—where Earth resides—cannot be found among the stars. To glimpse the solar system's early days, researchers must turn to primitive meteorites, specifically chondrites. By recording the decay rate of radioactive isotopes in the meteorites, we can establish the timing of the formation of the solar system and what occurred. In some meteorites, the decay rate does not match others of its classification, which might give possible clues into earlier times of the solar system. Using the scanning electron microscope, detectors in the device will record the electrons and x-rays emitted, giving readings of chemical composition and images. I will be scanning specifically for inclusions that were formed by unknown means, since the abundance of such specimens in scientists' hands is rare and the merging of such populations needed to decipher the records the FUN inclusions are needed.

Objective

The objective of this experiment is to use a scanning electron microscope and find inclusions in meteorites that were fractionated by unknown nucleosynthesis. (FUN inclusions).

Literature Review

Images from the studies of star-forming regions help our understanding of molecular cloud evolution, but not into the processes of the formation of inner area of our solar system (Gilmour). Solid bodies of extraterrestrial material that penetrate the atmosphere and reach the Earth's surface are called meteorites (Krot et al.).

Primitive meteorites are comprised of elements of their environment, and the isotopes they contain also act as solar system chronometers by comparing the amount of parent isotope decayed to the new isotope that formed, letting the age be determined. The radioactive clocks can be reset by geological events that cause heating, so the rocks on Earth are unreliable since they have been reheated so many times. That is where determining the age of chondrites is important, since they were detached from the Earth and formed or reset elsewhere in the Solar System (McWeen 40-41).

Primitive meteorites formed in the early solar system and came from asteroids. They contain chrondules, which are igneous particles, specifically "millimeter-sized spherical droplets" that crystallized rapidly in minutes to hours when flash heated and quickly cooled, although the heating mechanism is still uncertain (Gilmour) (Scott, Krot).

Large numbers of chrondrules are found in all chondrites, which are stony meteorites, named so for the chrondrules they contain. Although chondrites have undergone thermal or shock metamorphism, chondrites were never molten, unlike igneous chrondules (Scott, Krot). They never melted or experienced any other igneous diffrentiation, and so still have the preserved records of physical and chemical processes in the solar nebula (Krot et al).

Chondrites are also the oldest rocks known rocks, determined by comparing the amount of tungsten-182 that resulted from the decay of hafnium-182. The slight difference in amounts of tungsten-182 indicates different times of formation, but the difference is significantly large enough to say Earth and the meteorites are the same age. (There is a 30,000 million year difference, not very significant compared to the 4,567,000,000 billion years taken into account.) These "surviving witnesses" to the birth of the solar system make them the best source of clues for the origin of the solar system (Scott, Krot). Figuring out the records is the main goal of chrondrite studies (Krot et al). Chondrites also "provide the best estimates for the mean abundances of condensable elements in the solar system". The estimates obtained are important for developing theories about the formation of elements in evolved stars (Scott, Krot).

One of the three components of chondrites is refractory inclusions, which are tiny bits of rock "tens of micrometers to centimeters in dimension". They were produced by high-temperatures processes that included condensation, evaporation, and melting. One of the two types that are to be studied are calcium- and aluminum-rich inclusions, or CAIs (Scott, Krot).

CAIs are clasts (fragments of rocks made from pre-existing rocks) whose sizes range from submillimeter- to centimeter-sizes. They are found in chondrites and have been intensely studied since their first descriptions more than 30 years ago. Thermodynamic calculations were used to predict the phases that condense out of a gas of solar composition during cooling from high temperatures. The main focus at first was how similar the CAIs' mineralogy was to those phases predicted (MacPherson).

CAIs probably formed during the most energetic phase of protosolar disk evolution and are the oldest objects in chondrites excluding presolar grains. They are made of the minerals corundum, hibonite, grossite, perovskite, melilite, spinel, Al–Ti-diopside, anorthite, and forsterite, which are predicted to condense from a cooling gas of solar composition at temperatures 1,200–1,300 K and total pressure of 1025 bar (Scott, Krot).

An exception to CAIs are ones known as FUN inclusions, an acronym in reference to their *F*ractionation and *U*nidentified *N*uclear effects. These inclusions contain fractionated unidentified nuclear isotopic anomalies. It is speculated that they or their precursors might have been injected into the disk during a close pass with a rogue star, and thus FUN inclusions could predate other CAIs (Connolly) (MacPherson).

FUN CAIs have unusual isotopic properties. The characteristic signatures included little or no excess of 26Mg from the decay of 26Al, among others features. Although there are many different kind of strange inclusions (UN CAIS, F CAIS), one feature that "unites" them is that they contain little or no live 26Al at the time of their formation.

There is no certain way to recognize a FUN CAI except by isotopic analysis. A FUN inclusion may have an ordinary appearance that gives no hint of it peculiar isotopic properties.

There is still no understanding on whether isotopic fractionation of some FUN CAIs is the result of melt evaporation or other processes, and if the former, what the precursor materials might have been. "It is not even clear if 'normal' and FUN CAIs formed by the same or completely separate mechanisms." If they did form that way, it is problematic explaining why FUN CAIs show large degrees of isotopic mass-dependent fractionation when normal CAIS do not even though latter have equally or more refractory bulk compositions than FUN CAIs.

"A critically needed experiment" is to measure with very high precision the absolute radiometric age of one or more FUN CAIS and find out whether FUN CAIs are older, younger, or contemporaneous with normal CAIs. And it will not just help to better understand when and where FUN CAIs formed relative to "normal" CAIs, but this experiment is "critical" for better understanding observed differences in initial 26AL/27AL among early solar system objects. The reason is unknown, and the fluctuations to be detected in FUN CAIs may provide very important clues (MacPherson)

Research Methods

How a scanning electron microscope (SEM) works, in short, is that an electron beam is passed over the surface of the specimen and causes energy changes in the surface layer. These changes are detected and analyzed to give an image of the specimen. It yields information only from the surface or near-surface of the specimen. The specimens used in this experiment are whole meteorites. The following signals and images produced will apply to the meteorite as well.

The illumination beam is the "primary electron beam". These are the electrons being shot at the specimen. When it hits the surface changes are induced by the interaction of the primary electrons with the molecules in the sample. The beam is not immediately bounced back in the way light photons would in a light dissecting microscope. Instead, the energized electrons penetrate and "worm through" the sample before they actually collide with a particle. This creates a region known as primary excitation. The shape of the region is also known as the "tear-drop" zone, and a variety of signals are produced from the zone. The three signals to be discussed are secondary electrons, backscatter electrons, and X-rays.

Secondary Electrons

The most widely used signal produced from the primary electron beam is the sencardy electron emission signal. It's produced when the electron from the primary beam hits an electron from the specimen and loses energy. This ionizes the atom, and for it to re-establish the proper charge ratio following this event it may have to emit an electron. These electrons are called "secondary".

This is the most common type of image produced by modern SEMs. It's the most useful for looking at surface structure and gives the best resolution image of any of the scanning signals. Depending on the initial size of the primary beam and other conditions, the signal can resolve the structures of the surface down to 10nm or better. This is why secondary electrons produce "topographical" images, although the electrons must reach the detector to contribute to the final image. The electrons that don't appear as shadows or dark contrast then the regions that had a clear path to the detector.

Backscatter Electrons

These electrons are defined as some that underwent single or multiple scattering events and escaped. They're produced when colliding with atoms of the sample and still have about 80% of their energy. The higher the atomic number of the specimen, the more backscattered electrons are produced. So when a sample has two or more different elements which are different in atomic numbers, the produced images shows the actual contrast of the elements. Elements that have a higher atomic number will produce more of the electrons and appear brighter.

This time the region where the backscattered electrons are produces is larger then the one for secondary electrons. So the resolution is less (1.0 um). There is greater energy which the backscattered electrons escape from, thus the larger region.

X-Rays

When the electron from the inner atomic shell is displaced by colliding with the primary electron from the beam, it leaves a vacant spotin the electron shell. To re-establish the proper balance of the orbitals following that ionization event, the electron from an outer shell "falls" into the inner shell and replaces the spot. This falling electron loses and energy and that energy is referred to as X-Rays.

The falling of x-rays may also induce a cascade effect. It is known that atoms of every element have different energies for x-rays. For example, if an x-ray of 1400 electron-volts of energy is seen, then it came from a silicon atom. Counting the x-rays received allow us to identify how many atoms of the element are present. In short, a chemical analysis can be done with doing any chemistry, which is a very handy tool (SEM notes #1).

<u>Expected Research Results</u>

The expected result of all the scanning done on the meteorites is the discovery and identification of a FUN inclusion.

Expected Conclusions

The FUN inclusions found will have their isotopes analyzed and clues of their origins recorded. They will also be added to the population so FUN inclusions found, since only a handful have been identified and studied. All the conclusions scientists have drawn from FUN inclusions depends on the properties of the first few, and so the contribution of more specimens will carry greater potential to influence the studies. They will result in greater undersatnding of how the inclusions themselves formed, but also conditions when the Sun, planets, and asteroids were forming. Just the general addition of more information about chondrites will help us learn more about the compositions, which in its most extreme circumstance, might prove useful to assess what should be done about near-Earth asteroids that threaten Earth. A general understanding evidently goes a long way.

If no inclusions are found, then I will be able to say that the density of FUN inclusions are lower than a certain value I will determine later.

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Student E

Mr. Moore

Summer Vision Paper

1 June 2007

Introduction:

Currently, dementia remains a largely undiagnosed and untreated disorder in elderly patients until the disease/disorder has progressed past the treatable stages of the disease. This study is being done in order to possibly identify a new means of identifying undiagnosed patients. We hypothesize that Elder Law attorneys have the unrecognized opportunity to case find and refer clients after observing evident loss of memory. Positive findings might reveal an unexplored means to diagnose dementia at an earlier stage and begin management at a time when outcome can be optimized. Uncontrolled observation by dementia specialists suggest that cognitively impaired patients seek out elder law attorney services, for completion of powers of attorney, etc., prior to receiving a medical evaluation.

Objectives:

Through this exploratory study, we hope to identify a possible means of diagnosing dementia during its treatable stages with lawyer assistance.

Literature Review:

Dementia is the clinical syndrome characterized by acquired losses of cognitive and functional abilities severe enough to interfere with daily living and the quality of life.[1,2] It impairs a person's ability to live the life he or she is used to through language difficulties, anomia, visual and spatial deficits, apraxia, difficulty maintaining financial accounts, personality changes, etc.,[1,8] and can be caused by any of more than 55 different illnesses and disorders, including Alzheimer's disease, vitamin deficiencies, and vascular dementia.[1,2] Because of the broad definition of dementia, specific statistics are unknown, however, there are now more than 5 million people in the United States living with Alzheimer's disease alone.[8] Though there are 55 different illnesses/disorders that cause the disease,[2] all types of dementia are treatable, whether through drug therapy or counseling,[3] but dementia treatment is more effective in the earlier stages of the disease.[4,5] With this in mind, it is a problem that Primary Care physicians, because of limited patient contact, typically do not discover the presence of early stages of dementia in up to 90% of all cases.[6,7] It is generally agreed that more needs to be done in the early recognition of Alzheimer's disease, due to expected increase of patients in the future which will severely strain our limited health care facilities.

Expected Methods:

The first part of the project involved identifying our sample, which, because of a contact made with the head of the Elder Law and Advocacy Section of Michigan, Mr. Mall, will include all of the elder law attorneys in Michigan. Next, once the IRB approves our project, Mr. Mall will email all 1500 attorneys information on the study, including a link directing them to the 5-question, confidential, de-identified survey. Our third-party host will collect and tabulate the results, at which point we will statistically analyze the data against the hypothesis.

Expected Results:

We expect to see data that indicates attorneys assist clients exhibiting signs of memory loss, that the attorneys recognize that these clients have memory loss, and that only a percentage of these clients have been previously diagnosed with dementia.

Expected Conclusions:

We expect to conclude that, in fact, lawyers can do more to assist in the early recognition of dementia, and if the data does support our hypothesis, we will suggest that more work needs to be done on this topic.

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Junior Summer Vision

Student F

Mentored by Jamie Owen-De Schryver

Friday June 1, 2007

This paper describes goals and objectives for the coming months and expectations for this project. It includes the beginnings of what will hopefully become a published journal article and a calendar that outlines important dates throughout the summer.

Research Objectives for This Scientific Project:

We wish to advance the current literature on the development of play skills in children with autism using video modeling. We will hopefully discover at what age the models in these videos should be to most effectively teach children with autism play skills. With this knowledge we will be able to better apply behavioral treatment in hopes that these children will learn to better interact with their peers and ultimately the world around them.

Expected Results and Conclusions of This Project:

We anticipate that both the videos, with the peer model and the adult model, will have an effect on the play skills of the children with autism. Additionally, we expect that the children with ASD will model his or her peers' behaviors more accurately than the behaviors of the adult. This is expected because the peer's actions will be most similar to that of the autistic child's because of the closeness in age. This will help us draw a conclusion on how to make the most effective videos for behavioral treatment for children with ASD.

Adult versus Child Video Models: Effects on the Development of Play Skills in Children with ASD

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Student F

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We will assess differences in the ability of children with autism to learn play skills when an adult models behavior and a peer models behavior for them. This will be done by obtaining a baseline measure of play skill abilities in multiple children with autism spectrum disorder and then observing changes in play skills after they watch video models demonstrating appropriate play. These videos will be created once with a peer modeling play scenarios and again with an adult doing the exact same scenario. The videos will be shown to the children with autism after the baseline is obtained and then they will play with another adult while being scored on how well they model the verbal and play behaviors in the videos.

Autism is a neurodevelopmental disability characterized by impairments in social interaction, communication, and restricted and repetitive behaviors (American Psychiatric Association, 1994). Individuals displaying these characteristics may be diagnosed with a spectrum of disorders such as Autism, Pervasive Developmental Disorder-Not Otherwise Specified, or Asperger's Disorder, depending on the number and severity of their symptoms. Collectively, this set of disorders is referred to as Autism Spectrum Disorders, or ASD. It is estimated that ASD occurs in 1 in 166 births, and that these disorders are four times more common in boys than in girls (Centers for Disease Control and Prevention, 2005).

Children with ASD show deficits in social skills, including eye gaze and poor joint attention, as well as deficits in communication, such as echolalia, or few verbal initiations, as shown when studies compared them to normal children (Dawson et al., 2004). In addition, while typical preschoolers frequently engage in play, children with ASD do not engage in age-typical play skills. For instance, their play tends to be perseverative and inflexible, and they show poor symbolic, pretend, and social play when compared with typically developing children (Brown & Murray, 2001). Several researchers have noted the relationship between play behavior and the development of language and social skills in children without ASD (Lewis, 2003; Jordan, 2003). This previous research suggests that age-appropriate play skills should be a focus of intervention as it is possible that play skills may facilitate the development of skills in other domains (e.g., social-communication skills). In sum, the research consistently suggests that play skills, social skills and social-communication skills are important targets when designing educational programs for young children with ASD.

A method that has been used to teach play, social, and language skills to children with ASD is video modeling (VM). VM involves having the participant observe a model on a video who is engaging in a target behavior. The model may be an adult, a peer, or the child with ASD. Subsequently, the child is expected to demonstrate the behavior that she or he observed in the video. Corbett and Abdullah (2005) suggest in their study involving exploration of the effectiveness of video modeling that repeated viewing of the target behavior via watching the video encourages retention. In fact, there is considerable research reporting the effectiveness of video modeling as a technique to increase the skills of students with ASD. Skills that have been targeted by video modeling include compliment-giving, which has helped children with ASD show more interest in others and forge meaningful social relationships (Apple, Billigsley, & Schwartz, 2005), AND social initiations. In most cases, these skills were maintained for months after the video modeling (Apple, Billigsley, & Schwartz, 2005; Buggey, 2005; Nikopoulos & Keenan, 2003). In another study by Sherer et al. (2001), conversational skills were taught by having the children answer a series of conversation questions that were answered with 100% accuracy post-treatment. Perspective-taking is another skill that has been more successfully taught through video modeling than in vivo modeling (Charlop-Christy & Daneshvar, 2002). Finally, complex play skills have also been taught with video modeling, and have been shown to lead to the rapid acquisition of verbal and motor skills (D'Ateno, Mangiapanello & Taylor, 2003).

Several reasons have been hypothesized for the effectiveness of VM in teaching skills to students with ASD. First, VM capitalizes on some of the features or characteristics that are commonly found in individuals with ASD. These include over-selective attention (Charlop-Christy & Daneshvar, 2002), visual preferences and strengths (Corbett & Abdullah, 2005), and avoidance of face-to-face attention and uncomfortable social interaction (Charlop-Christy, Le, & Freeman, 2000). In addition, video modeling may improve the ability of individuals who have ASD to focus their attention by removing unnecessary, distracting stimuli. Children with ASD generally have strong visual processing abilities, which may make them more able to benefit from the visual stimuli provided by video models (Sherer et al., 2001). They also often have a high interest in watching television and videos. Therefore, video modeling is likely to be reinforcing, potentially making children with ASD more receptive to and more successful in learning from this teaching technique.

One aspect that could make a difference in the success of VM is the type of model used in the creation of the video. Although it's been suggested that using siblings in videos may make VM more effective because of the previous history of model-learner relationship (Peck, Cooke, & Apolloni, 1981), this does not always appear to be the case. Jones & Schwartz (2004) suggest that previous model-learner relationship does not always have an effect on learning the target behavior and therefore may be too narrow a perspective when testing the effectiveness of different types of models. Whether the models have a previous relationship to the learner and the age of the models (adult versus child) may also make a difference in the outcome of the VM sessions, but little research has been done in these areas. The current study has therefore been designed to assess the effectiveness of child versus adult models while using VM to teach play skills to preschoolers with ASD.

METHOD

Design. The proposed study involves the implementation of an alternating treatments design within a multiple-baseline (Cooper, Heron, & Heward, 2007; Kazdin, 1982). This design will be used to compare the effectiveness of adult versus child videotaped models on the development of verbal and motor play behaviors in preschool participants with ASD. In a multiple baseline design, simultaneous baselines for three or more students are obtained, and intervention is implemented after varying numbers of baseline data points for each student. Consistent with the alternating treatments design, the two treatment conditions will be alternated until differentiation is observed (i.e., student play behaviors improve more in one condition). The most effective condition will then be implemented for four consecutive sessions. If possible, probes will be carried out in an alternative environment (e.g., the child's classroom) to determine whether the play behaviors generalize to other settings.

Procedure. This study will be implemented in five phases.

Phase 1. In this phase, age-appropriate play activities will be identified, such as building with blocks, playing with play-doh, or playing with farm animals. These play targets will be determined based on their ability to elicit both physical play actions and verbal play language, and based on the likelihood that these play activities will be readily available to the children with ASD in current and future environments.

Phase 2. Phase 2 will involve identification of two age-appropriate peers to serve as video models. These peers will be videotaped while playing with the toys identified as play targets in Phase 1. An adult "prompter" will also be present in the video and will provide verbal or physical guidance to elicit appropriate play and language, e.g., "what are you making/doing?" "where's the ____?" After the videos with peer models have been created, the video clips will be transcribed and adult models will be identified to participate. The adult models will be videotaped while playing with identical toys and will engage in the same play behaviors and utilize the same language used by the peer video models. Adult prompters will also ask identical questions of the adult models in order to elicit the same verbal responses.

Phase 3. In this phase, three-four participants with ASD will be identified. These students will be of preschool age, and will communicate primarily through a verbal modality. Since verbal language is a target of the intervention, we will not include students who *primarily* communicate through an augmentative device or with the Picture Exchange Communication System (PECS). Students will be identified based on teacher recommendations regarding: (a) student verbal communication skills and (b) the appropriateness of play skills as targets for intervention. The first three-four participants for whom permission is obtained will be included.

Phase 4. In this phase, the three students with ASD will be observed during free play interactions with the targeted toys. Adult prompters will use the same verbal and physical prompts that will be used during the intervention phase to elicit physical play actions and verbal language. Verbal and physical play behaviors of the child will be scored.

Phase 5. The intervention phase, Phase 5, will involve a comparison of the two interventions. The student with autism will be exposed repeatedly to both conditions in random order, either experiencing one or two conditions per day depending on student schedules. In the Child Model condition, the student with autism will first observe the video of the child model playing with the toys. After watching the video, the child will be brought to a room with the targeted play materials, and will be observed during free play with the materials. The child will be observed for up to 3 minutes during free play with the materials; the adult prompter will again use identical verbal and physical prompts to elicit appropriate play. The Adult Model condition will be run identically, with the exception that the child will first observe an adult model demonstrating appropriate play in the video clip prior to engaging in free play with the materials.

Measures. The following behaviors will be scored during these free play activities in both the Child Model and Adult Model conditions: (1) *modeled physical play actions* (e.g., placing a cow in the barn, making a tunnel with the blocks), (2) *modeled verbal play statements* (e.g., having the cow "moo," saying "make a pancake" while playing with play-doh), (3) *novel physical play actions* (any appropriate play action that was not modeled in the video) (4) *novel verbal play statements* (any topically-appropriate verbal statements that were not modeled in the video), and (5) *social initiations* – verbal or physical initiations directed toward an adult that begin an interaction (e.g., handing a toy, requesting help, leading adult to an object).

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Student G

Research Seminar

Summer Vision

May 15, 2007

Junior Summer Vision Paper

I. Introduction

This summer I will spend seven weeks as part of the High School Honors Science Program (HSHSP). I will be working with Michigan State Mechanical Engineering Professor Indrek Wichman to design, build, and test and ad-hoc Drop Tower to measure the effects of zero-gravity on flame droplets as well as candle flames. As part of this experiment I will be designing and building a Schlieren Apparatus to visually capture the reactions of the flame and the surrounding gases when zero-gravity is established. Using the data we find we hope to better understand how flames behave in space.

II. Literature Review

Fire is one of humanity's greatest tools but at the same time one of its worst enemies. When in space this is no different. To better understand fire in space you must first understand it on earth. Combustion is a complex sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames. As this reaction occurs the heat and gases rise and creates the conical shape of a candle flame [1]. In a complete combustion reaction, a compound reacts with an oxidizing element to create compounds of each element. Complete combustion reactions rarely occur however because of varying amounts of fuel and because in most cases not all the fuel is burned.

On earth fires are hard enough to contain and suppress but in the unpredictable environment that is space it is even more challenging. When introduced to zero-gravity flames have different characteristics than they do on earth. Data from the Kimzey et al experiment notes that fire seemed to burn hotter in zero g's than it did in 1g. Through using airplanes flying in a parabolic patter they also were able to find that the flammability of many objects including paraffin, a fire starting substance, increases. This adds to the danger that astronauts and soon civilians will face in situations in space. At the moments of highest risk of fire breakout, take off and landing, astronauts are stuck in restraints and are unable to move and suppress the flames.[2]

To add to the fear of fires many scientists such as Robert Friedman suggest that the space station's automated fire suppression system is inadequate in its protection of the crew and needs new technology specifically designed for microgravity. Although he labeled the suppression systems on the space shuttle as adequate he recognizes a need for improvement in the detection and suppression of fires[3].

One area of fire suppression that is often overlooked is the creation of soot. Soot is the dark powdery left over fuel that travels in the air as smoke. Soot is very dangerous as it can cause blindness and asphyxiation. On earth people are taught to stay near the floor to keep away from the rising smoke. In space, however, smoke does not move at all because of the lack of gravity. The Oostra et al experiment found that soot production increases in a zero gravity environment. This happens because unlike the fuel on earth, which just sits on the ground, the fuel does not have the restrictions of gravity and can move and break up as combustion occurs. Using a similar procedure as the Kimzey paper the Oostra experiment found that increased soot production does occur and poses a great risk to the crew as well as their sensitive instruments with which they pilot the craft [4].

In the Joel A Silver et al experiment they used diode lasers to measure the concentration and temperature of the gases surrounding the flame. These lasers are not unlike the LED lasers that are found in many flashlights and laser pointers. This group found that Diode lasers are particularly good in ad-hoc drop towers because of their compact size and power supply. In there experiment they placed a diode laser in a drop rig to measure the gas and temperature changes as the rig was placed in zero gravity. They found that they were very good at detailing the changes in gas concentrations [5].

NASA is the largest group currently working on studying the effects of microgravity on everyday occurrences on earth. At the Glenn Research Center in Ohio NASA has two drop towers that they use to conduct experiments in zero-gravity that would be to expensive to take into space or use a jet in a parabolic maneuver. The Lekan et al paper talks about how the 2.2 second drop facility is maintained and operated. This facility was created out of an old fuel distillation tower and provides 2.2 seconds of complete weightlessness by dropping a rig several hundred feet down a shaft. The rig is where the experiment and usually video cameras and other sensors which document the drop[6].

One of the sensors often used is the Schlieren Apparatus. A Schlieren Apparatus is a device that measures the concentration, densities, and temperatures of gases by optical transmission. In the Schwarz et al paper the team used a Schlieren Apparatus to measure the gas concentrations around a flame as it experienced temporary weightlessness from a drop tower. They found that the Schlieren Apparatus was able to capture not only the concentration and densities of the gases but also how the moved when experiencing weightlessness[7].

III. Hypothesis

My hypothesis is that not only will weightlessness have a profound effect on the shape of the flame but also on the temperature of the flame and the behavior of the gases surrounding the flame.

IV. Methods

1.As the first part of the project I will calculate the height of the drop tower needed to have the rig experience weightlessness for 1 second.[6]

2. Next I will construct the tower out of steel framing to the desired height.[6]

3. I will then build a Schileren Apparatus to optically capture the effects of weightlessness on the flame.[7]

4. Inside the rig along with the Schileren Apparatus will be a high speed still camera and diode laser to study the reactions of the gases and the flame itself.

5. I will then pull the rig up to the desired height and drop it to the floor.

6. Then I will input the results into a computer for storing.

V. Expected Conclusions

I expect to find that the temperature of the flame and the gases surrounding it will increases temporarily but then lower due to an increasing lack of oxygen. I also expect that the gases and soot around the flame will not radiate out as quickly or as far on earth which will support my hypothesis.

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Chapter IV: Conclusions and Recommendations

Conclusion:

The purpose of this research project was to develop, implement, and assess the effectiveness of an independent science research program at the high school level.

The five general goals of the research program were to enhance the ability to use the Scientific Method, to conduct authentic research, to participate in the scientific community, to write scientifically, and to present scientific data.

Part I of the Data and Analysis showed that these goals were met by directly asking the students about their proficiency in these areas both before and after the pilot year. According to Figures 4, 5, and 6 in Appendix J, Part I showed an average 137% increase in self assessed proficiency in these areas, with most of the improvement in the area of participating in the scientific community and writing a scientific paper. This is not surprising, considering that none of the students who started the program this pilot year had ever had experience working with a scientist, and had never written a scientific paper. On the Likert scale of 1 to 5, with 5 being the most proficient, every single student in the pilot year of the research program jumped at least 2 scale values for each and every goal, with most jumping 3 scale values.

Part II of the Data and Analysis showed that these goals were met by talking to the student through an interview process [Appendix K]. These interviews illustrated several changes in the perceptions, habits, and skills learned by students during the pilot year. These interviews show the tentativeness of the unknown in the beginning of the year, and then show the confidence and pride of hard work yielding tremendous results that they student never thought they were capable of, and the lack of fear for tackling a seemingly insurmountable task. As student A put it, in Appendix K:

> *"My interest has been changed. I now appreciate what researchers go through every day so much more. There is so much thought and hard work and amazing stuff involved in research. But after all the hard work, reading, background research, running the experiment, and supporting one's hypothesis....now it doesn't get much cooler than that. I used to like science merely because I found it interesting. It was a once a day class that I looked forward to. Now, it feels normal to go home and look up the latest info in the science community or read up more on my topic."*

Part III of the Data and Analysis showed that these goals were met by giving actual examples of student work. These examples are descriptions of the authentic research projects that the seven junior students in the pilot year of the research program developed. To accomplish this singular feat, all five goals of the research program simply have to be met. If these goals were not met, then the process of project design would have immediately been halted at the point of breakdown, and the project design would not be able to commence until mastery of that particular goal is achieved.

The final culminating goal of each sophomore in the program was to have fundamental experimental skills, and to have secured a mentor in their interest area to start designing a an authentic research project. As the data in Part I and II of Data and Analysis show and examples in the Appendices D, E, F, and G show, this goal has been achieved. Each of the students in the sophomore class are now ready, with a mentor, to design and implement an authentic research experiment.

The final culminating goal of each junior in the program was to design and implement an authentic research project. As the examples in Part III of Data and Analysis show, every junior is presently at a lab with a mentor running a research project. As these projects are implemented, this goal has been achieved.

It is expected that the program will become self sustaining in future years. In this pilot year, because it is new and in development, the driving engine behind the program has been the teacher. In subsequent years, the main drive that will sustain the success of the program will lie with past, present and future students themselves, parents, the school community, the scientific community, and the faculty.

Overall, through the literature review, data analysis, and student examples, and my own teaching experience, I have concluded that the standard pedagogy in science education just is not working as well as this program does. There is not enough hands-on activity going on in science. Science has to go beyond just learning concepts. In science, we have to give greater attention to the development of scientific thinking and the process of scientific inquiry, with scientific education involving a student in situations and activities that are closer to the activities of the scientist, making it more authentic. Students are generally learning biology, chemistry, physics and earth science, and they are learning a lot of content matter, but there is another part of science called process. Students need to use the scientific method, engage in scientific thinking, conduct literature searches and do authentic experiments-not "cookbook" projects. In this program, the student has to learn how to organize the data, learn how to make formal presentations of the science, learn how to write science. I believe that these are important aspects that are not being addressed and have to be addressed in science education.

I believe that there needs to be a paradigm switch with science education. A lot of science educators today are referencing the future based on the past. That is the way that they were taught, and that is the way it has been done and so, therefore, it is going to work that way in the future. However, what worked in the past may work sometimes, but it may not at other times. Discoveries happen every day, by people that work hard. Students have to be caught early on and made to realize that science is fun and that science is investigative. I think the part of the program that I enjoy the most is listening to a student talk excitedly about a scientific topic that would never have come up in any of his/her science classes in any depth, where in this program he/she is allowed to spend as much time as he/she wants investigating an idea.

I think that this program is awesome, and I am humbled by the success that I feel it has achieved in the pilot year. I think that this program is going to launch the educational lives of many young men and women, increasing the likelihood of success in college, and in life, many times over. Students coming out of this program are going to have a swagger that challenges anybody to give them a problem to solve. Students in this program are reading hundreds-hundreds! of articles, completely without the teacher assigning them a single task. I had parents calling me telling me that their son/daughter is staying up all hours of the night reading articles about beta cells in diabetics, and when the parent asks them to stop and go to bed, the student launches into a short enthusiastic lecture about how beta cells work and how maybe they can be used to cure his sister of diabetes. If a program can spur moments like that, then something is working correctly.

Earlier in the pilot year, a student identified her interest area as shape changing polymers. She is fascinated by how they work, and what they are used for. In her process of journal reading, she came across some content that she could not understand, regardless of her efforts. On her own volition, she wrote to a chemical engineer at Michigan State University asking some questions. This email, and subsequent response from the professor at MSU, spurred a relationship of a student asking pointed and penetrating questions to an accomplished scientist and getting well explained answers. After about a month, I received a phone call from this professor, inquiring about the college plans for the student. The professor wanted to make sure that the student applied to MSU next year, and was willing to help with the application. The professor had perceived, and therefore assumed, the student to be a senior in Advanced Placement Chemistry. In fact, this student is a sophomore in high school, and has **never** taken chemistry in her entire life. Her questions were so advanced and complex, the professor volunteered to be her research mentor right there on the spot. This student had quite literally educated herself to a high level of content understanding in chemistry, and it was completely her choice. This phenomenon is a feature of this program, and it is amazing.

I believe that every school in the state of Michigan should have this type of program. I have no doubt, grandiose claim that it may sound, that if the majority of schools in this state adopted this type of program as a standard, the scientific literacy and ability of students to succeed in difficult and challenging environments would climb dramatically. Soon thereafter, Michigan would become a fertile ground of future scientists, engineers, and problem solvers.

Recommendations

Based on what was learned in the pilot year of the program, the author has many suggestions and changes that will be made in future years.

First and foremost, the idea of providing some kind of wet-bench experience to students prior to sending them to work with a mentor is going to be explored. Towards the end of the year, looking ahead to he second year of the program, the author wrote to several mentors and asked them for general feedback on the research program. When asked, mentors gave mixed responses to the idea of students having practice with certain methods before working with them [Appendix L]. It is of the opinion of the author that some kind of practice in basic experimental skills such as using a micropipette, electrophoresis, titration, spectrophotometry, etc. would be beneficial. However, some mentors argue that it is best taught by the mentor themselves, as most mentors have a very particular, and specific, way of doing procedures and it would be a better use of the student's time to not have to relearn a procedure once in the mentor's lab. I have decided, for the second year, to teach and practice several very general skills, but to leave most of the wet-bench training to the individual mentor. I think that this will allow for a relationship to begin, as well as trust between the mentor and student to forge.

Another aspect of the class that I am anxious to change is deadlines. Deadlines were often moved and/or ignored. The teacher was very inexperienced with the timeline of projects, assignments, and skill attainment, and therefore had a difficult time ascertaining how much time was needed for each. Several times during the year a deadline had to be moved back because the teacher did not allocate enough time for completion of a task. Students were tolerant of such changes initiated and made by the teacher. However, with the crux of the class lying in the ability of all students to work towards fixed goals and stay within deadlines, it is anticipated that next year I will be able to set out the deadlines accurately for the entire year, and they will not be negotiable and/or flexible.

One other aspect that I look to change is the presentation model. For the first half of this pilot year, my perspective was that the more the student had a chance to present, the more they would improve. However, because students were reading papers with high levels of technical content, it soon became apparent that they needed much more time to prepare for their presentations. They need time to simply learn the material before they present, so that they can take on more of a teacher role instead of simply reading text. Therefore, next year I plan on having higher expectations of fewer student presentations.

Lastly, one change that I hope to implement this year is to assign a senior member of the class to each sophomore to act as a personal mentor for class and research procedures.

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Appendix A: Program Application

Grand Rapids Catholic Central
Research Project Seminar
Application for the 2007-2008 School Year

Name: Phone:

Street Address (include street, village/town, zip):

e-mail:
Grade: Gender: M F (circle) Guidance Counselor:

Current Science Class: Current Science Teacher:
Current Science Grades: Q1: Q2:
Current Math Class: Current Math Teacher:
Current Math Grades: Q1: Q2:

Would you be willing to meet in Research Project Seminar during your lunch?

TO APPLY, PLEASE DO EXACTLY THE FOLLOWING:

1. Complete this application.
2. Write a short, grammatically correct, essay (1-2 pages word processed) describing why you would like to join Research Project Seminar. If you have had any experience in science fairs, science programs, or if you have special interests in science, we would like to hear about it.
3. Send stapled application (cover page on top) or **hand-deliver** it to the following address, so it is actually received by me (not postmarked) no later than Friday, March 16 at 3pm:

   Mr. Andrew Moore, Research Instructor
   Grand Rapids Catholic Central HS
   319 Sheldon
   Grand Rapids, MI 49503

Late applications will most likely be rejected. Admission to Research Project Seminar is competitive, and we regret that we cannot accept an unlimited number of students. This is an intensive program through which you will be working on your own, and entering many science competitions. Being able to meet deadlines is extremely important. One thing that you can do to increase your chances of being accepted, therefore, is to hand in a carefully prepared application ON TIME.

I would like to apply for admission to the Research Project Seminar:

Student Signature______________________________________ Date_________

Parent Signature_______________________________________ Date_________

Appendix A: Candidate Interview Questions

POSSIBLE CONSIDERATIONS & QUESTIONS FOR INTERVIEWING CANIDATES

CONSIDERATIONS

A. Was the student on time?

B. Was the student essay prepared as directed?

QUESTIONS FOR CANIDATES

1. Why do you want to take the course?

2. Talk about something you really wanted to do in your life and then failed at? What did you do next? Why?

3. Talk about chances you take.

4. Describe yourself as a self-starter.

5. Describe yourself as independent.

6. Describe yourself in three words.

7. Describe how you would prepare a surprise birthday party.

8. If you were not accepted for the course, would you do independent study?

9. What have you quit in life?

10. Do you belong to boy scouts/girl scouts?

11. Have you participated in science fairs?

12. Have you participated in the play, chorus, etc.

13. Do you play sports?

14. Tell me something you really wanted to do – and did it.

Appendix A: Candidate Acceptance Letter

April 16, 2007

Tom Kennedy
4610 Bradford NE
Grand Rapids, MI 49525

Dear Tom,

Thank you for your application for admission to Research Project Seminar. The essay that you provided was thoughtful, sincere and a pleasure to read.

I am very pleased to offer you a position in the Research Project Seminar.

The inclusion of this program into the curriculum at Catholic Central signals an important, historical change in the way that we teach science to gifted individuals. The success of this program will depend entirely on the acceptance of this responsibility by the bright students, like you, that are part of the program. I hope that you are as excited as I am to take on that challenge.

Please note that this position is conditional upon the ability of Catholic Central to schedule you into a section of Research Project Seminar. Scheduling conflicts can, and do, arise.

There will be an informational meeting for parents on Monday, April 30 from 6 p.m. to 7 p.m. It is important that you ***and*** your parents attend.

Congratulations on your acceptance to the Research Project Seminar.

Sincerely,
Andrew Moore
Instructor, Science Research Program
Grand Rapids Catholic Central High School
(616) 233-5830
andymoore@grcss.org

Appendix B: Freshman Summer Assignment

Science Research
Summer Assignment

You are now a student of research. You must do six things, in this order:

1. Purchase a lab notebook. This can be done online or at any bookstore. The lab notebook must be at least 100 pages with duplicates.
2. Read. Read. Read. When you read a newspaper or magazine, pay attention to what kinds of articles catch and hold on to your attention. Keep track of the topics that seem to interest you. It is expected, and normal, to have a very wide range of interests. This is a ***good*** thing.
3. Read and **KEEP** fifteen (15) articles from magazines, newspapers, or books. These articles should be of interest to you in your intended field of study for this coming year. These can come from any source of your choice.
4. **SUMMARIZE** each article in one page or less by giving the key points of the articles, indicating the author, and a 100-word summary and reaction to the article. This should be done in your lab notebook.
5. **IDENTIFY** the scientist and the location of the laboratory mentioned in the article.
6. For each article, ask three (3) questions about the topic that you are reading. These should be questions that you would want to find the answer to.

Expect emails from me throughout the summer with additional assignments. I will most likely not send out any additional work until mid-July, but you never know. So, get in the habit of checking your research email. Around the beginning of August, I will email you the syllabus for the class, and then we will be off and running.

I hope that you have a great summer, and I am excited to guide you through the wonderful world of discovery.

Moore

Appendix C: 10 Day Goal Sheet for One-on-One meetings

10-DAY GOAL SHEET FOR SCIENCE RESEARCH

DUE EVERY CONFERENCE DAY

Name: ______________________________________ Date: ____________

DIRECTIONS:

Please indicate those activities, readings, and goals that you accomplished during your **last** cycle. Organize your statements in logical order and write in complete sentences. This part must be completed before the meeting. (List additional activities on the back of this page).

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____

DIRECTIONS:

Please indicate those activities, readings, and goals that you intend to accomplish in the **next** cycle. Organize your goals in logical order and write in complete sentences. This part is completed with the teacher during the meeting. (List additional activities on the back of this page).

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____

The Laboratory Notebook

The lab notebook contains original raw data. It must be treated with care and respect.

REASONS FOR NOTEKEEPING

1. To preserve experimental data and observations.
2. To preserve clear, unambiguous statements of the truth as observed by the investigator.
3. To allow another scientist to pick up your notebook and repeat your experimental exactly- based on your entries.
4. To help you remember exactly how to repeat your own experiment.
5. To study the data and observations.
6. To give you a platform to analyze, evaluate, interpret and discuss your experiment.
7. To eventually write reports, papers, abstracts.
8. To maintain contact with scientists.
9. To review your work and plan future work.
10. To record your mathematical calculations.
11. To record your safety notes.
12. To keep track of supplies and names of manufacturers.
13. To record your drawings. Good drawings will save pages of writing.

GENERAL IDEAS

1. Your notes must be: clear, concise, and complete.
2. Notes must preserve failed experiments as faithfully as successful ones.
3. Your notes must be bound so that pages do not fall out. Slip in folders are not acceptable.
4. Your notebook must have a format of entries, and you must consistently follow this forma.
5. Your notebook pages must be numbered in sequence.
6. Your notebook must contain bound graph paper.
7. Your notebook must be in duplicate, and the duplicate must not be stored with the original.

A PROPER NOTEBOOK PAGE:

A proper notebook must be:

1. Dated when work begins on a daily basis.
2. Clearly headed with identifications that describe the work at hand.
3. Immediately entered before the investigator leaves the lab.
4. Legible and grammatically correct.
5. In permanent ink (black ballpoint is preferred)
6. on one side of a page only.

ORGANIZATION OF THE NOTEBOOK:

1. The key to the notebook is clarity. A clear layout and descriptions, good penmanship, and a high degree of organization must be apparent.
2. The format is flexible and is determined by your personality. However, all formats are logical, legible, complete and concise.
3. A notebook may contain a Table of Contents.
4. Each section should have
   - A purpose and experimental plan in a couple of sentences.
   - Statements such as: "To determine he effects or role of…"
   - Labeled diagrams, if appropriate
   - Methods and materials

Appendix C: Time Log

BI- WEEKLY RECORD OF INDEPENDENT RESEARCH TIME

Name:______________________________ Date:__________________

Date of Last Meeting:__________________

A. BIBLIOGRAPHIC RESEARCH:

1. Developing research skills _____hrs
2. Searching for topic _____hrs
3. Reading popular periodicals _____hrs
4. Reading professional journals _____hrs
5. Other (________________________) _____ hrs

Total Time Bibliographic Research. . . . . ________ hrs

B. COMMUNTCATING WITH PROFESSIONAL RESOURCES:

1. Writing E-mail, letters, faxes, etc. _____hrs
2. Telephone conversations _____hrs
3. Meetings, conferences, etc. _____hrs
4. Other (______________) _____hrs

Total Communicating Time ________hrs

C. LABORATORY RESEARCH:

1. Designing experiment _____hrs
2. Collecting Data _____hrs
3. Organizing, analyzing data _____hrs
4. Other (_________________) _____hrs

Total Laboratory Research Time ________hrs

D. PRESENTATION PREPARATION:

1. Journal articles _____hrs
2. Poster _____hrs
3. Oral _____hrs
4. Final Paper _____hrs

Total Time Preparing Presentations ________hrs

TOTAL TIME COMMITTED TO RESEARCH PROJECT ________hrs

Appendix C: Student Bi-Weekly Evaluation Form

Bi- weekly assessment of student performance

STUDENT NAME:______________________________ Date:__________________

1. During this cycle, did the student do and appropriate amount of bibliographic research on:
   a.) General literature (SIRS, etc.)
   b.) Scientific journals (Google Scholar)

   YES NO N/A

2. During this cycle, did the student achieve appropriate advancements in the journal readings, *i.e.*, did the student progress from general literature to specific journal scientific readings? Did the student read an appropriate amount of literature this week?

   YES NO N/A

3. Did the student order journals and did the student attempt an appropriate journal retrieval effort?

   YES NO N/A

4. During the cycle, did the student's work focus on the hypothesis or the area of research?

   YES NO N/A

5. During this cycle, did the student meet every deadline without additional reminders?

   YES NO N/A

6. During this cycle, did the student use e-mail, the Internet, the telephone, or the fax machine to further his/her research?

   YES NO N/A

7. During this cycle, did the student communicate with the primary mentor?

   YES NO N/A

8. During this cycle, did the student achieve appropriate and timely progress in the research experiment he/she chose to do?

   YES NO N/A

9. During this cycle, did the student design his/her research with the aid of journal literature to help shape it into a compound, complex, and state of the art body of research?

   YES NO N/A

10. During this cycle, did the student spend sufficient time on his/her research?

YES NO N/A

11. During this cycle, did the student exhibit a clear direction in his/her work and is he/she approaching the research in an enthusiastic manner?

YES NO N/A

12. Is the portfolio neat, complete, and updated?

YES NO N/A

13. Is the student using class time appropriately?

YES NO N/A

OVERALL STUDENT/TEACHER IMPRESSION:

6 5 4 3 2 1 0

Student's signature: ______________________________

Date: ______________________________

Teacher's signature: ______________________________

Date: ______________________________

Appendix D: Article Dissection

THE ANALYSIS OF A PROFESSIONAL
SCIENTIFIC RESEARCH PAPER

Junior First Quarter Dissection Paper
Sophomore Third Quarter Dissection Paper

Please use a separate sheet of paper for each section. You must answer your questions using the same format as posed by the questions, i.e., using Roman numbers and the Arabic subdivisions to clearly address each component of the analysis.

I. *The Abstract*:

1. Count the number or words in the abstract. Identify the percentage of words dedicated to the Review of Literature, the Hypothesis, the Methods, the Results, the Discussion, and the Conclusion.
2. What can you conclude about how to write an abstract?

II. *The Title Page*

1. Identify the name of the article, the authors, the journal, the year, the volume, and the pages.

III. *The Review of Literature (Introduction)*

1. Identify how many references have been citied.
2. In bullet fashion, explain each reference (from the Review of Literature) and also give the full reference.
3. Now, in composition style, identify how these bullets created the "funnel" i.e, justify why reference one is reference one; why reference two, why reference three is reference three, etc. Your justification must follow the logic of most general to specific.
4. Summarize how to write a Review of Literature.

IV. *The Hypothesis*:

1. Clearly identify the hypothesis.
2. Summarize how the Hypothesis/Objective is linked to the Review of Literature. You must be very specific in your explanation. This is the key to the Hypothesis.

V. *The Methods*:

1. Identify the format (construction/architecture) used by the author to address the methods and materials? Identify and explain the subsections used by the author.
2. Give two specific examples of how one writes Methods and Materials.

VI. *The Results*:

1. Count the number of graphs, charts, tables, and pictures used by the author.
2. Copy or scan: a graph, a chart, a table, and a picture into your answer. Explain exactly components of each of these visuals. Comment on the axes, the legend, the title, the figure number, the location of the graph/table on the page, the amount of lines or bars found in the graph, the open and closed data points on the graph, and any other interesting item that you have noticed.
3. Summarize the key elements required when you include a graph, chart, table and picture in your paper.

XII. *The Discussion*:

1. Explain how the author **united the discussion with the results and resolve the hypothesis**. Give two examples of this union among the results, discussion and hypotheses.
2. Why did the author use other references in the discussion?
3. What is the role of the Discussion? What are the key ingredients of a Discussion section?

XIII. *The Conclusion*:

1. How did the author indicate that the aim of the study was achieved?
2. Copy the author's words onto your report to identify the Conclusion.
3. Where did the author discuss the significance of the research. Copy the author's words onto your report to identify the significance.

XIV. *The Bibliography*:

1. How many references did the author use?
2. How was the bibliography arranged?
3. Give one example of how the author wrote a reference.

Appendix D: Student Example of Article Dissection

Sophomore Article Dissection

I. The Abstract:

1. There are 121 words in the abstract. The percentages of the words are devoted to different categories as follows:
   i. Review of Literature: 0%
   ii. Hypothesis: 0%
   iii. Methods: 28.9%
   iv. Results: 34.7%
   v. Discussion: 18.2%
   vi. Conclusion: 18.2%

2. In this article, the writers focused mainly on what they did and what they found. They dedicated no time to the review of literature and hypothesis. They assumed the reader would know about the topic if they were reading the abstract. They simply stated their procedure, their results, and how their results relate to results of other similar experiments. In an abstract, you only have a short paragraph to explain the entire experiment. This restricted paragraph must be utilized well to explain the entire experiment. The review of literature and the hypothesis are just fillers. The only necessary parts are the methods, results, discussion, and conclusion.

II. The Title Page:

1. Name of the Journal: p16^{INK4a} and p53 Deficiency Cooperate in Tumorigenesis

2. Authors: Norman E. Sharpless, Scott Alson, Suzanne Chan, Daniel P. Silver, Diego H. Castrillon, and Ronald A. DePinho

3. Publication Info: Cancer Research 62, 2761-2765, 2002

III. The Review of Literature (Introduction):

1. The introduction cited 11 sources in 9 unique references.

2. The references appeared in the journal in the order as follows:

- (1, 2) "The Rb pathway can be perturbed in several ways, including D-type cyclin overexpression, *Rb* deletion, CDK4 point mutation of amplification, and p16^{INK4a} deletion, point mutation, of promoter silencing." This explains how the Rb pathway to cell senescence may be deactivated. It gives a wide variety of causes.
  1. Sherr, C. J. The Pezcoller lecture: cancer cell cycles revisited. Cancer Res., *60:* 3689-3695, 2000.
  2. Malumbres, M., and Barbacid, M. To cycle or not to cycle: a critical decision in cancer. Nat. Canc. Rev., *1:* 222-231, 2001.

- (1) "In the p53 pathway, loss of function is typically attributable to *p53* point mutations or deletion, *MDM2* amplification, or $p14^{ARF}$ ($p19^{ARF}$ in mice) deletion" This reference gives a wide variety of reasons for p53 pathway inactivation.
  1. Sherr, C. J. The Pezcoller lecture: cancer cell cycles revisited. Cancer Res., *60:* 3689-3695, 2000.

- (2, 3) "Various combinations of these lesions occur in human cancers, but the combination of p53 and p16$^{\mathrm{INK4a}}$ loss appears most common, particularly in adult carcinomas." This reference talks about the causes of cancer that will be studied in the journal.

2. Malumbres, M., and Barbacid, M. To cycle or not to cycle: a critical decision in cancer. Nat. Canc. Rev., *1:* 222-231, 2001.
3. Sharpless, N. E., and DePinho, R. A. The INK4A/ARF locus and its two gene products. Curr. Opin. Genet. Dev., *9:* 22-30, 1999.

- (4) "Loss of p53 has been suggested to fuel genomic instability, provide resistance to chemo-radiotherapy, and attenuate growth arrest in response to telomeric shortening, hypoxia, and nutrient deficiency." This references tells what p53 loss may do to a cell to cause cancer in certain conditions.

4. Levine, A. J. p53, the cellular gatekeeper for growth and division. Cell, *88:* 323-331, 1997.

- (5) "The tumor-specific stimuli that induce $p16^{INK4a}$ expression, however, are less clear but may relate to the need to bypass the replicative senescence checkpoint," This tells that the exact causes of p16 expression are not pinpointed, but are vaguely known.

5. Duan, J., Zhang, Z., and Tong, T. Senescence delay of human diploid fibroblast induced by anti-sense p16INK4a expression. J. Biol. Chem., *276:* 48325-48331, 2001.

- (6, 7) "as well as the pressure to deactivate G_1 phase control in the setting of suboptimal growth conditions." This gives another condition when p16 expression occurs.

6. Ramirez, R. D., Morales, C. P., Herbert, B. S., Rohde, J. M., Passons, C., Shay, J. W., and Wright, W. E. Putative telomere-independent mechanisms of replicative aging reflect inadequate growth conditions. Genes Dev., *15:* 398-403, 2001.
7. Wieser, R. J., Faust, D., Dietrich, C., and Oesch, F. p16INK4a mediates contact-inhibition of growth. Oncogene, *18:* 277-281, 1999.

- (8, 9) "or oncogene activation." This reference gives one more cause of p16 expression.

8. Zhu, J., Woods, D., McMahon, M., and Bishop, J. M. Senescence of human fibroblasts induced by oncogenic Raf. Genes Dev., *12:* 2997-3007, 1998.
9. Serrano, M., Lin, A. W., McCurrach, M. E., Beach, D., and Lowe, S. W. Oncogenic ras provokes premature cell senescence associated with accumulation of p53 and p16INK4a. Cell, *88:* 593-602, 1997.

- (10, 11) "Early passage MEFs from the $p16^{INK4a}$–specific knockout mouse ($p16^{INK4a-/-}$) have been shown to possess similar growth kinetics compared with littermate wild-type control cultures when passaged at nonsaturating densities." This reference tells the growth patterns of mice with p16 deficiency.

10. Krimpenfort, P., Quon, K. C., Mooi, W. J., Loonstra, A., and Berns, A. Loss of p16Ink4a confers susceptibility to metastatic melanoma in mice. Nature, *413:* 83-86, 2001.
11. Sharpless, N. E., Bardeesy, N., Lee, K. H., Carrasco, D., Castrillon, D. H., Aguirre, A. J., Wu, E. A., Horner, J. W., and DePinho, R. A. Loss of p16Ink4a with retention of p19Arf predisposes mice to tumorigenesis. Nature, *413:* 86-91, 2001.

- (11) "However, the major distinction of $p16^{INK-/-}$ cultures was a greater ease of immortalization when passaged serially on a 3T9 protocol." This tells how p16 deficient cells grow in comparison to cells with normal p16 grown on the same protocol.

11. Sharpless, N. E., Bardeesy, N., Lee, K. H., Carrasco, D., Castrillon, D. H., Aguirre, A. J., Wu, E. A., Horner, J. W., and DePinho, R. A. Loss of p16Ink4a with retention of p19Arf predisposes mice to tumorigenesis. Nature, *413:* 86-91, 2001.

3. The authors definitely funneled their information as they made references. The first two references gave vague wide causes of pRb and p53 deactivation. The next reference told of some vague causes of cancer. The funneling already begins with the next reference. This one connects p53 deactivation to a cause of cancer. Next, the references move to explain another protein, p16, used in the experiment. This protein was researched more in the experiment so it has more specific information. This is why it is explained later in the introduction. The next three references all give conditions when p16 is expressed. The reference after these tells how expression of that protein affects growth in mice. Finally, to complete the funnel, the last reference tells how p16 deficient cells grow compared to cells with functional p16. This last fact was tested in the experiment, along with p53 deficiency.

4. In order to write a review of literature, you must do a lot of research. Many times, you may read separate articles to receive the same information. You must have all of this information to create a good funnel effect towards what you want to study. This funnel will give the reader of your journal good background information on what you are researching. First, they will receive basic information about the field you are studying. Then, the information will become more and more specific, telling the reader everything they will need to know to understand the journal, without assuming there is general knowledge that they already have. When writing an introduction, you must assume that your reader has no knowledge of the subject, and that you must give all the information they would need to have to understand the research.

IV. The Hypothesis:

1. The journal did not have a hypothesis but it had a goal. This was to find if "p16^{INK4a} loss conferred additional tumor-relevant capabilities in the setting of p53 deficiency." It can be assumed, however, that they thought it would.

2. This hypothesis was linked to the last reference of the review of literature. They both had to do with the affect of p16 deficiency on cell growth. Therefore, when you write a review of literature, your last reference must be clearly closely connected to your hypothesis. This way, your funnel effect will lead you directly to your hypothesis, and therefore, directly to your research.

V. The Methods:

1. The experiment was divided into five major parts. First, they gave procedure information that applied to the entire experiment. They gave this information in three subsections. They explained how the mice used were obtained and bred, how the cells used were obtained, grown, stained, and analyzed, and finally, how tumors were found and analyzed. Then, it went on to the different sections of the experiment. Each section had a different type of procedure and a different type of results. To avoid confusion, they talked about one section's procedure and its results entirely in the results section. Then they started a new section, talked about its procedure, and then gave its results, and so on.

2. Here are two examples of how Methods and Materials were written in the journal:
   A. "**Mouse Colony and Histopathology.** Animals were generated as described previously (11). *p16INK4a_/_* males (_75% FVB/n) were mated with *p53_/_* females (*n* _10 FVB/n; Ref. 12). Nonlittermate *p16INK4a_/_ p53_/_* females were then mated with *p16INK4a_/_ p53_/_* or *p16INK4a_/_ p53_/_* males to generate the experimental colonies (_87.5% FVB/n). Littermate controls were analyzed in all instances for tumor-free survival. Animals were genotyped by PCR and monitored as described previously (11, 12). Histological characterization was done as described previously (11). We did not perform immunohistochemical analysis on the majority of tumors in this work, and, therefore, many tumors were classified as malignant spindle cell neoplasms.

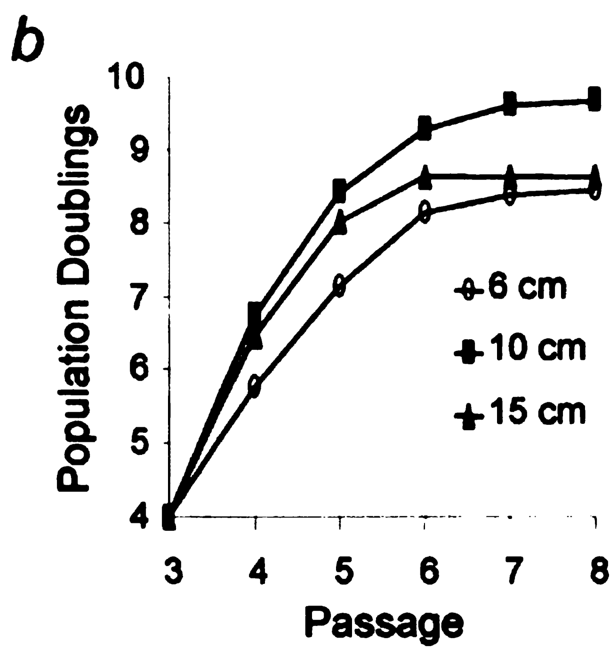
These tumors generally do not express markers of specific mesenchymal differentiation (Myf, S100, desmin, and CD31) yet most likely represent poorly differentiated sarcomas and are termed "fibrosarcoma" or "malignant fibrous histiocytoma" by others. It is possible that a minority of these tumors represent poorly differentiated squamous cell carcinomas, amelanotic melanomas (particularly given that this analysis was performed on albino mice), or other poorly differentiated malignancies."

B. "**Tumor Analysis.** Primary tumors from 18 *p53_/_* and 17 *p53_/_* were analyzed; the distribution of *p16INK4a* genotypes is shown in Table 2*a*. Western blotting for p53, Rb, p16INK4a, and p19ARF was preformed as described on primary tumors (11). In brief, tumors were lysed in EBC _ protease inhibitors, and cell lysates (50 _g) were resolved on either 16% Tris Glycine or 4–12% NuPage (Novex) gels. In addition to antibodies described previously, membranes were also blotted for Mdm2 (1:200 2A10, gift from A. Levine). LOH analysis of the *p16INK4a* and *p53* loci and MSP were performed as described previously (11). For the purpose of Table 2*a,* tumors were considered to have an Rb pathway lesion if they lacked expression of p16INK4a or Rb. Tumors were considered to have a p53 lesion if: (*a*) they lacked detectable p53 and demonstrated increased p19ARF expression (*e.g.,* tumor #9; note *p19ARF* is repressed by functional p53); (*b*) overexpressed p53 with low mdm2 (*e.g.,* tumor #6; note *mdm2* is a p53-inducible gene); (*c*) overexpressed mdm2 (*e.g.,* tumor #11); or (*d*) lacked p19ARF expression with low p53 (*e.g.,* tumor #3)."

VI. The Results:

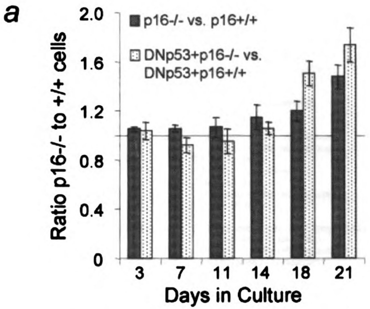
1. This journal contains 4 graphs, 2 charts, 3 tables, and 3 pictures.

2. A. A Graph from the Journal



This graph shows the growth of wild-type MEFs at varying densities. Each of the three lines in the graph represents a different density. 6 cm is the densest because it is the smallest dish. 15 cm is the least dense because that is the diameter of the largest dish. The number of population doublings was recorded at each passage (up to 8 passages). The cells were passaged every 3 days. Therefore, the passage is the x-axis and the number of doublings is the y-axis. As shown by the graph, the dish with medium density grew the most.

B. A Chart from the Journal



This chart illustrates the ratio of p16 deficient cells to cells with functional p16 grown at high density. The ratio is the y-axis and the days in culture make up the x-axis. The ratio was recorded at three to four day intervals. Data was recorded for 21 days. There are two bars at each recording. As the legend shows, the shaded one represents normal cells, and the speckled one represents cells with a mutant ineffective form of p53. These are both included to see if deficient p53 would create a difference as well. There is a horizontal line in the graph at one to show when the ratio is above or below one. When it is above one, there are more p16 deficient cells than ones with functional p16, and vice versa when the graph is below one. As the graph shows, p16 deficient cells grew much more than cells with functional p16 regardless of whether there was functional p53.

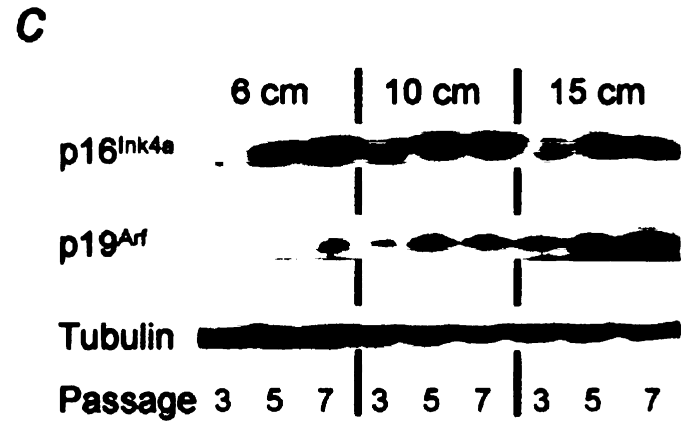
C. A Table from the Journal

Table 1 Spontaneous tumor spectrum of $p16^{INK4a}$ and p53-deficient mice (see "Materials and Methods" for histologic description and criteria)

p53 [illegible]	
p16 [illegible] (1 tumor from 42 mice)	[illegible] Malignant spindle cell neoplasm
p16 [illegible] ([illegible] tumors from 1[illegible]0 mice)	[illegible] Lymphomas (4 histiocytic)
	[illegible] Malignant spindle cell neoplasms
	[illegible] Angiosarcomas
	[illegible] Osteosarcomas
	[illegible] Squamous cell carcinoma
p16 [illegible] (1[illegible] tumors from 50 mice)	[illegible] Malignant spindle cell neoplasms
	4 Angiosarcomas
	3 Osteosarcomas
	3 Lymphomas (all histiocytic)
	[illegible] Melanomas
p53 [illegible]	
p16 [illegible] ([illegible] tumors from [illegible] mice)	[illegible] Malignant spindle cell neoplasm
p16 [illegible] ([illegible] tumors from 13 mice)	3 Malignant spindle cell neoplasm
	[illegible] Osteosarcomas
p16 [illegible] ([illegible] tumors from [illegible] mice)	4 Lymphomas (3 histiocytic)
	[illegible] Angiosarcoma
	[illegible] Malignant spindle cell neoplasms
	[illegible] Lung carcinoma
p53 [illegible]	
p16 [illegible] ([illegible] tumors from 10 mice)	[illegible] Thymic lymphomas (small lymphocytic)
	[illegible] Angiosarcomas ([illegible] metastatic)
	[illegible] Malignant spindle cell neoplasms
p16 [illegible] (2[illegible] tumors from [illegible] mice)	10 Angiosarcomas ([illegible] metastatic)
	[illegible] Thymic lymphomas (small lymphocytic)
	6 Malignant spindle cell neoplasms
p16 [illegible] (19 tumors from 15 mice)	9 Angiosarcoma ([illegible] metastatic)
	6 Thymic lymphomas (small lymphocytic)
	[illegible] Teratocarcinoma
	[illegible] LN Lymphoma (small lymphocytic)
	[illegible] Malignant spindle cell neoplasm

This table shows the number and types of tumors that developed in mice with varying amounts of functional p16 and p53. The left column tells whether the mice have fully functional, no functional, or half of the regular amounts of functional p16 and p53. +/+ means fully functional protein. +/- means half of the regular amount of functional protein. -/- means no functional protein. The left column also tells the number of tumors observed from the number of mice observed. The right column tells every type of tumor found and how often it was seen in that particular combination of p16 and p53. As the table shows, as p16 and p53 decrease, the number and types of tumors increase.

D. A Picture from the Journal



This picture shows the result of a western blot analysis run by the authors. This analysis shows the expression of p16^{INK4a} and p19^{ARF} at different passages at different densities. The dish with the 6 cm diameter is the densest because it is smallest. The dish with the 15cm diameter is the least dense because it is the largest dish. The dishes are separated in the picture by thick vertical lines. Also each dish is divided again by its passage. The dishes were passaged once every three days. These readings were taken on passages 3, 5, and 7. Also, each row of blots measured something else. The first row measured p16 expression; the second: p19 expression; the third: tubulin. As shown by the picture, tubulin remained constant at all densities and passages. p16 expression increased with each passage. Also, it was slightly higher in passage 7 of the highest density than in the passage 7 of lower densities. Also, p19 expression increased with every passage. It increased as density decreased as well.

3. When you include a graph, chart, table, or picture, you must include enough information to let the reader understand what it means. Each axis must be labeled and have divisions. Also, the legend must make sense in order to explain the information in the graph. The diagram must also be explained in the paper. It cannot stand alone. It needs words to back it up and explain it more deeply. If it is not explained in the paper, then it will seem like a last-second add-in. It must be weaved into the paper well to create a fuller understanding of the research in the reader.

VII. The Discussion:

1. The authors linked their results and hypothesis to their discussion in this paper. Immediately, the authors said that their results suggested that deficiencies of p16 and p53 cooperate in forming tumors. This was their hypothesis. The discussion, results, and conclusion were all wrapped up in one sentence together. The authors did not stop there. They went into much deeper detail with what their data found. They also spoke of unexpected findings. They said their results suggested that growth at high density (as in a tumor) could be a cause of p16 deletion or silencing. This was not expected in their hypothesis, but it is still good information found. This connects their results and discussion.
2. The authors used more references in the discussion to compare their findings to other similar papers. These comparisons could lead to helpful conclusions about solving the p16 and p53 anticancer pathways.

3. The Discussion is one of the most important parts of the paper. It gives explanations for expected findings and tries to find causes for unexpected findings. Also, it compares the study to other similar studies. This way, the information can be compared to see if it is unusual or points to any new conclusions. For a good discussion, first, you need to state your findings. Next, you must relate them to your hypothesis. Afterwards, try to find an explanation for your findings. Finally, compare your findings to the findings of other similar papers. If you compile both of your works, you could create a new conclusion.

VIII. The Conclusion:

1. The authors did not clearly state that the aim of the study was achieved, but they did state, "in human cancers… loss of p16INK4a and p53 cooperate in tumorigenesis." That was their hypothesis. Therefore, the aim was achieved.

2. The conclusion and the discussion were blended together so there is no definite starting or stopping point to the conclusion. I believe the conclusion begins when they say, "A few features of these results are notable and somewhat unexpected." They then state their important and unexpected findings.

3. The significance of their study is mentioned more than once. They say, "Elucidating the molecular nature of these density-mediated signals, and determining if they are the same signals that mediate *p16INK4a* induction and ultimately loss, in nascent tumors may lead to an improved understanding of this barrier to cancer." Also, they discuss the significance of their study when they say, "Our data are consistent with the high frequency of *p16INK4a* methylation seen in human cancers and suggests *p16INK4a_/_* mice provide a useful platform for the study of this process." Both of these quotes tell what type of studies could be run in the future to further our knowledge of p16 and p53's involvement in the formation of tumors.

XI. The Bibliography:

1. The authors used 25 references.

2. The bibliography was arranged numerically. The sources were listed in the order they were cited in the journal.

3. This is an example of one the references written by the authors:

1. Sherr, C. J. The Pezcoller lecture: cancer cell cycles revisited. Cancer Res., *60:* 3689–3695, 2000.

Appendix D: Student Example of Article Dissection

Junior Article Dissection

I. The Abstract

1. There are 217 words in the abstract.

i. Review of Literature: 19.4%

ii. Hypothesis: 7.8%

iii. Methods: 15.7%

iv. Results: 16.6%

v. Discussion: 32.7%

vi. Conclusion: 7.8%

2. What can be concluded about writing an abstract is that the main bulk of the abstract will be on discussing the data in the results. Less time is spent on the hypothesis and conclusion, since both are the results of a funnel effect, present in the literature review and in the method-results-discussion process.

II. The Title Page

1. **Title:** Presolar stardust in meteorites: recent advances and scientific frontiers
2. **Authors:** Larry R. Nittler
3. **Publishing Information:**

   Earth and Planetary Science Letters 209, (2003) 259-273

III. The Review of Literature (Introduction)

1. Three cited references in the Introduction.

- E. Zinner, Stellar nucleosynthesis and the isotopic composition of presolar grains from primitive meteorites, Annu. Rev. Earth Planet. Sci. 26 (1998) 147-188.
  "There have been several reviews of the subject over the last decade [1-3] and the reader is referred to these and the current literature for more details on the topics discussed here."
- E. Anders, E. Zinner, Interstellar grains in primitive meteorites: Diamond, silicon carbide, and graphite, Meteoritics 28 (1993(490-514.
  "There have been several reviews of the subject over the last decade [1-3] and the reader is referred to these and the current literature for more details on the topics discussed here."
- T.J. Bernatowicz, E. Zinner, Astrophysical implications of the laboratory study of presolar materials, AIP Conf. Proc. 402, Woodbury, 1997.
  "There have been several reviews of the subject over the last decade [1-3] and the reader is referred to these and the current literature for more details on the topics discussed here."

3. These bullets create a "funnel" effect because reference one first speaks about what stellar nucleosynthesis *is*, and includes information on the isotopic composition of the presolar grains. Reference two comes next it specifies what types of presolar grains are present in the spoken-of meteorites, listing off diamond, silicon carbide, and graphite. Reference three is the last because it sets the stage for the hypothesis, speaking about the astrophysical implications of laboratory studies of presolar materials.

4. To write a Review of Literature one must "funnel", using references to support stated facts that narrow in specificity as the reader proceeds through the Introduction. But the author(s) must also keep in mind that the Review of Literature is also part of the even larger "funnel" effect: the article itself. Thus, the Review of Literature must maintain the "funnel" and avoid ending too specific.

IV. The Hypothesis:

1. There are two hypotheses in this article.

i. I highlight some recent advances in presolar grain research

ii. I…suggest where new insights might come. A recurrent theme is how progress in this field has gone hand in hand with the development of new analytical techniques.

2. The Objectives are linked to the Review of literature because the author states that he will elaborate further on what he has previously spoken generally about. In the Introduction he had spoken about different types of research, and the grains themselves, linking to the first objective. Also in the Introduction he spoke about possibilities of where the research could be headed, connecting them to the current research endeavors. This links to the second Objective, where he will suggest different methods of research.

V. The Methods

1. The format used by the author to address the methods and materials is in compositional form, with further citations and inserting tables and pictures. He begins in general, speaking about the mineral phases and the presolar grains, than narrows the topic and speaks about the types of grains, being more specific.

2. Examples:

i. There are probably other presolar phases present in meteorites, especially silicates, which are dissolved in the procedures currently used to concentrate presolar grains.

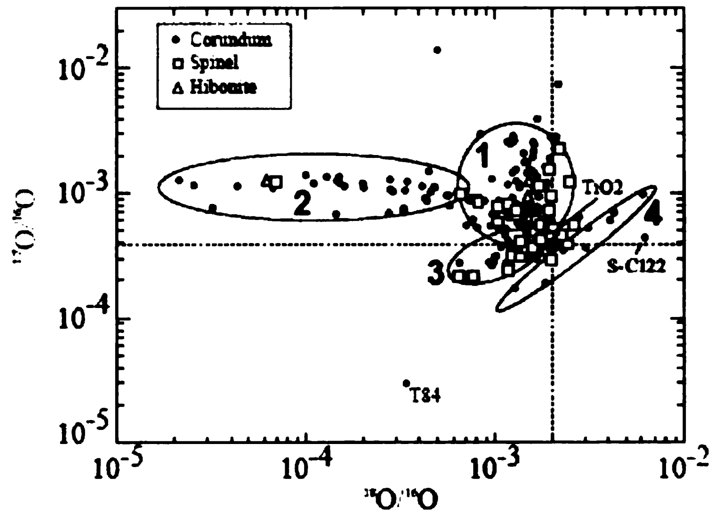
ii. Nanodiamonds (V2.5 nm diameter) are the most abundant, but least understood type of presolar grains. They are identified as presolar on the basis of containing highly unusual Xe and Te isotopic ratios, which seem to reflect nucleosynthetic processes in supernovae (SN) [5,6].

VI. The Results:

1. 11 graphs, tables, and pictures are used by the author.

2. Examples:

i. Graph



This graph depicts the oxygen isotopic ratios measured in presolar oxide grains from meteorites. The scale is in scientific notation, and is very miniscule. The ellipses indicate grain groups.

ii. Table

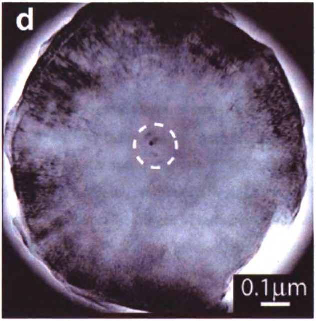
Table 1
Types of presolar grains in meteorites

Phase	Abundance (ppm)	Size
Nanodiamond	1400[a] [71]	2 nm
SiC	14[a] [71]	0.1-20 μm
Graphite	10[a] [71]	1-20 μm
TiC, ZrC, MoC, RuC, FeC, Fe Ni metal	? (sub-grains within presolar graphite) [12]	5-220 nm
Si_3N_4	>0.002[b] [21]	~1 μm
Corundum (Al_2O_3)	~0.05[c] [16]	0.5-3 μm
Spinel ($MgAl_2O_4$)	≤0.05[c] [16,20,58]	0.1-3 μm
Hibonite ($CaAl_{12}O_{19}$)	0.002 (three grains)[c] [17]	~2 μm
TiO_2	? (one grain)[c] [18]	~1 μm

[a] Abundance from: Orgueil (CI1).
[b] Abundance from: Murchison (CM2).
[c] Abundance from: unequilibrated ordinary chondrites.

This chart depicts the types of presolar grains in meteorites. The first column are the phases of the grains the second, the abundance measured in parts per million. The sizes are measured in nanometers, and are in the third column.

iii. Picture



This is the transmission electron microscope (TEM) image of a V100-nm-thick slice of a V1-Wm presolar graphite grain. The dotted ellipse indicates a cluster of tiny TiC crystals that probably served as a nucleation center for the growing graphite sphere.
Nucleation is when a bubble or other structure appears spontaneously at a random or unpredictable spot.

3. Key elements required when including a graph, chart, table, and picture in a paper is that a thorough explanation is required so that there should be little effort from the reader, who must be a bit well-versed in the topic. Understandable legends and clear groupings in columns are also required. Information on pictures must also be present, since the information will not be in the picture itself.

VII. The Discussion:

1. The author united the discussion with the results by drawing upon the data from the results and accomplishing what he had stated in the hypothesis, to highlight recent advances in presolar grains research.

i. "It is now well established that the majority of presolar SiC grains originated in C-rich AGB stars and most of the oxide grains formed in O-rich red giants and AGB stars. The strongest evidence for both conclusions is the similarity of measured isotope distributions (C in SiC, O in oxides) with direct spectroscopic isotope measurements of the stars (e.g. [26,27])."

a. These statements summarize the data about oxide distribution in the grains. He states the evidence came from the measurements, a form of data retrieval he had briefly spoken about.

ii. "Infrared spectroscopic features of SiC and corundum have also been observed around such stars. Moreover, the ranges of many isotopic ratios observed in the grains are in good quantitative agreement with theoretical predictions for these types of stars [9,16,30]."

a. Once again the author refers back to the data mentioned in the previous example (also taken from the Results). He speaks about the SiC and corundum, and states that thos features have been noticed around other stars. This connects the data from previously in the article to the methods he spoke of near the beginning of the article.

2. The auther used other references in the discussion because he had to support what he stated, and the evidence was presented in the results, which would never have been present if it did not have the hypothesis to guide its aim.

3. The role of the Discussion is to discuss what the data retrieved consisted of, also tying it to the hypotheses. Key ingredients of a Discussion are referring to the results, mentioning the hypotheses to ground the evidence, and elaborating further on the data retrieved in results.

VIII. The Conclusion:

1. The author indicated that the aim of the study was achieved by stating how information retrieved from microscopic presolar dust grains are very important in learning more about stars and other objects we are incapable of learning more of, including composition and origin. He then proceeds to detail further possible avenues of presolar grain research.

2. Author's words:

Microscopic presolar dust grains are clearly an exciting new source of important information about cosmic objects tens of orders of magnitude larger than themselves (Fig. 1). However, there are still many unsolved problems, some of them fundamental, some in the details. I have touched on some puzzles in this brief review (e.g. the still uncertain origins of nanodiamonds, high-density graphite, A+B SiC and Group 4 oxide grains) but there are of course others, including the origin of 15N enrichments in SN grains [48,52] and the paucity of presolar oxides relative to C-rich presolar grains [16]. Although many of these problems will undoubtedly be solved, we are certain to encounter both new surprises and new puzzles in the future. Some of the most promising routes to interesting new insights are given below.

3. The author discussed the significance of the research at the beginning of the Conclusion.

Microscopic presolar dust grains are clearly an exciting new source of important information about cosmic objects tens of orders of magnitude larger than themselves (Fig. 1).

IX. The Bibliography:

1. 79 references were used.

2. The bibliography was arranged in order of use, with no regard to alphabetical. The authors are listed, then the title of the article, then the journal, volume, and date. The page numbers are last.

3. Example:

[57] L.R. Nittler, C.M.O'D. Alexander, J. Wang, X. Gao, Meteoritic oxide grain from supernova found, Nature 393 (1998) 222.

Appendix E: Mentor Recruitment Letters, Student Example

Dr. Lawrence Karl Olsen,

My name is Sophomore Student. I am sixteen years old and a sophomore at Catholic Central High School in Grand Rapids, Michigan. Catholic Central is the oldest coed Catholic high school in the United States and this year was voted one of the country's top 50 Catholic high schools in academics. I am currently enrolled in a three-year class called Scientific Research Seminar at my school. This program is unique at the high school level in the state of Michigan. The class was founded at the end of last year by my teacher, Mr. Andrew Moore. Mr. Moore encouraged me to apply to be in this class where I could pick my own topic to research and design my own experiment. My older sister has had type 1 diabetes for 12 years, so picking a topic was easy for me. I completed an application essay discussing why I wanted to take this three-year class and how I could be an asset to the program. I was selected along with nine other freshmen and seven sophomores out of 70 applicants.

In my first year of Scientific Research Seminar, I have learned about experimental design and techniques through group and independent guided instruction. Until this class, I have left all of my science classes wanting more than the book could provide. After learning what happened, I wanted to learn why it happened. This class has given me the opportunity to answer these questions on my own. My focus this year has been on possible cures and treatments for type 1 diabetes. I have read over 50 articles and six scientific journals on this subject.

Because the knowledge I gain through experimentation, data collection, and article reading can only take me so far as an independent researcher, a mentor to guide me through more professional work is an essential aspect of this class. I received your name from Dr. Laryssa Kaufman at Michigan State University in early March of 2007. Since then, I have done extensive internet research on your work pertaining to diabetes and pancreatic cells. I have read all of your abstracts written about diabetes, as well as the full texts of *Effects of Tacrolimus (FK506) on Human Insulin Gene Expression, Insulin mRNA levels, and Insulin Secretion in HIT-T15 Cells*, *Differentiation of Glucose Toxicity from Beta Cell Exhaustion during the Evolution of Defective Insulin Gene Expression in the Pancreatic Islet Cell Line, HIT-T15*, and *Increased expression of GPI-PLD-specific phospholipase D in mouse models of type-1 diabetes*. I have spent the most time with the final journal. Three weeks ago, I presented this journal to the students in my class through a Power Point presentation.

I am writing you to ask if you would be able to advise me and guide me in my research. I am intrigued with the work that you have done, and I would be honored if given the chance to work with you next summer. I am a very good student and a very hard worker. I am currently ranked 2nd in my class of 190 students and have a cumulative GPA of 4.57. I am taking four honors classes, including Science Research Seminar, and am receiving A's in all of them. I am extremely self-motivated and learn very quickly. I also volunteer weekly at my church and volunteer as needed for the West Michigan chapter of the Juvenile Diabetes Research Foundation. My father, Dr. Sophomore Student, received his medical degree from the College of Human Medicine at Michigan State University in 1980. He was on the Board of Directors for JDRF for three years. I would truly appreciate the opportunity to work with you next summer, performing a self designed experiment on type 1 diabetes that would be submitted to the Intel Science Competition my senior year. Although my goal is not to win this competition, I would like to gain the experience of designing and completing an authentic and publishable experiment.

Thank you for taking the time to read this request. Please respond back by email at your earliest convenience. If you have any questions, feel free to contact me or my teacher, Andrew Moore, at (616)233-5830 or at andymooore@grcss.org.

Sincerely,
Sophomore Student
sophomorestudent@yahoo.com

Appendix E: Mentor Recruitment Letters, Student Example

Dr. Schwartz:

My name is Junior Student and I am a 17 year-old junior at Catholic Central High School in Grand Rapids, Michigan. This year, my school has begun a three year program called the Authentic Research Seminar in which talented students can pursue independent research in the area of their choosing. Even in the program's first year, competition for entrance was extremely competitive, with only 17 of over 70 students accepted. By the end of the three years, it is expected that each student will have completed a 20-page research paper and entered it into the prestigious Intel Science Talent Search. Unlike any other high school class, this program allows students to truly find their passions and push themselves beyond the limits of the traditional classroom. A vital part of this program, though, is finding a mentor to guide our research.

I have always been interested in science. For years, I had my heart set on exploring the reaches of the universe until a science teacher introduced me to molecular biology in 7th grade. Last year, I rediscovered my love of proteins in AP Biology where I became fascinated with the entire transcriptional and translational processes. When it came time for me to focus on my interests this year, I was logically drawn to the mechanisms governing transcription. After college, I would like to pursue a Ph.D. and a career in research.

Knowing that success in the world of research does not come easily, I have done everything in my power to give myself the necessary background to excel. I read over 55 general articles concerning neurobiology, cancer genetics, and stem cells before beginning to read journals regarding transcription. I have read 10 of these, 1 of which was your paper "C/EBPγ Has a Stimulatory Role on the IL-6 and IL-8 Promoters." As I am absolutely fascinated with the various molecular interactions regulating transcription, I was particularly interested by C/EBPγ's ability to stimulate C/EBPβ activity. In fact, I'd love to be able to read your paper "Differential roles of C/EBP beta regulatory domains in specifying MCP-1 and IL-6 transcription," as I was unable to obtain a copy.

If you afford me the opportunity to work with you, I will only add vitality and passion to your lab. I am first in my class of 187 with a weighted GPA of 4.6. I received a perfect score on the AP Biology test last year as a sophomore in a class of primarily seniors, while on the PSAT I received 228 out of 240, placing me in the top .5% of juniors nationally. However, numbers are rarely an effective way of judging a person's character. I have a genuine passion for knowledge and am incredibly driven in everything I do. I learn quickly and would be honored to research with, and learn from, someone with your experience.

I would be extremely grateful if you would agree to mentor me through a research project. If you have any further questions regarding this program, please feel free to contact my teacher, Mr. Andrew Moore, at andymoore@grcss.org or at 616-233-5830. Thank you very much for your time, and I would appreciate it if you would respond to this email at your earliest convenience.

Sincerely,
Junior Student
juniorstudent@gmail.com

Appendix E: Mentor Acceptance Letter From Teacher to Mentor

Dear Dr. Hord,

My name is Andrew Moore, Sophomore Student's research instructor. I wanted to take a moment to provide you with some information regarding the Science Research Seminar program at Grand Rapids Catholic Central High School.

Our students are enrolled in a three-year program called Science Research Seminar. It is a graded program, the goal of which is to provide students with the opportunity to discover, and subsequently to become intensely involved in, an area of passion for them in science.

During the first year of the program, students learn about experimental design and techniques through group and independent guided instruction. They read dozens (sometimes hundreds) of periodicals and journal articles on their topic, learn the fundamental science associated with their chosen field of study, and learn to critically and formally dissect research papers. Along the way, they hopefully find a mentor in their field, which is where you have so kindly stepped in.

During the second year, students are expected to accelerate their studies on their topic. They now focus on the work of the mentor and commit truly large quantities of time towards learning the material - this is necessary because while the students may be motivated and talented, they are obviously still young and have much knowledge to gain in a relatively short period of time. During this time, their mentor guides the student through the literature, as they work together to develop a plan for the coming months. I call this the *Junior Vision Plan*. Rather than simply being a course of study, it is intended to become plan of action. Depending upon their relative location, mentors communicate with the student through email correspondence, telephone, or through face-to face meetings at a convenient time. Some students begin work at the laboratory or facility during junior year. Typically, mentors get a sense around this time of the potential ability of their student and help to guide him or her in a direction of independent or semi-independent work within the area of interest. The goal, which is often (but not always) realized is to eventually have the student work on a small piece of the "scientific mystery" on their own or in collaboration with you, your doctoral students, or your colleagues. This original work is not gratuitous - the student must earn the respect of the mentor to the extent that he or she becomes a true asset rather than a time liability for the mentor.

At this point, real learning can occur. Many students have contributed significant findings to their mentor's work and have been complemented on being better than many graduate students in their dedication and ability. Of course, there is never a guarantee that things will "gel" this well, and the main onus for follow-through always rests with each individual student.

Between junior and senior year, there is typically a period of intense work. This is the culmination of the year-plus of reading and study and involves the possibility of contributing a novel piece, however large or small, to the research. This is a tall order for a high school student, but it is tremendously exciting for them. This work may continue through the beginning of the student's senior year but it must be concluded early in the fall because at that point, the student will write the formal paper that is the highlight of senior year. This paper may then be entered into the Intel Science Talent Search, for which there are only forty annual finalists from the entire nation. In addition to their entry into the Science Talent Search, the students present their work both at school as well as at formal symposia.

Dr. Hord, Sophomore Student is deeply indebted to you for your assistance with this part of her education. It is only through the generosity of intellects such as yours that the next generation of scientists may emerge, and what you are doing today will produce far-ranging positive consequences for tomorrow. Please know that each student is supported here at Grand Rapids Catholic Central High School and that I am available to assist in any way that he or you might need. I hope that this helps to clarify the Science Research Seminar program, but if questions remain please get in touch. I am attaching my contact information below.

Sincerely,

Mr. Andrew J. Moore
Grand Rapids Catholic Central High School
(616)233-5830
andymoore@grcss.org

Appendix F: Sophomore Mid-Year Report

THE SOPHMORE MID-YEAR SCIENCE RESEARCH REPORT

The following assignment will help you to reconstruct the planning, research, and thought processes you have done so far in your research. It will also assist your research organization in the second half of the year.

As you are all at different stages of your work, there will be considerable variation in your papers. However, each item below requires a minimum of a one-page discussion. Your work should be typed and double spaced. This report is due February 27.

1. What is (are) your current area(s) of interested research? Discuss how your interests or direction have changed over time due to both personal and practical reasons.

2. Write three plausible hypotheses you would like to pursue based on your work to date. Explain each of these hypotheses.

3. Write:
    a) A Review of Literature of the most important readings you have done. Include at least ten items.
    b) Also, include three of the most prominent researchers you have found.
    c) Lastly, indicate the research facilities where this research is occurring.
4. Write: Design three possible experiments of your own to support your three hypotheses above. Include all materials and methods to the best of your ability.

5. In as much detail as possible, write a timeline for the second half of the year. Do not forget preparation time for your presentation in class.

6. Assess your research based on the rubric found in the portfolio. Explain in great detail why you chose this grade.

Appendix F: Junior Vision Plan

<u>Junior Vision Paper</u>

- At this time, you should be envisioning the end of your Science Research Project, i.e., what do you want to have as your research product in June of your Junior year? *This vision will be initially prepared by you and turned in by the 2nd week of November. You and your mentor will review and revise this plan.*
- Write the goals and objectives that you intend to accomplish this year. The purpose here is state where your research progress should be at the end of your Junior year and before you begin your research in Junior summer.
- Your research plan should contain:
    1. your research objectives
    2. a timeline from October through June
    3. the methods you will use to accomplish your goals
    4. your expected research results.
- Your plan should contain a clear timeline, by month and/or by experiments bringing you to June of Junior Year.
- After this plan is revised with you and your mentor, it must be dated and signed by you and your mentor. A copy of the signed plan must also be left with your mentor and one given to me.

Appendix F: Junior Vision Plan, Student Example

Junior Vision- 11.26.2006

This year I aim to accomplish in my research a clear understanding of what subjects of astronomy I am interested in and capable of comprehending to the best of my ability. I also wish to secure a mentor who works in one of the fields I will have identified, and that I will be able to assist/work with the mentor, no matter how tedious. Gaining a more general understanding in my chosen field would also be desired and worked for. I am interested in finding more about optical and radio astronomy, since the physics might not be too staggering, although that is what I hope as I research.

November and December will be mostly finding the specific field and compiling a list of potential mentors to be narrowed down in the future. I will also find a journal article to be dissected and turned in by December. Choosing the mentor will be in December, where contact will be worked on. By January I should already have received news from the possible mentors and have been accepted.

February will be the literature review, as recommended by the mentor. March will include more literature and development of the method of the experiment. April will be more in-depth with the method. May and June will be the objective, which will be carried out in July and August through the experiment.

I will use the Internet, most likely the sites Science Daily for little tidbits, which will link me to interesting journals. Discover also has interesting articles more aimed at the average person. Scientific American has a lot of journals to look at. Google scholar is the hotspot for journals I will be searching for. I will also use various communication devices like the telephone and email to contact various possible mentors.

I expect for results that I have gained more understanding on my mentor's work, and that I will have successfully secured one and am assisting/working with the person. I will also have gained a better understanding of how to navigate through science journal articles, and the workings of one.

Appendix F: Junior Vision Paper, Student Example

Junior Vision Paper

Year Goal: Complete an undergraduate level research paper to be presented at the Spring Symposium and refined through summer research.

"To give anything less than your best is to sacrifice the gift." This quote from Steve Prefontaine in regards to running is equally applicable to scientific research. In my personal research this year, I am aiming for nothing less than perfection while passionately pursuing a subject I enjoy. If perfection means failure, then so be it. Such is science.

By the end of this school year, I hope to have completed an undergraduate level research paper which I will present at the Spring Symposium. Ideally, I will then work with my mentor this coming summer to refine that paper in order to enter it into the Siemens Westinghouse Competition and Intel Science Talent Search my senior year.

In order to reach this point, I will be reading journals during the entire month of December. By the beginning of January, I hope to have contacted a researcher with the intention of securing a mentor and ideally would like to have heard back from them by mid-month. The remainder of January will be spent working on a procedure, and by the beginning of February I would like to have begun experimentation.

Realistically, I expect to spend the months of February, March, and April on my experiment. By the end of April, though, I should be organizing my data into a research paper. From that point on, my person work will primarily consist of finishing my paper for presentation in the May Symposium.

As I do not yet have a firm idea of my specific line of research, this paper will have to be updated at the end of December. By that point, I expect to have a clear idea of my experiment and expected results.

Outside of this class, I will be self-studying for the USA Biology Olympiad, which begins in early February. If I perform well in those opening rounds, I will have the chance to compete at higher levels later in the school year. I do not expect this to alter my research plan, however.

In addition, I will be applying to the Research Science Institute, hosted by MIT next summer. Though my chances of being accepted are close to 4%, that still means I have a 1 in 25 chance of attending and I see no rational reason not to apply. Everyone needs a dream. I have wanted to attend RSI since 7th grade and I'm not stopping now.

In short, my long term goal is nothing less than a nationally competitive research paper. However, no award is worth it if I don't thoroughly enjoy my work.

Appendix F: Junior Mid-Year Plan

THE JUNIOR MID-YEAR SCIENCE RESEARCH REPORT

As part of your mid-year report card grade, you are required to submit a 10-page document of your research status to date. The paper, which must be typed and doubled spaced, is due by January ______________. It must consist of the following reports:

1. The Title Page: Clearly identify the title of your research project. (The title may eventually change.)

2. The Review of Literature: Write a review of literature which clearly demonstrates the "funnel effect." That is, your review must chronologically and logically be in order, indication the historical and logical progression of the research. You must use the proper citation format: Title, Author, Journal, Volume, Page, and Year. Your review must indicate a void in literature which leads to your present hypotheses. You should indicate how the review helped form and shape your present hypotheses.

3. Hypotheses: Write a statement of your goals, objectives, or purposes of your research. Your hypotheses should always be compound, complex, and the state of the art.

4. Methods and Materials: List and explain the methods and materials used in your research to date. This may include your intended questionnaires, data check-lists, and any other tool (instrument, survey) you will use to collect data. The use of a flow-chart would be helpful to indicate the progress and continuity of your research project.

5. Results: Include here any data you already have. Any data you report must be explained with tables, charts, and graphs. You may also include your expected data.

6. Discussion: Use this report to explain and fully discuss the meaning of your results. This report should clearly explain every detail of your results.

7. Significance: Indicate what is the significance of your results. Indicate, also, the value of your research data.

8. Conclusions: List your conclusions to date. Your conclusions should refer directly to your hypotheses.

9. Acknowledgments: Include here all those people that have significantly helped you in your research (mentors, teachers, parents, etc.) and indicate why you are thanking them.

Appendix F: Sophomore Summer Vision Plan

Summer Vision Plan
Sophomores

This assignment is due May 21.

1. It is time for you to prepare for your junior year. At the end of your junior year, you will be running an authentic research project with a mentor.
2. This vision is to be created by you ***and*** your mentor.
3. In paragraph style, please create a vision of your research idea and how you are preparing to run the project.
4. This research vision should contain:
    a. A summary of what you have done to date (readings, procedures, etc.)
    b. A preliminary project objective
    c. A summary of concepts that you need to learn to test objective
    d. A summary of procedures (lab, survey, statistical, etc.) that you will need to have mastered before running the project or analyzing data
5. In addition to the written paper, create a calendar for the months of June, July, and August which indicate your objectives for each month. Additionally, if possible, specify your goals for each of the twelve individual weeks. ***This is to be completed with the advice of your mentor.***
6. The joint created plan (with your mentor) should be dated and signed by both you and your mentor.
7. Three copies are to be made: One for Mr. Moore, one for your mentor, and one for yourself. The copy to Mr. Moore should be digital, and a single file.

This plan will prepare you to do your Junior Vision paper in September, as well as your first 10-week plan.

Appendix F: Sophomore Summer Vision Plan, Student Example

Sophomore Vision Paper

To date, I have learned of the methodology of conducting an experiment and read 80 abstracts and six journal articles. The learning of the research process took place in the Science I, II, and III projects. Science I taught preliminary skills and introduced the fundamental concepts of observational studies through an experiment within a river ecosystem. Although the actual study conducted by my group and I failed, the experience helped to emphasize the importance of peer review, limiting variables, and the relationship between data and the hypothesis – supported, never proven. Science II allowed for an experimental study, which for my group studied the correlation between the numbers of eggs to the height that a soufflé raises over time. With the lessons learned from Science I, the procedure was more refined to limit as many variables as possible and subject to a more extensive peer review. As a result, the data supported the hypothesis. Finally, Science III permitted an independent scientific study in order to thoroughly test the familiarity with the basics of a well-done study and force students to experience all of the scientific procedure, which is impossible in a group setting. My own research searched for a correlation between video game experience and learning a new video game. This was the first study in which I had to write a full paper, which included the Literature Review. The review was integral in forming and refining the hypothesis and the procedure. The most valuable lesson taught in this study was the usefulness and difficulty of a Literature Review.

As for the independent research, which began at the beginning of the year, I first began with psychology but moved toward optics as I read through popular articles from

Discover, Scientific American, and *ScienceDaily*. Originally, I was more interested in IQ than telescopes but that changed when I learned of an article involving an invisibility cloak. I read about the cloak but I then became disinterested on the subject, but I retained my fascination of light. Eventually, I came upon an article discussing telescopes and the "war" for funding. Finally, I decided to pursue telescopes as a topic of interest, which bloomed into an interest involving methods to increase telescope resolution.

When it comes to reading journal articles, I have read 51 abstracts and five journals by Rebecca Bernstein. The writings were about galaxy dynamics, spectroscopic instruments, the Dark Energy Survey Camera for the Blanco 4-m telescope, the MIKE spectrograph within a Magellan Telescope, and the Giant Magellan Telescope. Afterwards, so far, I have read 29 abstracts and one journal by John Monnier. His writings were mainly about infrared interferometry and diffraction-limited imaging, which leads to millarcsecond resolution, and observing nebulae, Herbig Ae/He stars, Wolf-Rayets, as well as other types of stars with interferometry to discover facts about stellar evolution.

As of the writing of this paper, my mentor has not been officially secured. Therefore, unless my mentor says otherwise, my preliminary objective is to answer the following question: Do techniques used to increase angular resolution work on the small, amateur telescope as well as they do on the large, professional telescope, particularly aperture masking? In order to test this objective, I would have to build my own telescope and learn how to make non-redundant and partially redundant aperture masks. In addition, I would have to learn the basic concepts of engineering so that I can pick the correct materials and accurately and precisely cut the correct holes in the mask as well as making any necessary electrical connections. Also, learning how to program a computer to capture independent, fast images and then combine them would also be useful. It would particularly help also to learn more about the properties of light. The most important concept to know, though, is Fourier analysis.

Appendix F: 10 Week Plan

10 Week Plan

At the beginning of each quarter we will sit down together and go through a 10 week plan that you have written. The plan must have the following parts:

- A written statement of what you have accomplished over the past 10 weeks.
- Goals that you wish to accomplish in the next 10 weeks
- An individual 10-week timeline per goal set for the quarter
- The 10-week timeline is placed on an actual calendar with each goal receiving a separate calendar.

Each goal is put forth with as many specifics as possible. For example, it is inappropriate to simply say that you are going to do 10 article readings. Where are you going to get them? What topic? From mentor? Etc....

Appendix F: 10 Week Plan, Sophomore Example

Research Seminar 2nd Hour

12 December 2006

10 Week Plan

10 Week Accomplishments

Over the past ten weeks in Research Seminar, I feel like I have accomplished many things on my way to becoming at better researcher. Before taking this class, I knew very little about diabetes, except that my sister has it and that she has to take shots every day to control the amount of sugar in her blood. After researching the topic and reading and summarizing 50 articles about it, I finally understand why. What I am most proud of is my ability to understand the material I read. Usually, everything comes very easy to me in school. But that is not the case with this class. I cannot say that I have understood the articles I have read on the first try, but I have developed a habit of underlining words or phrases I don't understand and looking them up before I move on to the next article. For me, the language of the articles is the most strenuous part of medical research. Also, apart from my individual research, I conducted my first research project. The River Project was not something that I've ever done before, but I feel like I gained a lot of experience from collecting samples, testing them, recording the data, writing a paper, and presenting the results. It was a great experience for me to learn how to perform a real research project. So far, I am pleased with the progress I have made.

Week 1 (Nov. 26)

This week, my goal is to read my first journal. It will be on a very general subject to diabetes, yet still contain information that I have been researching in the articles I have read. I plan to get most of my journals from MD Consult, a journal website that my dad subscribes to, and Google Scholar. MD Consult has tens of thousands of journals on a wide range of topics. What I hope to do with this journal is to read it over the weekend, underline words that are difficult to understand, look up the underlined words, read the journal over again for clarity, and, during the last few days of the week, summarize it in my process journal. On Friday, I will fill out the project forms for my meeting. Those that I do not finish at school, I will finish when I get home Friday, or on Saturday afternoon.

Week 2 (Dec. 3)

My goals for this week are similar to those of week one. During week two, I will find a journal that narrows in on the immunology of diabetes. By now, I hope to start closing in on that area. Most of the week, I will follow the same routine as in week one— reading, underlining, and summarizing. I know that this journal will be much more difficult to read than the first journal, so I am dedicating an entire week to understanding all of the concepts in it.

Week 3 (Dec. 10)

This week, I will find two journals (or two studies) that deal specifically with the immunology of diabetes. These two journals will be found on MD Consult or on Google Scholar. If there are not two good journals either of these sites, I will go to Discover or Science Daily to find material. Because this is my first week reading two journals, I expect it to be a very busy week. I will dedicate as much time as I have to learning more about immunosuppressive drugs and vaccination treatments. I want to become familiar with immune reactions and research them later in the semester.

Week 4 (Dec. 17)

I will spend week four finishing journal summaries and projects from week three, and looking for articles online about immunology. I will right down the names of reoccurring researchers in my research. At the end of the week, I will search for a journal that is appropriate

for my Dissection Paper. This journal should be a study that was conducted on immune system treatments of patients with type 1 diabetes. At the end of the week, I will begin summarizing the journal that I have chosen.

Week 5 (Dec. 24)

Over Christmas Break, I will finish summarizing the journal that I will dissect and fill out any project reports for my next meeting. I will become as familiar with the journal as possible, and I will also learn any new terms that seem important to the type of research that I am planning to continue. The last three days of the week will be spent creating an outline for the Dissection Paper. This outline will provide me with a rough draft of my paper.

Week 6 (Dec. 31)

At week six, I plan to begin writing the introduction to my Dissection Paper. I will finish the paper on Monday and Tuesday before I go back to school. On Wednesday, I will find two articles in class. I will read them both and underline new terms. I will summarize the articles at home, and fill out the project reports for the articles on Thursday. On Thursday, Friday, and Saturday I will write the second part of my Dissection Paper.

Week 7 (Jan. 7)

Week seven is dedicated to my Science Thursday Presentation. Most likely, I will be presenting the article that I have chosen to dissect because I will have had the most experience with this particular journal. On Sunday through Wednesday, I will be working on my Power Point and my oral presentation. I plan to be very comfortable with the material that I am presenting by second hour on Thursday. On Friday, I will complete any project reports pertaining to my Science Thursday Work.

Week 8 (Jan. 14)

During week eight, I will finish my Dissection Paper. On Sunday, Monday, Tuesday, and Wednesday, I will work on and finish the third section of my paper. On Thursday, Friday, Saturday, and Sunday (Dec. 21), I will work on and finish the fourth section of my paper.

Week 9 (Jan. 21)

Because week nine is exam week, I expect to be very busy studying for other classes. I do not plan to do any individual research this entire week. If I do have any spare time at all between studying, I will spend it outlining my Semester 1 Vision Paper.

Week 10 (Jan. 28)

I will spend the first three days of week ten finding 5 articles, summarizing them, and filling out the projects that pertain to each. I plan to spend the rest of week ten writing my Semester 1 Vision Paper. This paper will take me more than just week ten to finish, and will continue on into my next ten week plan.

Appendix F: 10 Week Plan, Junior Example

Mr. Moore
Research Seminar
27 November 2006

10-Week Plan: 2nd Quarter

Over the past 10 weeks, I have walked from the darkness of ignorance into the light of knowledge. Before, my plans for my life focused on restrictive international business. Because of this class, my attention has turned toward a field with much more freedom, much more compassion, and much more room to grow as a person. Yes, Mr. Moore has successfully caused me to consider scientific research as a fulfilling career. After all, last year, I was falling asleep during my economics class, and this year, reading a journal about the connections between Alzheimer's Disease and Down Syndrome wakes me up.

Ok, so now that we have that bit of creative genius out of the way, let's get down to business. Since August, I have read approximately 100 different articles on a broad range of topics, including global warming, premature birth, and cancer. The one topic that really piqued my interest, however, was Down Syndrome. As I conducted research to further my knowledge about Down Syndrome, I discovered some progress that was being made by researchers about the connections between Alzheimer's and Down patients, especially at the Down Syndrome Research Center at Stanford University. I identified a possible mentor, Ahmed Salehi, and have been reading articles written by him and other members of the lab where he performs his research since. On the side, I have completed an observational study on how storm drains affect fecal coliform levels in the Grand River with Shannon, Katie, and Maggie, and I am in the process of completing an experimental study on the best appliance for baking a cooking as a measure of moisture content with Ann and David.

In this next quarter, I hope to contact and secure a mentor, complete our experimental study, and start brainstorming what experiment I want to perform.

In order to contact and secure a mentor, I will need to read at least five more articles written by Ahmed Salehi. I will read at least one each week from now until Christmas break, and one more over Christmas break. I will find my articles through Google Scholar, as well as the Mobley Lab website (the lab where Ahmed Salehi works.) I will focus on the articles dealing with Alzheimer's in relation to Down Syndrome, but I will not turn down other articles he has written. Over Christmas break, I will compose my letter to Ahmed Salehi and email it to Mr. Moore. Hopefully, by the end of break, my letter will have been sent. If Dr. Salehi has not replied by January 12th, I will attempt to make contact again.

As far as completing our experimental study, I will make the remaining two batches of cookies on December 1st, and begin typing up my results December 2nd. I will obtain my data on Monday, December 4th, and by Friday, December 8th, I will have completed typing up my results. During class the week of December 4th, I will work with Ann and David to complete our background research. On December 9th, I will try to get together with my group in order to write our paper and finish up our work. By Wednesday, December 13th we will hopefully be ready to present.

Every other week through the next quarter, I will have one day in class set aside as a brainstorming day. On this day, instead of working on my journal article, I will browse the web for other Alzheimer's and Down information, talk to others, and hopefully use it to take a step back and make sure I'm still on track with where I want to be. Also, I will use it to brainstorm specific experiments I may want to perform with my mentor. These will fall on Fridays, specifically, December 1st, December 15th, and January 5th.

Appendix G: Methodology Practice Project

Testing the Hypothesis in a Controlled Experiment

BACKGROUND:

A hypothesis is best tested with an experiment. The results of your experiments are compared to your hypothesis in order for you to determine if your hypothesis is correct.
All experiments must have an experimental condition and a control. The experimental factor or variable is the part of the experiment that tests the hypothesis. You can have only one experimental factor at a time. The control serves as the comparison against which the experimental factor can be judged. All factors in the experimental condition are identical to all of the factors in the control except for one variable—the **experimental factor.**

PURPOSE:

Once you have completed this activity, you should be able to:

1. Define the term hypothesis
2. Identify the experimental factor and control of a given experiment.
3. Designate the logical steps a scientist would take in conducting a controlled experiment.

MATERIALS:

Pen and paper.

PROCEDURE, PART I:

Read the following passage and answer all questions:
When the Salk vaccine for the prevention of polio was tested, two nearly identical groups of children were tested. These children were of the same ages, sex, in the same classes, lived in the same area, had similar diets, etc. One group of children received the Salk vaccine and the second group of children were "vaccinated" with injections of saltwater instead of the Salk vaccine. The two groups were compared one year later. Among the thousands of children who had received the Salk vaccine, only a few children got polio. Among the thousands of children who had received the saltwater, hundreds of children contracted polio.

Questions:

1. What is the experimental factor in this experiment?
2. What is the control in this experiment?
3. State a possible hypothesis for this experiment.
4. What could the doctors conclude from the results of this experiment?

PROCEDURE, PART II:

Design a controlled experiment based on the following information:
Some plastic wraps are more air-tight than others. The more air-tight the plastic wrap, the longer food will keep fresh when wrapped in it. Seeds need air to sprout and grow.
Design an experiment that could determine how air-tight different brands of plastic wrap are. Your design should follow a logical sequence that includes a statement of the problem, materials section, and procedure.

ANALYSIS AND CONCLUSIONS:

Based on your experimental design, answer the following questions:

1. What is the problem that you are trying to solve with your experiment?
2. What is your hypothesis?
3. Identify your experimental factor and control.
4. How would you know if your hypothesis was correct?
5. Describe the experimental results you might expect to obtain.

Appendix G: Causality vs. Correlation

Causality and Correlation

If everyone in this class earns a grade of A on each Biology or Chemistry test, does that mean that if a student transfers into this class they will also earn an A on Each Biology or Chemistry test? There is a correlation between being in this class and earning a good Biology or Chemistry grades. Does this information prove a cause and effect relationship?

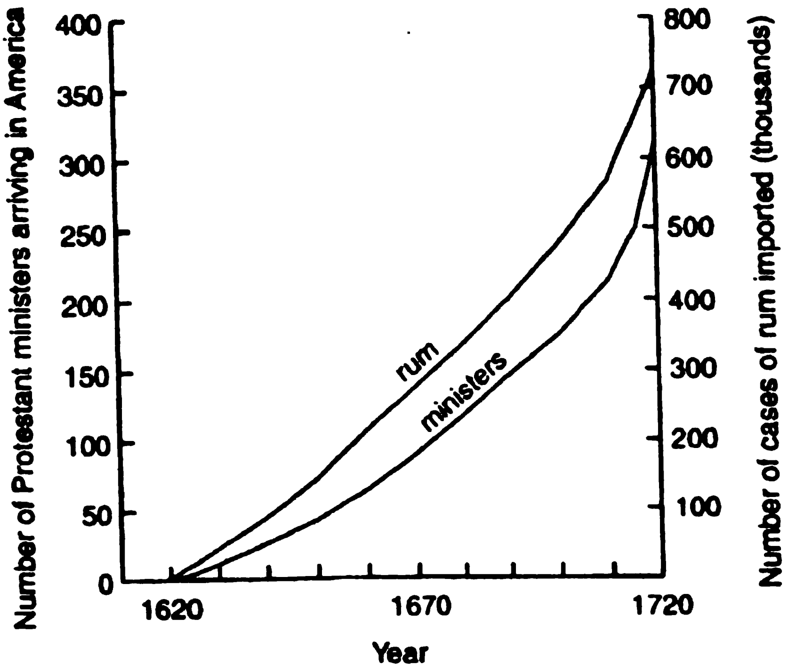
Does smoking cause lung cancer? That question has been one of the most widely discussed health issues in the second half of the twentieth century in the United States. Cigarette smoking, once less common, rapidly gained popularity in the 1930's and 1940's. Eventually, two out of every five Americans were counted as smokers.

Some health experts became concerned about this trend. They began to see a rise in the number of respiratory diseases, such as chronic bronchitis, emphysema, and lung cancer. They suspected that cigarette smoking might be the cause of this rise.

Cigarette manufacturers disagreed. They could not deny the increase in cases of respiratory diseases. But, this increase was not caused by cigarette smoking, they argued. It was only a coincidence that respiratory diseases and cigarette smoking increased at the same time.

This story illustrates the problem that scientists have in separating **cause-and-effect** relationships from **correlational** relationships. A cause-and-effect relationship is one in which it is possible to say that factor A *causes* event B to take place. Health workers were saying that cigarette smoking caused a respiratory disease.

A correlational relationship is one in which two **variables** change according to a similar pattern. But there may or may not be a cause-and-effect relationship between the two. To pick an absurd example, if you graphed the number of Protestant ministers coming to the United States from 1650 to 1750 and the number of cases of rum imported during the same period, a result like the one in the figure below might be obtained. There is obviously a correlational relationship here. But is there also a cause-and-effect relationship? If so, what is it?



1. State, in words, the correlational relationship shown by the graph.

2. State two possible cause-and-effect relationships that could account for the data shown by the graph.

3. What does the term *variable* mean in mathematics and science?

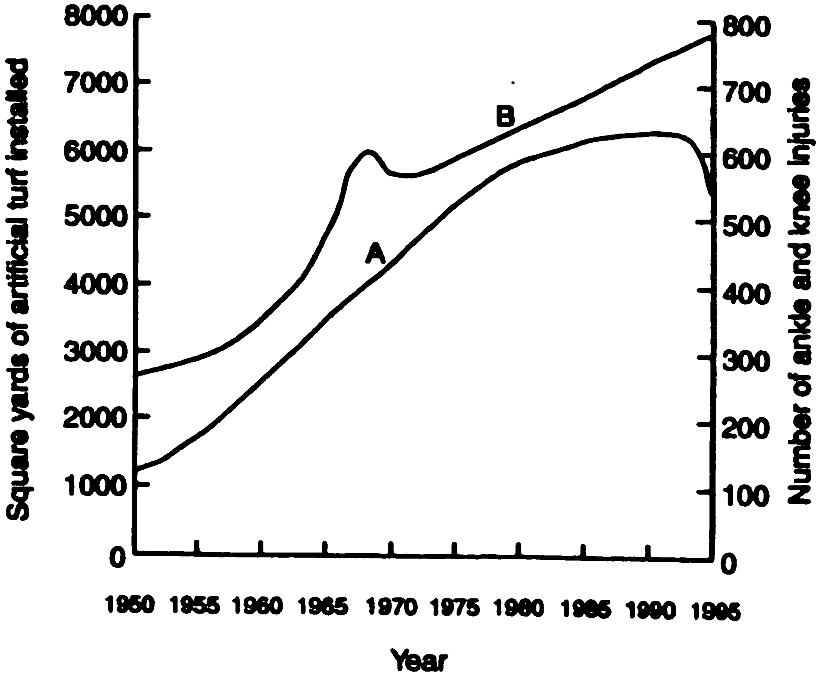
4. Can you find four variables mentioned in the information in the previous reading?

Tracking Down the Cause

Beginning in the 1950's, many owners of football stadiums began to replace the natural grass or turf in their facilities with a grass-like plastic substitute called artificial turf. Builders of dome stadiums, such as Houston's Astrodome, had no choice in the matter, since grass could not grow in the artificial light of the stadium. Line A in the following graph represents the number of square yards of artificial turf installed in football stadiums each year since 1950.

Shortly after stadiums began installing artificial turf, sports physicians began to see an increase in the number of knee and ankle injuries experienced by football players. Line B on the graph shows the number of such injuries reported each year since 1950.

Examine the graph and use it to answer the questions:



1. This graph shows a correlation between variables A and B. How do you know?

2. Is the correlation between A and B perfect? How do you know?

3. Is there any possible cause-and-effect relationship between A and B? If so, what is it?

4. How else can you explain the correlation between A and B other than as a cause-and-effect relationship?

5. How could you test to see if the correlation between A and B is also a cause-and-effect relationship?

Conclusion:

1. What conclusions can you make about the relationship between the use of artificial turf and knee and ankle injuries? Write them in a paragraph.

2. Your town notices that every time there is a heavy rain and extra water runs through the storm drains into the local creek, dead fish are found downstream. How could your town find out if there is a cause-and-effect relationship between the events?

Appendix G: Asking a Testable Question, Setting up a System

Make Ice Cream in a Baggie

Materials:

- 1/2 cup milk
- 1/2 cup whipping cream (heavy cream)
- 1/4 cup sugar
- 1/4 teaspoon vanilla or vanilla flavoring (vanillin)
- 1/2 to 3/4 cup sodium chloride (NaCl) as table salt or rock salt
- 2 cups ice
- 1-quart Ziploc™ bag
- 1-gallon Ziploc™ bag
- measuring cups and spoons
- cups and spoons for eating your treat!

Procedure:

1. Add 1/4 cup sugar, 1/2 cup milk, 1/2 cup whipping cream, and 1/4 teaspoon vanilla to the quart ziploc™ bag. Seal the bag securely.
2. Put 2 cups of ice into the gallon ziploc™ bag.
3. Use a thermometer to measure and record the temperature of the ice in the gallon bag.
4. Add 1/2 to 3/4 cup salt (sodium chloride) to the bag of ice.
5. Place the sealed quart bag inside the gallon bag of ice and salt. Seal the gallon bag securely.
6. Gently rock the gallon bag from side to side. It's best to hold it by the top seal or to have gloves or a cloth between the bag and your hands because the bag will be cold enough to damage your skin.
7. Continue to rock the bag for 10-15 minutes or until the contents of the quart bag have solidified into ice cream.
8. Open the gallon bag and use the thermometer to measure and record the temperature of the ice/salt mixture.
9. Remove the quart bag, open it, serve the contents into cups with spoons and ENJOY!

Analysis:
Describe the system that is being used to make the ice cream. Within this, describe any and all variables that can or are present in this system. Finally, describe at least ten experiments that can be done with this system, fully describing both the variable involved, the controls, and the entire system involved.

Appendix G: Science I, Sophomore Example

Correlation of Soil Properties to River Oak and Birch Concentration at the Grand River

Introduction:

River floodplains have greater clay content and lower soil silt content due to flooding. This influences the vegetation in the area. (Burke et al, 2002). Another study in the Blackhawk Island, Wisconsin, shows that climate and soils influence the composition of Wisconsin forests. Relative effects on each were not determined, but determining effects of soil properties on species composition is needed in a single climatic regime (Pastor et al, 1982). A variation in quantity of plants inputs to the soils contributes to the variation in microbial biomass. The soil is related to the variation among species of the grass (Dijkstra, Hobbie, and Reich, 2006). Tree community physiognomy correlates with soil properties. A canonical correspondence analysis, along with Spearman's rank correlations, demonstrates that species' abundance distributions are significantly correlated with the soil properties. Differences in soil nutrient content and in ground water are the leading factors determining tree species distribution within the fragment (Oliveira-Filho et al, 2001).

pH is also known to affect the tree population around the area and also microorganisms. pH of 6.6 to 7.3 is favorable for microbial activities that affect nitrogen, sulfur, and phosphorus in soils. This, in turn, affects the tree biomass (Soil Quality Indicators: pH, 1998). River birches are also affected by pH. They are found commonly along low pH streams in southeastern Ohio (Bartuska and Ungar, 2005). At the Sierra Occidental of northwestern Mexico, there are distinct patches of evergreen-oak woodland, which are surrounded by subtropical deciduous forest in a mosaic pattern. The patches occur on extremely acid, infertile soils, while deciduous vegetation dominates on less acid, more fertile soil showing the correlation between soil and tree species present (Goldberg, 1982).

It is evident, then, that soil does influence tree biomass, and that river birches favor lower pH environments. Silt and clay ratios affect types of vegetation living in the area, and that there are correlations with tree communities and soil properties. This affirmation narrows down factors we tested for in our experiment.

This experiment was an observational study of the correlation of soil properties to tree species concentration. We took data on soil pH and its composition, ranging from sandy, silt, and clay. There were three soil samples taken from areas with no trees, serving as our control. Three samples of dirt were taken near each tree we used and then brought back to the lab. We used Dish Drops dishwasher detergent mixed with dirt and water to determine the proponents of the dirt, estimating from the proportions what made up the soil. Our hypothesis was that soil pH and composition influence the concentration of river birch, maple and oak near the river, which was the Grand River near the B.O.B. in Grand Rapids, Michigan.

Procedure:

First, our group picked different types of trees to take samples from. By the Grand River there were oaks, river birches, and maples. We decided to use these as our trees to take samples from. We simply took samples next to the trees we tested for. This was so samples could be used to compare the soil properties with different types of trees. Soil samples were taken from 5 centimeters deep, but we had no time to measure out the amount we took. We simply filled two soil sample bags, which came out to be roughly 350 milliliters of soil. We scooped the soil into the bags with a small shovel. We took four samples from oaks, four samples from river birches, three sample from maples, and three samples from areas where there were no trees to serve as controls. The samples of river birch A were taken on September 26, 2006. The temperature was 47° and the dew point was 44°. There was 90% humidity and no wind. There were scattered clouds. All the maple samples were also taken on September 26 but later in the day. The temperature was 59°F and the dew point was 40°F. There was 49% humidity and 3 mph wind. It was partly cloudy. The next samples were taken on September 27. These samples were all the oak samples and controls A and B. The temperature was 56°F and the dew point was 50°F. There was 87% humidity and 12 mph wind. There was also light rain. Our last samples were taken on September 28. These samples were for river birch B and control C. The temperature was 47° and the dew point was 43°F. The humidity was 86% and the wind speed was about 4 mph. There were scattered clouds.

We then ran tests on each sample from September 27th to the 29th and from October 2nd to the 29th. To determine soil composition and pH, we put about 100 mL of soil in a 600 mL jar. We then added about 50 mL of water to make a muddy mixture. Using a pH meter, we recorded the pH measurement of each sample. After filling the rest of the jar with water (about 100 mL) and putting one drop (1 mL) of soap inside, we shook the jar until it was thoroughly mixed. The soil separated into layers after about five days of sitting. The sand, which was a lighter color than the silt, sat on the bottom. Silt, which was darker, sat on top of the sand. Then on top was clay, which was the lightest color of all. We measured each layer's height in millimeters and took percentages accordingly. We then recorded all the data we took and graphed it. We searched the graphs for any correlations that could hopefully support our hypothesis or suggest a trend other than our hypothesis.

Results:

Compositions

Controls

After our tests, we received the following results. In the controls, A and B had a similar composition. Their sand contents were high at 88.9 and 94.7% respectively. Their silt contents were low at 8.9 and 5.3%, and their clay contents were also low at 2.2 and 0%. Control C, however, was different. Its composition had no sand, and it was 96.7% silt. Similar to the other controls, though, it did have low clay content at 3.3%. Figure 1 illustrates these results.

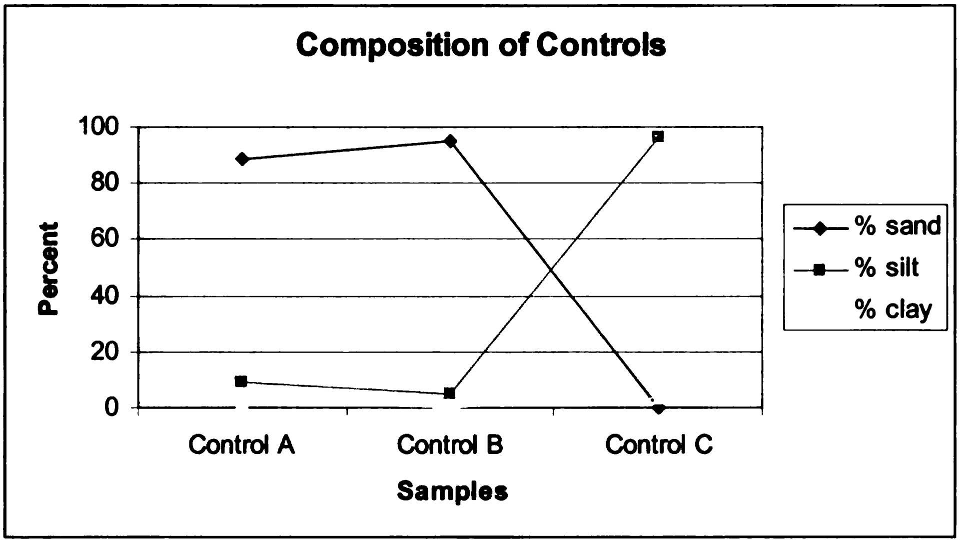


Figure 1

Maples

The maple samples differed greatly in their results. Their sand composition ranged from 62.5 to 0% with an average of 37.5%. The silt content ranged from 35.7 to 93.3% averaging at 55.5%. Finally, however, clay content was somewhat similar, ranging from 0 to 14.3% clay and averaging at 7.0%. Figure 2 illustrates these results (following page).

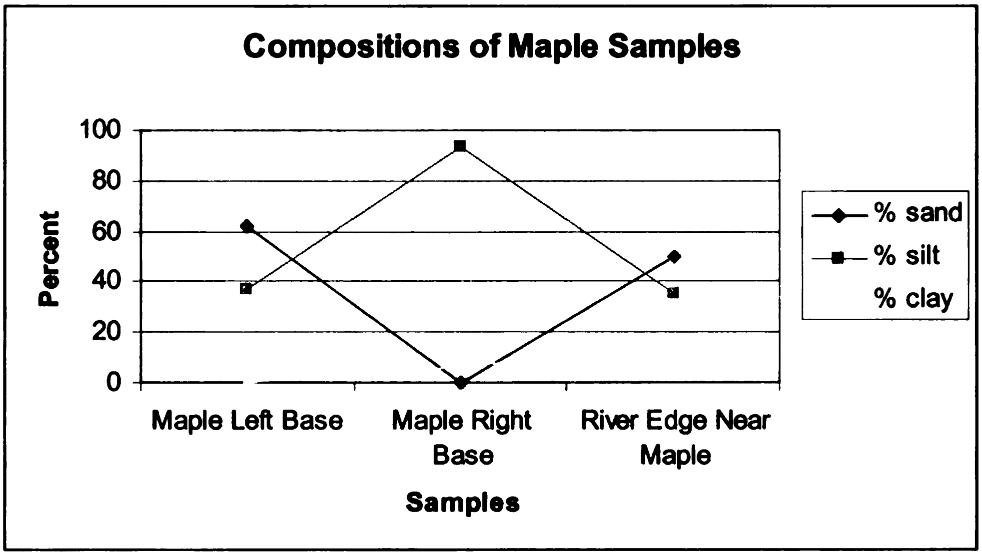


Figure 2

Oaks

The oaks were all very similar in their composition results. Their sand content ranged from 81.0 to 88.0%, with an average of about 84.9%. The content of silt had minimum and maximum of 8.0 and 16.7%. Its average was roughly 12.6%. Finally, clay ranged from 1.8 to 4.0%, averaging at approximately 2.5%. Figure 3 displays these results.

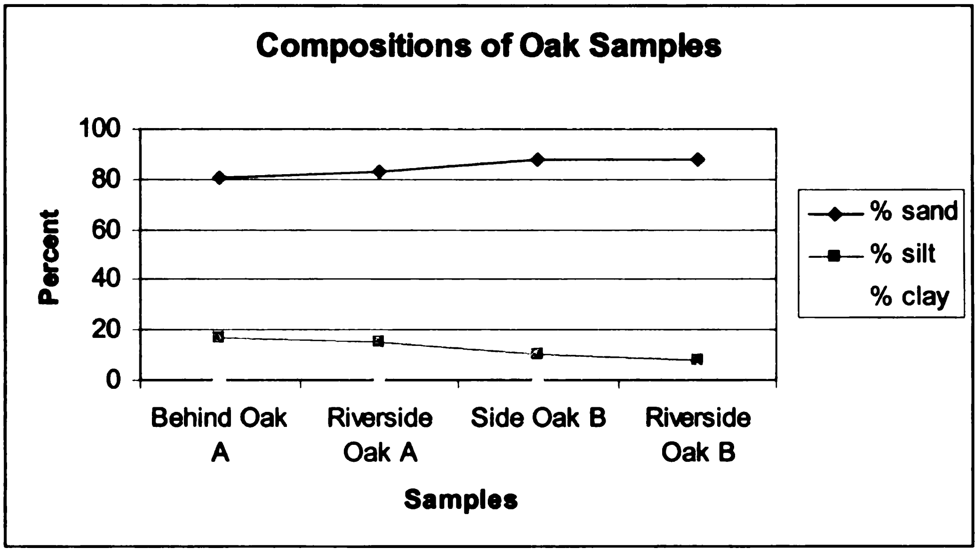


Figure 3

River Birches

The river birch results were also largely similar to each other except for the sample taken from the river edge near river birch A. Excluding this different sample, the results to the composition tests were as follows: The samples had 0% sand content. They had high silt content ranging from 90.8 to 98.4%, averaging at 95.3%. Their clay content had a minimum and maximum of 1.6 and 9.2%. Its mean was 4.7%. The one different sample had a high sand content of 75.0%, a relatively much lower silt content of 21.4%, and a similar clay content of 3.6%. Figure 4 graphically shows these results.

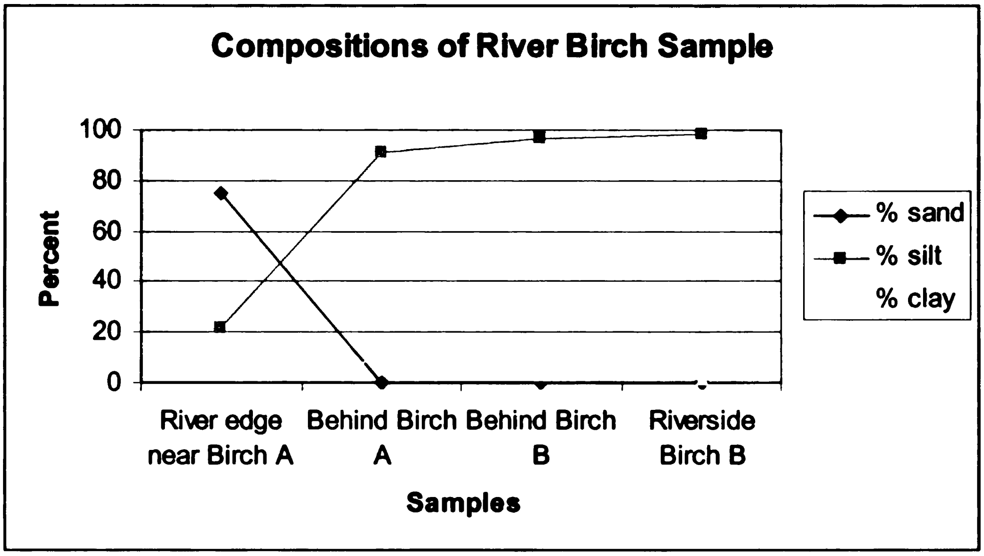


Figure 4

pH Levels

The pH levels of all the samples were very similar. Control A was the only sample of all of them that was significantly different. Its pH was 4.8. Controls B and C had pH levels of 6.5 and 6.7 respectively. The maple samples had a minimum and maximum of 6.5 and 7.0. The average was roughly 6.8. The oak samples' pH levels ranged from 6.4 to 6.8. The mean was 6.5.

Finally, the river birch samples had a minimum and maximum of 5.8 and 6.8, averaging at 6.4. Figure 5 shows these results using a bar graph.

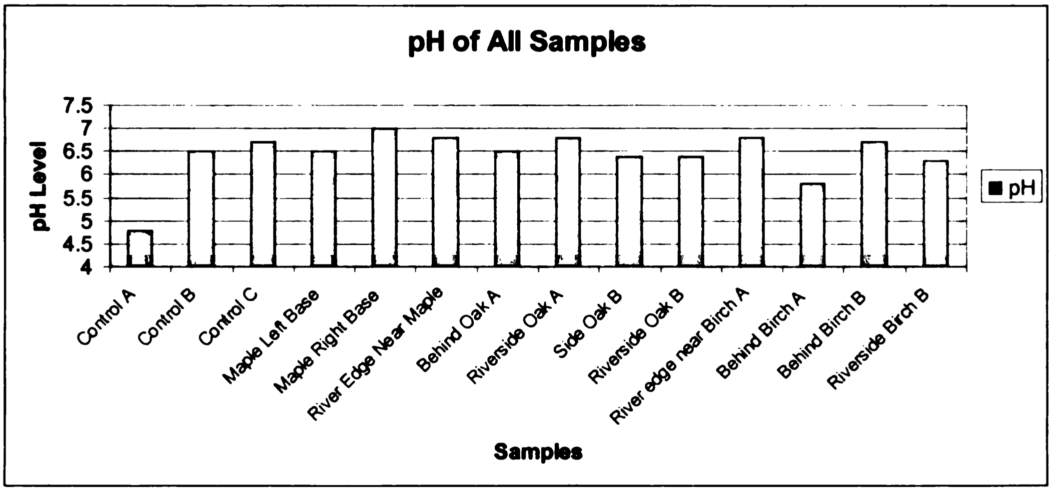


Figure 5

Discussion & Conclusion:

In view of the data collected the hypothesis was not supported. There was no definite correlation or causation. In order for the hypothesis to have been supported, the pH and composition of each type of sample had to differ from each other. This, however, was not fulfilled because the soil pHs of the samples were all similar to each other and the composition only vaguely suggests a correlation. The lack of difference between samples was unexpected because cited works stated that there should be some distinction between the soils. Limitations within this study included the lack of time, inability to control the weather, and the incapability to collect a large number of samples. If these factors could be eliminated, the accuracy of the results would have greatly improved. Data on proximity to the river, the depth to the bedrock, the salinity of the soil, the types of microorganisms, and the types of minerals in the soil should have been collected. The proximity to the river and the presence of specific kinds of microorganisms could have revealed the reason for the presence or lack of certain trees because of possible flooding affecting the tree growth; the depth to the bedrock would have revealed whether or not there was even enough soil for tree germination; the salinity of soil would have determined the types of trees near the river as would the types of minerals.

Work that could be done at the experimental site is the gathering the previously mentioned data. Besides taking more samples, proximity to the river and the depth to the bedrock could be measured via string (for the distance to the river) and by digging down to the bedrock and then measuring the distance. Salinity of soil could be tested at the same time as the minerals by common tests done after filtering the soil. Such tests would be similar to solubility and testing the reaction of certain minerals to specific chemicals like calcium to hydrogen peroxide (H_2O_2). Tests on the presence of microorganisms could be done via testing kits provided by companies such as Flinn Scientific, Co. Taking all of the samples in the most limited amount of time within one day could limit the varying weather conditions, but this would require a larger group of collectors or a greatly lengthened period to obtain data from the river. The findings of this study differed from that of other studies. The pH of the controls, which were areas with no trees, had no apparent significant difference than that of the experimental groups, meaning no correlation could be determined between soil composition and pH vs. lack of trees. The cited studies, though, showed a correlation between soil pH and tree populations and between soil composition and tree populations. Data taken by this study was not complete enough to determine that each type of tree (maple, oak, and river birch) although the controls had a different composition of soil, which could suggest a correlation and possibly causation.

Limitations of observational studies, in general, include the inability to affect the groups being observed. This disallows stating causation between factors and outcomes because no variables can be changed to affect results, and every variable cannot be monitored, especially if you are observing an already established natural system. Because all variables similar to temperature and moisture cannot be controlled and made the same throughout the entire study, there is greater difficulty to determine the exact cause and causality of the resulting data because all factors cannot be taken into account and made to be the same throughout the entire study. Although there are limitations, there are also valuable reasons for observational studies. When a controlled experiment is unethical (for example a study about what effect smoking has on the human body), researchers utilize observational studies. Also, observational studies enable data to be taken on subjects as they are acting naturally and, therefore, may be more useful outside of a study.

Future research based on the findings of this study includes a study about the possible relationship between pH and soil composition, between other types of vegetation besides trees with soil composition and pH, or between proximity to the river and soil composition/pH. If a relationship is found between soil composition and pH, then it could be possible to manipulate one and change the other. If non-tree vegetation is related to soil composition and pH, manipulating the composition and/or pH could increase the success of the vegetation. If a relationship is found between river proximity and soil properties, then one could plan ahead to the location for planting or change the pH of one to change the pH of the other in order to promote the growth of plants of the population of life in the river. These three studies could be useful for economic purposes such as tourism, farming, and the promotion of the consumption of goods by gardeners.

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An Observational Study on the Correlation between the Number of Fecal Coliform Colonies and Dissolved Oxygen Levels

1 Introduction

The water quality standard for fecal coliform bacteria requires there to be an average of no more than 200 colonies per 100 mL of water over at least 5 tests [1]. If this limit is exceeded, it would indicate that the water is polluted; in our experiment, this would imply that the section of the Grand River we are performing tests on is polluted.

Fecal coliform is an indicator bacteria, meaning that it may indicate the presence of harmful parasites and pathogens [2]. Individuals exposed to these parasites and pathogens which travel with fecal coliform could experience diarrhea or become ill with fever, nausea, and stomach cramps. Serious illnesses, like typhoid fever, hepititis, gastoneteriris, and dysentery, can be contracted as well. These pathogens enter the body by way of mouth, nose, ears, or any opening in the skin, such as cuts or scrapes [3]. Sewage dumps and animal wastes washing into the river may cause a rise in the number of fecal coliform present in that water source.

Fecal coliform levels rise due to many different factors such as human or animal wastes washing into the river. UV light impedes the growth of coliform bactiera. Therefore, at deeper levels of the river, where there is not as much sunlight, the amount of fecal coliform should be higher [4].

On the other hand, dissolved oxygen has separate factors that affect the different levels. Some of these include: the current (a higher current allows more oxygen to enter the water,) temperature (a colder temperature means higher dissolved oxygen levels,) time of day (late afternoon allows for higher levels of dissolved oxygen,) altitude (a lower altitude means more dissolved oxygen), and organic wastes (the more wastes, the more dissolved oxygen) [5].

To account for the differences in temperature, which affect the dissolved oxygen levels, saturation will be used. Saturation is the representation of both the temperature and the amount of dissolved oxygen. Saturation levels between 90% and 110% are considered to be good [6].

1.1 Hypothesis

We hypothesize that there will be an inverse correlation between the percent saturation of dissolved oxygen and the number of fecal coliform colonies present in 1mL of sample water.

Work by Melanie L. Clark and Jodi R. Norris of the US Geological Survey has indeed shown an inverse relationship between these two factors [7]. These researchers also found that the levels of fecal coliform are higher in the summer and fall months as opposed to the winter months.

Based on this background research, our group believes that there is significant reason to believe an inverse relationship between the amount of dissolved oxygen in the water and the number of fecal coliform colonies exists. In order to test this hypothesis, we will be conducting an observational study by taking water samples from our study area on the Grand River without changing any parts of the water system.

The general area of this study is on the bank of the Grand River. Nearby are many trees, rocks, and soil. There is a steep incline which allows for other items to be washed into the river, specifically at our area. Our site is near a group of rocks which jut out into the river, allowing the current to be weakened, and the samples easier to obtain. There is also a storm drain nearby, which empties into the river and will be used to do additional testing.

2 Methods

The area we studied was located in the Grand River, near the bank, in Grand Rapids, Michigan. One can access this area by the building called "The BOB". The entire area is moist from the river and shaded in most parts. We took our first sample from the storm drain. When we refer to the storm drain, we are discussing a structure used to drain rain water from higher elevations throughout Grand Rapids into the Grand River. This structure is made out of large stone blocks with mold on the inside surfaces where the water is touching or has touched. The storm drain is approximately one hundred yards long and several yards wide. We could not measure the length of the storm drain due to a lack of instruments capable of measuring such a distance accurately. The entire structure and our area lie on a steep incline with vegetation such as trees. From the storm drain we used in our experiment, two small streams appear where there are openings. Many tiny runoffs from the storm drain resulted from unintentional cracks between the adjacent stone blocks. A separate upstream creek is identified in the experiment when we discuss a meter upstream of the series of storm drains, and a downstream creek is identified when discussing a meter downstream of the storm drain. The entire area is filled with dirt, trees, and rocks. Sporadic leaves, therefore, were commonly seen in our area of study.

2.1 Sample Collection

Our first sample was taken directly at the site where the storm drain empties onto the bank. The water from the storm drain empties itself into a stream which then runs until the river, over rocks and mud. Then, we gathered a sample from a meter upstream of the first storm drain. The second sample was taken from the surface of the actual river next to a bunch of rocks. We collected the third sample from a meter downstream of the last storm drain. This sample was taken from the surface of the water. This experimental set-up is illustrated in Fig. 2.1. All samples were taken with a test tube labeling their specific location. For the first sample from the storm drain, we labeled the tube "SD". The second sample from the river, a meter upstream of the series of storm drains, was labeled "S_-". The third sample from the river, a meter downstream of the series of storm drains, was labeled "S_+".

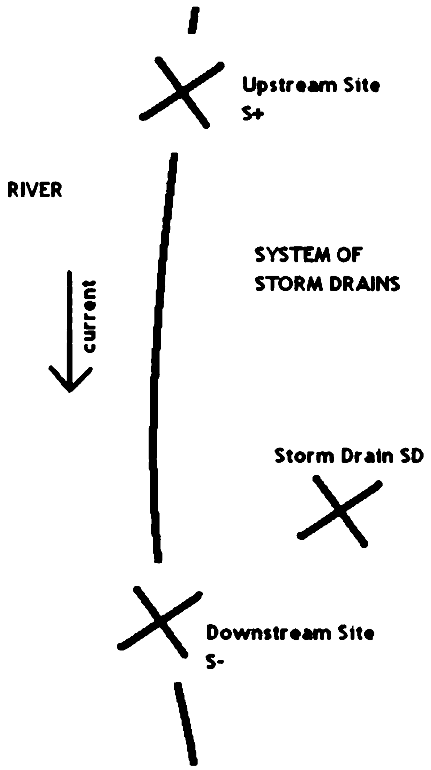


Fig. 2.1

We used sterile glass test tubes to collect our samples of water from the three previously mentioned sites. We took the "SD" samples from the original point of entry for the storm drain water into the streams; in this way, we eliminate all other factors affecting the water quality of the storm drain water. Then, we took samples from a meter upstream of the first storm drain, expecting less fecal coliform because the water lacks the runoff from the storm drain. Next, we took a sample from downstream of the storm drain, expecting more fecal coliform in comparison to "S_+" since the water has been exposed to the runoff from the storm drain.

Our first sample collection was on September 26, 2006 by Margaret Kennedy, a student at Grand Rapids Catholic Central High School. She collected the samples by holding the test tube to the surface of the site's water, allowing the water to flow into the test tube until full. She then capped the tube immediately to prevent any change in dissolved oxygen level or contamination.

2.2 Data Collection

Back in the lab, we followed the Standard Innoculation Procedures as provided by the Fecal Coliform Culturing kit. The directions follow:

1. Place the Petrifilm Aerobic Count Plate on a flat surface. Carefully peel open the Petrifilm plate being careful not to touch the nutrient gel with your fingers.
2. With a pipet perpendicular to the Petrifilm plate, place 1 mL of sample (inoculum) onto the center of the bottom film.
3. Release top film; allow it to drop. Do *not* roll top film down.
4. With *ridge* side down, place the spreader on the top film over the innoculum.
5. Gently apply pressure on the spreader to distribute the innoculum over a circular area. Do not twist or slide the spreader, simply apply a gentle downward pressure to the spreader.
6. Lift the spreader. Wait at least one minute for the gel to solidify.

We counted the colonies 72 hours after culturing the water, recording them in the number of colonies per mL. We measured the fecal coliform in such a manner because we knew from background research that two or more colonies per 1mL (derived from 200 colonies per 100mL) meant that the water was polluted with unsafe levels of fecal coliform [1].

Then, we tested the dissolved oxygen levels by pouring the remaining water into a beaker. Using the Vernier dissolved oxygen probe measurement system, we then swirled

the probe in the water until the readings stabilized. The probe only works when water is passing over its tip; for this reason, swirling is essential. Standard installation procedures for the Vernier products were used. All measurements were found in milligrams per liter, or mg / L.

2.3 Distribution of Labor

Shannon Moran prepared the fecal coliform cultures and dissolved oxygen on the 26th. Katie Fatum measured dissolved oxygen and Maggie Stein prepared fecal coliform cultures on the 27th, 28th, and 29th.

On September 27, Kennedy also collected samples. Due to a misinterpretation of standard inoculation procedures, our cultures for September 27 were erroneously prepared and measured by Fatum and Stein. Therefore, these results must be disregarded and are thus not reported in the following pages. The data collection and analysis on the dates of September 28 and 29 follow the procedure explained for September 26.

3 Results

Without further analysis, inconsistent correlation seems to be evident between the number of fecal coliform colonies present after 72 hours and the level of dissolved oxygen in mg / L observed. Table 3.1 displays our raw data from testing and the dates on which the readings were taken. Figures 3.2-3.4 illustrate the correlation between dissolved oxygen levels and fecal coliform colony counts at our 3 separate testing locations. The solid black line on each graph is the "trend line," which shows the general trend in the data. You will notice that at locations S- and S+ a strong positive correlation is evident while at location SD a weak inverse correlation exists. Figure 3.5 clearly illustrates the inconsistent correlation by placing all 3 locations' data sets and the control onto one graph.

S-		
Date	DO Level	Colonies
28-Sep	7.3	6
29-Sep	7.9	3
26-Sep	9.6	55

S+		
Date	DO Level	Colonies
29-Sep	7.5	2
28-Sep	7.5	3
26-Sep	9.4	6

SD		
Date	DO Level	Colonies
28-Sep	7.3	7
29-Sep	7.3	2
26-Sep	9.4	3

Table 3.1

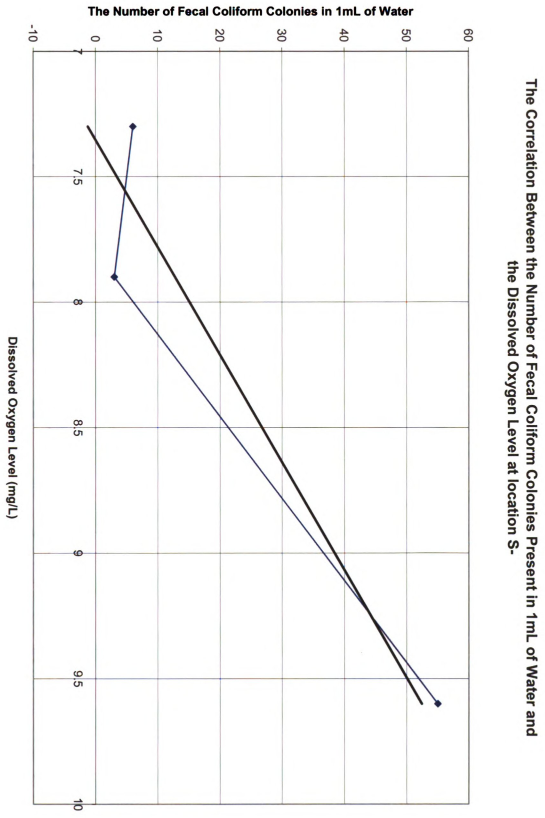

The Correlation Between the Number of Fecal Coliform Colonies Present in 1mL of Water and the Dissolved Oxygen Level at location S-
The Number of Fecal Coliform Colonies in 1mL of Water
-10
0
10
20
30
40
50
60
7
7.5
8
8.5
9
9.5
10
Dissolved Oxygen Level (mg/L)

Fig. 3.2

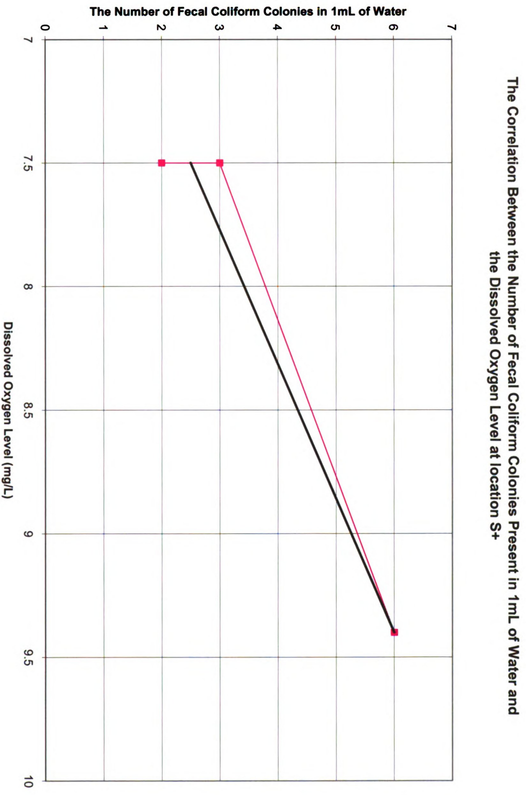

The Correlation Between the Number of Fecal Coliform Colonies Present in 1mL of Water and the Dissolved Oxygen Level at location S+
The Number of Fecal Coliform Colonies in 1mL of Water
0
1
2
3
4
5
6
7
Dissolved Oxygen Level (mg/L)
7
7.5
8
8.5
9
9.5
10

Fig. 3.3

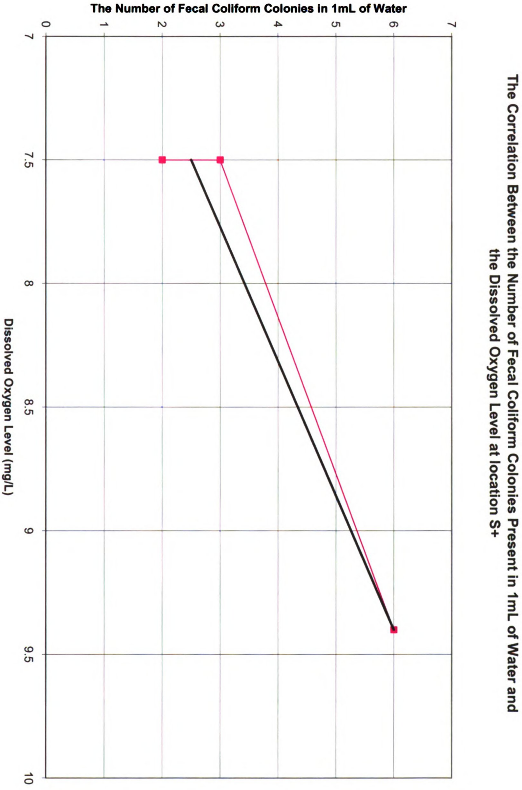
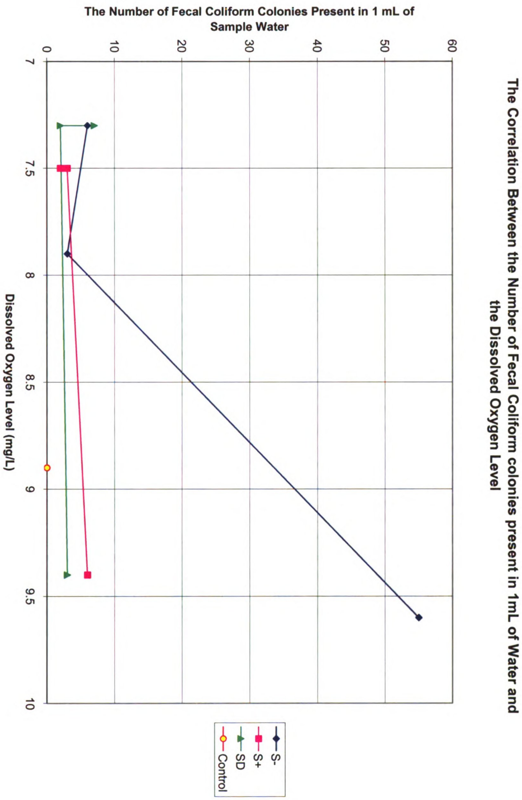

The Correlation Between the Number of Fecal Coliform Colonies Present in 1mL of Water and the Dissolved Oxygen Level at location S+
The Number of Fecal Coliform Colonies in 1mL of Water
0
1
2
3
4
5
6
7
Dissolved Oxygen Level (mg/L)
7
7.5
8
8.5
9
9.5
10

Fig. 3.4



The Correlation Between the Number of Fecal Coliform colonies present in 1mL of Water and the Dissolved Oxygen Level
The Number of Fecal Coliform Colonies Present in 1 mL of Sample Water
0
10
20
30
40
50
60
7
7.5
8
8.5
9
9.5
10
Dissolved Oxygen Level (mg/L)
S-
S+
SD
Control

Fig. 3.5

3.1 Dissolved Oxygen Percent Saturation

Thus, other factors must be accounted for when analyzing and reading this data. First of all, it was cloudy on all 3 of our testing days, allowing us to rule out the differing effects of sunlight on dissolved oxygen levels [4]. Also, all samples were taken within the time frame oi 9:00 to 9:30 in the morning and wei taken at altitudes of statistically insignificant difference. Ruling thes out, only three other factors influencing dissolved oxygen remain: current, temperature, and organic wastes. While we could not easily measure current speed nor easily account for it in our analysis, and since fecal coliform itself was being used to indicate organic wastes, we had to account for the temperature of the water.

To do this, we used a measurement called the percent saturation which accounts for both the oxygen level in mg / L and the water temperature in degrees Centigrade. The chart used for measuring this is shown in Fig. 3.6. To find the percent saturation, one uses a straight edge to connect the water temperature in Centigrade with the level of oxygen in mg / L. The percent saturation is located at the point where the straight edge intersects the line of percent saturation.

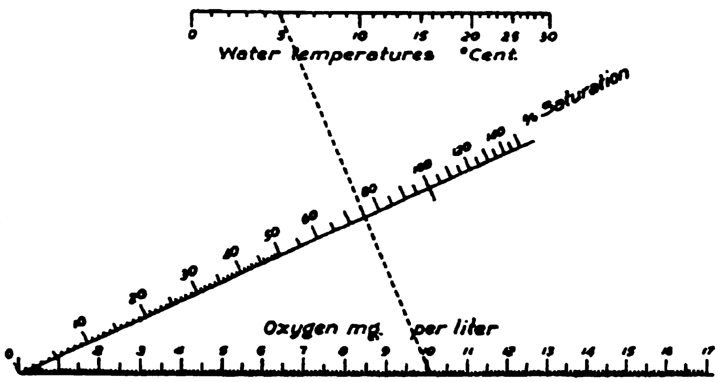


Fig. 3.6

Thus, using this method we use the water temperatures from each day, found in Table 3.7, and find the following data outlined in Table 3.8. Figures 3.9-3.11 illustrate the correlation between fecal coliform colony counts and the percent saturation of dissolved oxygen. As with the last set of graphs, the thick black line is the "trend line" and displays the trend of the data. At location S-, a strong inverse correlation is shown while location S+ shows an extremely weak negative trend and graph SD displays a strong positive correlation. Again, there is inconsistent correlation. Figure 3.12 clearly displays this by placing all 3 locations' data sets and the control onto one graph. Note: The water temperature on September 26 was due to the fact that we kept our samples in ice for 2 hours until we were able to culture them.

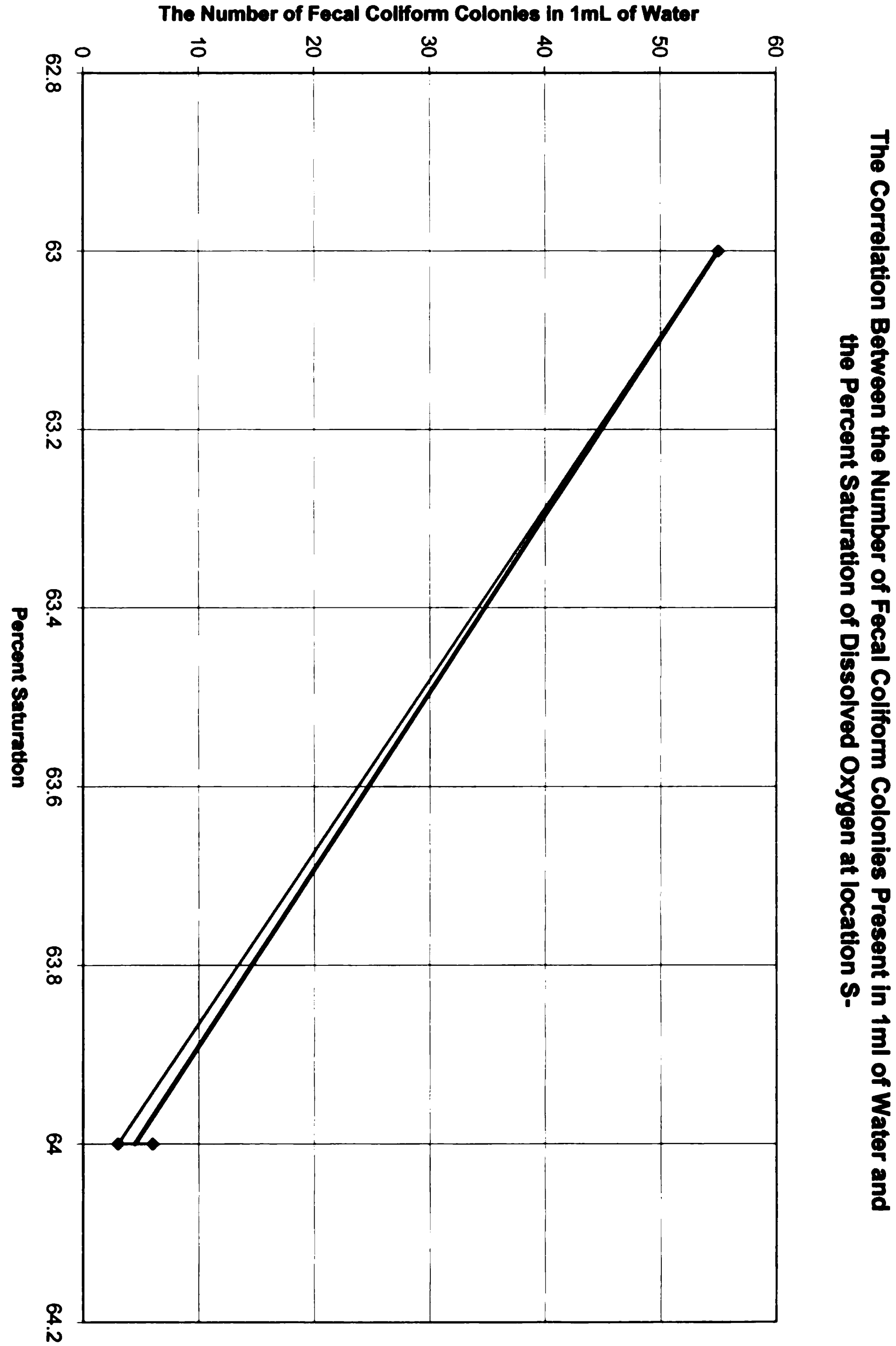

The Correlation Between the Number of Fecal Coliform Colonies Present in 1ml of Water and the Percent Saturation of Dissolved Oxygen at location S-
The Number of Fecal Coliform Colonies in 1mL of Water
0
10
20
30
40
50
60
62.8
63
63.2
63.4
63.6
63.8
64
64.2
Percent Saturation

Fig. 3.9

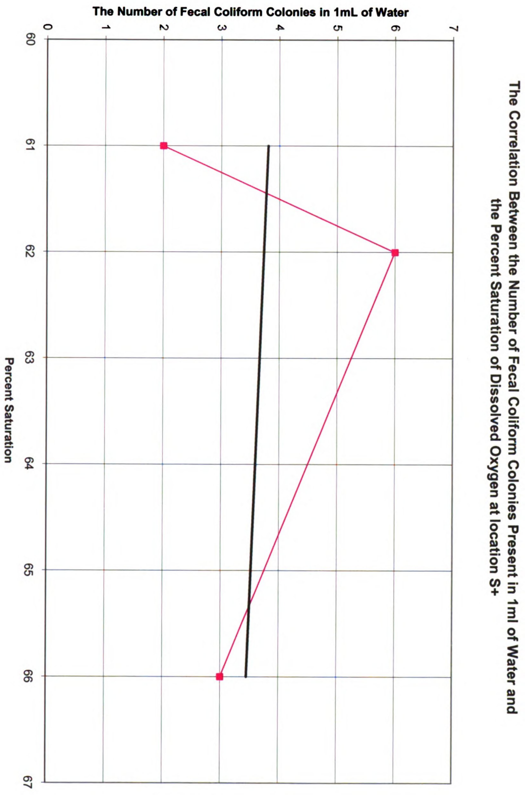

The Correlation Between the Number of Fecal Coliform Colonies Present in 1ml of Water and the Percent Saturation of Dissolved Oxygen at location S+
The Number of Fecal Coliform Colonies in 1mL of Water
0
1
2
3
4
5
6
7
60
61
62
63
64
65
66
67
Percent Saturation

Fig. 3.10

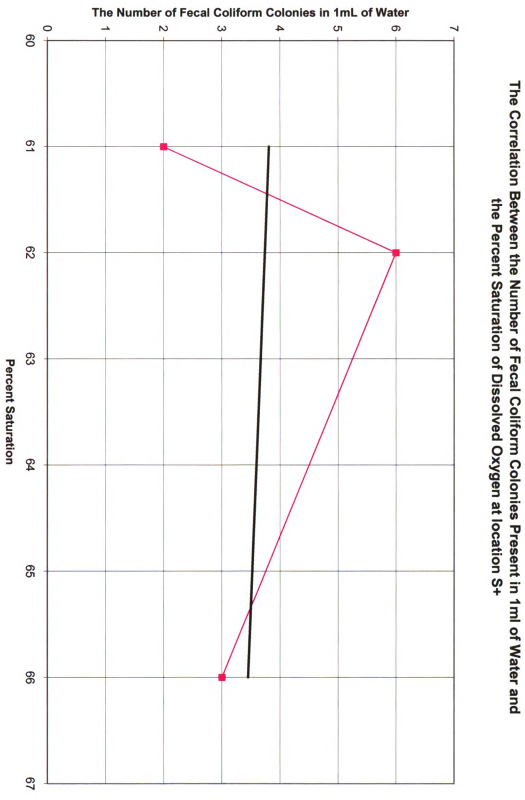

The Correlation Between the Number of Fecal Coliform Colonies Present in 1ml of Water and the Percent Saturation of Dissolved Oxygen at location S+
The Number of Fecal Coliform Colonies in 1mL of Water
Percent Saturation
0
1
2
3
4
5
6
7
60
61
62
63
64
65
66
67

Fig. 3.11

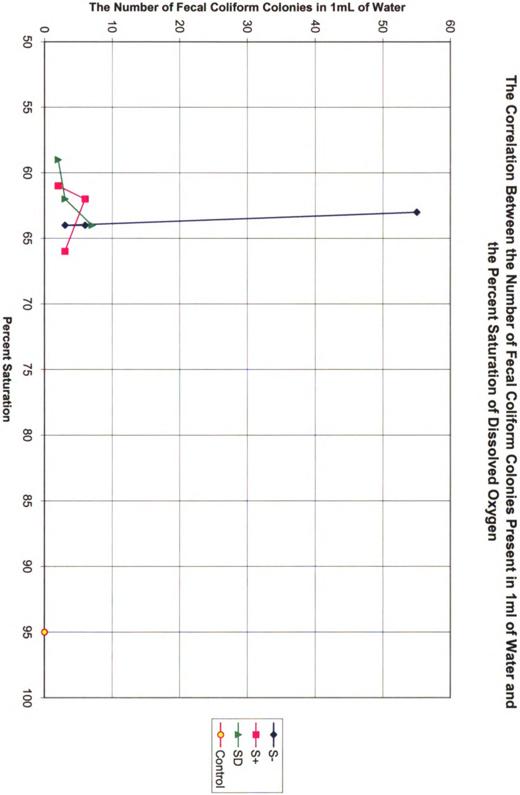

The Correlation Between the Number of Fecal Coliform Colonies Present in 1ml of Water and the Percent Saturation of Dissolved Oxygen
The Number of Fecal Coliform Colonies in 1mL of Water
0
10
20
30
40
50
60
50
55
60
65
70
75
80
85
90
95
100
Percent Saturation
S-
S+
SD
Control

Fig. 3.12

3.2 Fecal Coliform Colonies
The number of fecal coliform colonies, as stated earlier in this paper, was counted 72 hours after the culture was made. The colonies appeared as dark blue dots on the Petrifilm.

3.3 Control
For the sake of comparison, we also used a control of tap water. We received the expected results of no bacterial growth, as shown below in Table 3.13.

Control		
% Sat.	DO Level	Colonies
95	8.9	0

Table 3.13

3.4 Further Testing
We cannot say with any degree of certainty that our hypothesis is supported. Though our original plan had called for 15 days of testing, which would have supplied us with sufficient evidence to either support or deny our hypothesis, 3 days of testing provided too many anomalies and inconsistencies to draw any real conclusions from the data.

Thus it is that this observational study would need, at the very least, 3 more days of data collection. We cannot even claim that the Grand River is polluted; though our data shows that in all cases the fecal coliform levels are either at or exceed the acceptable water quality levels, without 5 testing days to draw an average from we cannot say for sure.

4 Conclusion and Discussion
When our group performed our observational study, we, by definition of observational study, did not manipulate the environment from which we took our samples. We merely collected the samples in glass, capped test tubes. We could not control factors such as weather and our results may have been affected by the heavy amounts of rain just prior to our data collection. However, the rain would have affected all of our sites and would not have affected the overall correlation. Thus, we do not need to account for it in our data analysis. An observational study, however, was ideal to test our hypothesis because we wanted to observe the number of fecal coliform colonies that were evident in their natural environment.

As stated above in 3.4, the duration of our testing did not provide enough support for us to either prove or disprove our hypothesis. All our collection results do, however, indicate bacteria levels above what is considered polluted. Our data, especially for 26-Sep, demonstrates that, as mentioned in the introduction, humans do have an effect on these pollution levels in the Grand River because the number of fecal coliform colonies at S- was significantly greater than the number at S+, indicating that run-off from the series of storm drains may have played a role. Further testing would need to be completed in order to obtain more conclusive results. Also, if a separate experiment were to be performed, our group would recommend testing multiple storm drains along that section of river because there are multiple drains in a row and the particular drain we tested did not show the drastic amounts of fecal coliform we saw in our first day of data sampling. Though our testing did not occur over a long enough period of time, our data did lead us to infer that the numbers of fecal coliform colonies in further tests would also be above the levels that are considered safe and non-polluted.

5 Bibliography

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Appendix G: Science II Student Example

The Correlation of the Number of Eggs in the Base of a Soufflé and the Time Needed for Deflation

Introduction:

This experiment was an experimental study that tested the effect of the number of eggs in the base of a chocolate soufflé on the time needed for deflation of the soufflé. Our group used the recipe for *Chocolate Soufflé with White Chocolate Chunks* from *Cookwise* by Shirley O. Corriher [1]. We tested soufflés with different egg amounts varying from zero to four and measured the number of soufflés that fell after certain time amounts.

A soufflé is a light, airy mixture that usually begins with a thick egg yolk-based sauce or purée that is lightened by stiffly beaten egg whites. They may be savory or sweet, hot or cold, but baked soufflés are much more fragile than those that are chilled or frozen because the hot air entrapped in the soufflé begins to escape (causing the mixture to deflate) as soon as the dish is removed from the oven. Every soufflé is made of the two components of a base, which is a flavored cream sauce that provides the flavor, and the beaten egg whites, which provides the "lift" for the soufflé [2].

Factors that affect the soufflé are temperature and noise. Temperature change can cause bubbles that hold the soufflé together to fall. When the heat is too strong, particularly the heat from above, a crust immediately forms on the soufflé, creating a barrier that prevents the heat from penetrating the inside. This means that it will cook superficially and not rise well. When the heat is too weak, the soufflé languishes and risks running over the sides of the dish when it rises, because the heat is not strong enough to solidify the ingredients as the soufflé rises [3]. The same is for noise. Often, the larger the soufflé, or the dish the soufflé is in, the harder it is to keep the soufflé from falling because it is the sides of the soufflé are where the most structural support exists. The sides are most supportive because the molecules have support from the ramekin, or porcelain cylinder shaped bowls, and they cooked more, becoming crunchy .Another factor that affects the soufflé is that when cooking at a high altitude, they do tend to fall faster. Because of these factors, we made sure to keep the temperature in the house constant, and to make very little noise. The altitude stayed constant because we mad the soufflés in the same oven each time [4].

The type of oven has an effect on the soufflés. A convection oven works by forcing hot air through fans so it circulates around food, cooking it quickly and evenly [5]. Usually the soufflés would be better if the oven heated from the bottom up, but this was not an option for us. They placement of the soufflés in the oven also has a great affect on them. The soufflés should always be on the lowest rack of the oven with all other shelves removed so the heat reaches the parts of the soufflés in the most accurate way [3].

In the base, the whole eggs and the egg yolks are combined with a cream sauce to create the base. The base contains milk, sugar, and flour. The flour contains long chains of molecules, otherwise known as starches. Flour that is not cooked has starch molecules that are crammed closely into granules, or pieces. The heat from the stove causes the granules to swell as they absorb water from the milk. In time the granules burst and some starch molecules escape into the milk. The long starch chains entrap and entangle each other while the granules that remain are caught in this "net" that is formed in the sauce. This is how the sauce is created thick.

The fluffy egg whites that cause the lift in the soufflé are created with egg whites and cream of tartar. Distilled white vinegar can be substituted for cream of tartar when beating eggs because white vinegar will provide the right amount of acid [7]. As the egg whites are beaten with the vinegar, the coiled protein molecules, which usually stabilize the egg, uncurl and position themselves at the surface of the bubbles. This prevents them from collapsing [8].

The amount of whole eggs in the base affects how long the soufflés stay risen is because of the protein in the egg yolk as well as white. The protein adds to the structure of the soufflé. If it wasn't for the coagulation of the egg white, the soufflé structure would not rise very well, but also fall immediately. The tiny bubbles in the beat egg whites are usually the only factor that hold the soufflé up. By adding extra whole eggs, there is more whole proteins in the entire mixture. The whole egg would be added with the egg white because of the protein, but if there is any sign of an egg yolk with the whites when whipped, the soufflé will not rise. The whole eggs, therefore, are added to base. This makes the soufflé more dense, less airy, but also more stable [9].

Procedure:

We followed the recipe for Chocolate Soufflé with White Chocolate Chunks from *Cookwise* by Shirley O. Corriher. We took twelve six-ounce ramekins and buttered them well and coated the sides with sugar with a total of two tablespoons. Next we heated one tablespoon of water, three tablespoons of Kahlúa, one cup of semi-sweet chocolate chips, and two teaspoons of instant coffee in a small saucepan over low heat until the chocolate just melted. After this, we blended a third cup of bleached all-purpose flour, a quarter cup of sugar, and an eighth of a teaspoon in a medium saucepan. We slowly whisked in three-quarter cups of milk into the mixture until smooth. Then we heated it for two minutes, stirring constantly. After removing from the heat, we mixed in one tablespoon of pure vanilla extract, and the chocolate mixture. This is where the experiment varied. We mixed five large egg yolks with varying amounts of whole eggs. Our amounts were 0, 1, 2, 3, and 4 whole eggs. The batch with zero eggs served as our control. We put four tablespoons of the chocolate mixture into the eggs to warm them and prevent coddling. Next we folded the entire egg mixture into the rest of the chocolate mixture. While waiting for that to cool, we beat six egg whites in a large bowl using a KitchenAid electric mixer at the highest setting until foamy (5 seconds). Then we added three-quarter teaspoons of vinegar. We continued beating until soft peaks formed (30 seconds). We added a quarter cup of sugar on tablespoon at a time, every 15 seconds. We beat until the egg whites formed soft peaks that did not fall over when we lifted the beater (75 seconds). Then we stirred a quarter of the egg whites into the chocolate mixture. After this, we folded in the remaining egg whites. We then began filling the ramekins with the mixture. When they were filled halfway to the fill line, we added roughly 15 white chocolate chips. Then we filled the ramekins the rest of the way to the fill line about 3.3 centimeters high. The ramekins were then put into a Jenn-Air convection oven preheated to 375 degrees Fahrenheit (191 degrees Celsius) for 25 minutes. Once time was up, all of the soufflés were taken out of the oven. A five minute timer was started as soon as all of the soufflés were removed. The height above the rim of the ramekin was recorded. The height of the ramekin was Afterwards, every 30 seconds, we recorded the number of soufflés that had fallen below the rim of the ramekin. The rim of the ramekin was 4.5 centimeters high. Usually, we started recording roughly a minute or a minute and a half after they were all taken out because we had to spend time measuring how high each soufflé had risen over the top of the ramekin. We did this so we would be able to see how the soufflés fell over time. On Tuesday, October 31, we all worked together to make the soufflés with two eggs in the base. This batch had 12 soufflés. Afterwards, we made the batch with three eggs in the base. This also made 12 soufflés. Mary and Josh had to leave before the data could be taken for these soufflés. Lorene measured them and recorded the time for them to fall alone. Later, on November 5, we made the batches with zero, one, and four eggs. The batches with zero eggs and one egg only had enough batter to make 10 soufflés. The batch with four eggs, however, had enough batter to make 15 soufflés. We all worked on each of these together. To analyze our data, we used the number of soufflés that deflated and converted to percents (to prevent disagreements in data between the different batches). We graphed the percent of soufflés still inflated over time (equal to or above four centimeters) for each batch.

<u>Results:</u>

The control for this experiment was the batch of soufflés with zero eggs. The resulting data (see Figure 1) matched the expected results, which were that few or no soufflés would puff up past 4.7 cm. Therefore, all of the soufflés were below the deflation line (edge of ramekin) before the five minute mark (see Table 1), which was when data collection for a batch ended.

Figure 6
The batch of zero eggs served as the control. As expected, all soufflés deflated as soon as they were removed from the oven (before data collection).

Time v. The % of Inflated Soufflés with Zero Eggs	
Time (sec)	% Of Inflated Soufflés
0	0
30	0
60	0
90	0
120	0
150	0
180	0
210	0
240	0
270	0
300	0

Table 1
No inflated soufflés

The batch with one egg exited the oven with 90% of the soufflés above the edge (4.7 cm high) of the ramekin (see Fig. 2). However, after five minutes only 10% were still above the edge (see Table 2). This set of soufflés had the most puffed soufflés of the entire study but it also deflated the fastest.

Figure 7
The soufflés puffed the most of any group directly out of the oven but deflated the quickest.

Time v. The % of Inflated Soufflés with One Egg	
Time (sec)	% Of Inflated Soufflés
0	90
30	90
60	80
90	80
120	70
150	70
180	60
210	40
240	30
270	30
300	10

Table 2
One egg soufflés had the highest percent of puffed soufflés but had the least after 5 min

The soufflés with two eggs, which was the number prescribed by the recipe, came out of the oven (see Fig. 3) with 83% inflated soufflés, and after 300 seconds, 58% were still inflated (see Table 3). This batch had the most stability of any within this experiment.

Figure 8
The soufflé batch created by recipe was the most stable

Time v. The % of Inflated Soufflés with Two Eggs	
Time (sec)	% Of Inflated Soufflés
0	83
30	83
60	83
90	83
120	83
150	75
180	75
210	75
240	67
270	67
300	58

Table 3
The batch with two eggs had the least change in percent of inflated soufflés over the five minute time period

With three eggs, the soufflé batches had similar results as the two-egg batch (see Fig. 4). The only significant difference was that the three-egg batch deflated faster and more often than the other batch. However, both have the same percent of inflated soufflés after five minutes (see Table 4).

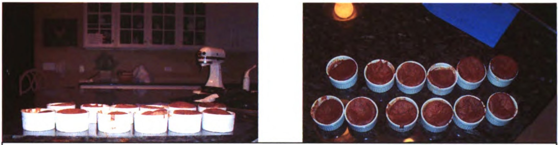


Figure 9
The batch with three eggs had similar results as the two eggs but came out of the oven with more deflated soufflés

Time v. The % of Inflated Soufflés with Three Eggs	
Time (sec)	% Of Inflated Soufflés
0	83
30	83
60	83
90	83
120	67
150	67
180	58
210	58
240	58
270	58
300	58

Table 4
The three-egg batch decreases in percentage significantly at one point but then appears to level off

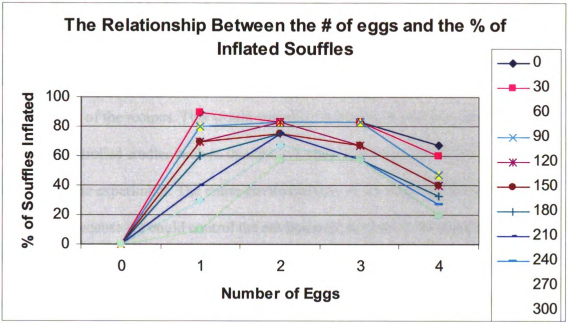
The final group of soufflés consisted of four eggs. This set deflated at a rate similar to the two-egg group. Although, the starting percent of soufflés (right out of the oven) began lower than the bunch with two eggs. Therefore, it had a low percent of inflated soufflés after 300 seconds (see Table 5).

Time v. The % of Inflated Souffles with Four Eggs	
Time (sec)	% of Inflated Souffles
0	67
30	60
60	47
90	47
120	40
150	40
180	33
210	27
240	27
270	20
300	20

Table 5
Although the batch with four eggs decreased in percentage at the same rate as the batch with two, this batch started with a lower percent than all the others (except the control) so the ending percent is lower.

Discussion:

The results did not support our hypothesis. Also, the results did not support our null hypothesis. The relationship between eggs and the time for deflation did not show a direct or inverse correlation. Instead, the data showed a bell curve. The time the soufflés stayed inflated increased as the number of eggs increased until there were two eggs. Then it began to decrease. With no eggs, none of the soufflés rose. Then with one egg, the soufflés rose very high, but fell very quickly. With two eggs, a decent amount of the soufflés rose, and they fell slowly. The soufflés with three eggs were not much different. They had the same beginning and ending amount of risen soufflés, but they fell slightly earlier than the two egg soufflés did. Finally, the soufflés made with four eggs, had little soufflés rise. They also fell somewhat slowly.



This graph shows the relationship between the number of eggs and the percent of soufflés remaining inflated. Each line represents one time period at which the number of soufflés still inflated was recorded. This graph shows the bell curve relationship between the amount of eggs and the time it takes for them to deflate. Therefore, both our hypothesis and our null hypothesis were incorrect.

<u>Conclusion:</u>

Mainly, we found that as the number of eggs increases the time increases for the soufflés to stay inflated increases, up to two eggs. After two eggs, the time for deflation decreases. The more eggs you have the more stable the soufflé is, but the more eggs there are the denser it is as well. If there are too many eggs, the soufflé is too dense to rise well. If there are too little eggs, then the soufflé is too unstable to stay risen. This creates the bell curve. For future experiments, we could replace eggs with water when we change the number of eggs used in the recipe. This would keep the volume the same for each batch of eggs. We also could have used a conventional oven instead of a convection one. This would be consistent with the recipe, and it would cause the heat to rise from the bottom inside the oven. If we were to do the experiment again, we could have left the white chocolate out of the recipes. This would stop their interference with the rise of the soufflés. Controlled studies such as this remove many variables from affecting the outcome of the experiment. The entire environment is in our control. This helped our experiment because we could control the environment to make it the same in each batch. There were no significant differences between each batch. However, when dealing with living things, controlled experiments may not be the most convenient. If we were to control the environment of a living thing, they would be interacting with an environment that is not natural.

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Appendix G: Science III, Student Example

Learning the Wii: Zelda: Twilight Princess and Learning

Review of Literature

Video games, in general, are known to be able to teach and to develop a wide array of cognitive skills.[1] Also, previous studies show that access to computers like at schools, public libraries, etc. – not the ownership of the computers or video games – increases cognitive development,[2] making it possible to test for development in a lab with both people who own game systems and those who do not.

Cognition itself consists of multidimensional visual-spatial skills, of which, video game players (VGPs) normally have a higher skill level than those who are non-video game players (NVGPs).[3] However, VGPs only perform better on visual tasks specific to the video games that they play. Although VGPs perform better on those skills, it takes repeated practice for hours[4] (this requirement makes it possible to include those who play very little video games to be included into the NVGPs category for testing). Those visual-spatial skills include reading visual images as representations of three-dimensional shapes (representational competence),[3] spatial visualization,[4] a large field of vision,[5] enhanced allocation of spatial attention over the visual field,[3,6] greater attention capacity,[6] the ability to retain mental maps,[3] quick visual searches, better target location, faster responses, and greater efficiency at minding targets.[5] Studies show that video games caused the increased spatial abilities since VGPs have no inherently better attentional skills or superior hand-eye coordination than NVGPs.[6]

Even though VGPs do not have inherently better visual-motor skills, hand-eye coordination is required. Thus, multitasking and making connections is needed for doing well with video games, especially action video games. As a result, VGPs can multi-task and think on multiple levels more efficiently than NVGPs.[3, 7, 8] This multitasking leads to the ability to take in multiple, interconnected information[7, 8] and process it quickly to make decisions.[3, 7] By swiftly analyzing data, VGPs have an increased ability to process information over time.[6] In other words, they learn faster. VGPs, though, learn through inductive discovery, which is, in video games, deducing the rules from playing rather than reading the instructions and understanding complex systems through experimentation.[3, 7] Through the combined effects of learning quickly and inductive discovery, VGPs can create strategies for overcoming obstacles that they come across in their games.[7]

With the information gathered, it is hypothesized that VGPs will perform better than NVGPs as the two groups learn how to play *Zelda: Twilight Princess*, an action game. Also, within the VGP group, those with experience in action-type video games will perform better than those who do not have the same knowledge.

Methods

Participants

This study used data from 20 students at Grand Rapids Catholic Central (GRCC). Nine were VGPs (people who played action video games for more than one hour a week for the past six months) and eleven were NVGPs (people who never played video games or played less than one hour a week for the past six months). The tested VGPs had never used the Wii. The participants were sophomores and juniors enrolled at GRCC. There were ten females and ten males. The participants completed a preliminary survey to determine their eligibility and past video game history. Also, all were asked to abstain from caffeine during their day of testing in order to prevent inflated results.

Measures

Video Game Performance

Performance on video games was measured via the time necessary to complete a specified level in *Zelda: Twilight Princess*. The level required participants to take the role of the main character Link and herd goats into a barn on a horse. This particular game was chosen because the game was the only action game for the Wii at the time that the study was designed. The Wii was chosen as the game system because the new format of the controller helped to level the playing field between VGPs and NVGPs (VGPs would have been used to the format of a standard controller). The shorter the time needed to complete level, the better the performance at the video game. None of the participants required more than five minutes.

Procedures

In order to participate in the study, participants were advised to complete a consent form and a preliminary survey to determine whether they would qualify for the study. The basic questions asked included whether or not they had ever played a Wii, and stating the length of time that they played a video game.

Participants were asked to refrain from caffeine during the day of testing in order to prevent exaggerated results. The time that it took the participant to complete the level was recorded with a stopwatch.

Each participant saw a proctor play the game for about thirty seconds before the proctor gave the Wii Remote and Nunchuck to the participant. Then, the participant was given instructions to walk toward a horse and speak to a character in the game. No help as to how to move, get on a horse, etc. was given. Next, the actual timed portion of the test began as the participants began to herd goats into a barn. When ten goats were herded into the barn, the timing and the test ended.

Testing of the participants happened over a four-week period for four days a week. Each participant was tested for a total of 10 minutes or the time required to complete the specified level, and two students were tested per day. The remaining days (one Monday of each of the four weeks) were to make up for any missed days if the participants could not make their appointments for various reasons or scheduling constraints.

Statistical Analysis

Averaging the time for each VGP and NVGP group. The category with the lowest mean time had a better overall performance with the action video game *Zelda: Twilight Princess* for the Wii.

In order to determine whether or not players with an action video game history performed better, a box-and-whiskers graph was utilized. Within the graph, the group with the lowest median, first quartile, and third quartile performed the best.

Both of these methods of analyses helped to reduce the effects of outliers in data.

Table 1: NVGPs v. VGPs Time		
	NVGPs (s)	VGPs (s)
	69.072	50.555
	72.291	56.804
	77.399	67.15
	103.495	109.19
	113	119.604
	128.401	125.014
	174.369	199.509
	183.748	251.444
	241.054	269.565
	298.878	
	479.952	
Average	176.514455	138.7594

Table 2: NVGPs v. VGPs B&W		
	NVGPs (s)	VGPs (s)
First Quartile	77.399	61.977
Median	128.401	119.604
Third Quartile	241.054	225.4765
Minimum	69.072	50.555
Maximum	479.952	269.565
Range	410.88	219.01
IQR	163.655	163.4995

Results

Non-Video Game Player and Video Game Player Performance

As shown in Table 1, VGPs had a better average time than the NVGPs. Although there were more NVGPs than VGPs, the data was consistent in each group so it is likely that any additional data would have minimal effects on the results. In fact, the gap in the execution of the given task between the two groups and the range of data in each group was large enough to allow a slight difference in the amount of data in the data set.

Within the box-and-whiskers graph (Figure 1) and data (Table 2), VGPs had a lower time in the first quartile, median, and third quartile than the NVGP. Also, the interquartile range of both group was only about 1.5 tenths of a second apart, which means that both sets of data are equally consistent when outliers in data are eliminated.

Action Video Game Player Performance

The collected data was further analyzed to yield the data in Table 3, which was then used to create Figure 2. When the data from the VGPs who had never played action type video game was eliminated, the performance of the group greatly improved. All data analyses dropped, except for the minimum time, which remained the same. This group of individuals performed better than the VGPs as a whole. This revealed the fact that those without experience with action video games worsened the times of the VGPs when the group was analyzed as a unit.

Table 3: Action Video Games

	NVGPs (s)	VGPs (s)
First Quartile	77.399	56.804
Median	128.401	114.397
Third Quartile	241.054	125.014
Minimum	69.072	50.555
Maximum	479.952	251.444
Range	410.88	200.889
IQR	163.655	68.21

Discussion

All of the analyzed results from this study showed that VGPs learned faster at how to play a new action game than do those without any prior video game experience. Also, VGPs who played action type video games, which for example, involve racing and shooting, prior to the study generally performed better than those without the same opportunity. The average and median of the VGPs were lower than the NVGPs.

When the results were analyzed for action VGPs, the action VGPs had a smaller first quartile, median third quartile, and IQR than the VGPs without an action game background. Because these major data points are consistent in supporting the same group as the better performer, the data supports the hypothesis.

Conclusion

Created to discover the rate at which video game players learn, this study uncovered the video game players' increased ability to learn at a new game. However, further research is needed to fully utilize this finding. Future studies could seek to determine the particular elements of a game that cause this increase rate of learning and then place those characteristics into an educational game to enhance learning in the classroom.

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Appendix G: Science III, Student Example

The Effect of Temperature on the Corrosion of Copper

Introduction

This was an experimental study on the effects of temperature on the corrosion of copper. Corrosion is a state of deterioration in metals caused by oxidation or chemical action [5]. Because corrosion occurs when the material is exposed to oxygen and oxygen was present in all tests, I concluded that corrosion should happen in each test. Furthermore, the more corrosion should appear in the higher temperature due to collisions of high energy molecules. Ferric chloride ($FeCl_3$) and sodium chloride (NaCl) were used to speed up the process of corrosion [2] [3]. $FeCl_3$ increases the amount of iron and therefore increases the amount of corrosion. NaCl reacts with the water and works as a catalyst to speed up the reaction. To measure corrosion, the copper was weighed in grams before and after testing [1]. Also, a visual description including percent of copper corroded and pictures of the corrosion were recorded.

Methods

Testing was performed four times over a sixteen day period. A copper strip in air acted as the control. Three covered jars were filled with 800 mL of water, 14g of $FeCl_3$, and 6g of NaCl. Three 15x1.2cm strips of copper were weighed separately and placed in separate jars. The first jar labeled A was placed in an incubator kept at 65°C. The second jar labeled B was placed in a room temperature cupboard kept approximately at 20°C. The third jar labeled C was placed in a refrigerator kept at 10°C. Two sets of three jars were tested on the first eight days followed with two more sets in the next eight days. A visual description was recorded after seventy-two the first time and every twenty-four hours for the next five days. At the end of the experimentation period, each copper strip was and weighed. The second measurement was subtracted from the first to get the total corrosion.

Results

Cycle One

The first two jars in the incubator, A1 and A2, corroded completely at the end of cycle one. The corrosion began immediately and continued constantly. A1 went from 4 grams to 0 and A2 from 4.2g to 0. Visual observations were recorded in table 1.1. The jars in room temperature, B1 and B2, gradually turned a lighter color. In the end, both samples showed a little corrosion at the top of the strip [table 1.2]. B1 started as 4.5g and corroded to 3g and B2 3.7g to 2g. The jars in the refrigerator, C1 and C2, did not show visible corrosion, except for some thinning towards the end of the cycle. C1 measured corrosion from 4.6g to 3.4g and C2 from 4.5g to 3.2g.

Cycle Two

In the second cycle, the jars in the incubator acted differently. A3 showed significant corrosion immediately and fully corroded by the fifth day. A4 also showed significant corrosion immediately, but at the end of the cycle, only a little more than half of the strip was corroded [table 2.1]. A3 corroded from 3.6g to 0 and A4 from 5.1 to 2.2. B3 and B4 acted the same in cycle two as in cycle one with only some visible corrosion at the top of the strip [table 2.2]. B3 corroded from 4.4g to 2.9g and B4 from 4.5g to 3.1g. The final jars in the refrigerator, C3 and C4, did not show any corrosion [table 2.3]. C3 showed a slight bending and went from 4.2g to 3.4g. C4 displayed a build up of chemicals on the top of the strip and went from 4.2g to 4g.

Discussion

Results in both cycles supported my hypothesis. The most corrosion was in the highest temperature and corrosion was present in all tests. A1, A2, and A3 fully corroded [graph 4.1]. A4 only corroded half way, but this could possibly be due to the fact that the A4 copper strip was at least a gram heavier than the other three strips. If the test was carried out further, the strip would have corroded rationally in accordance to the other samples. The 'after' measurements for the B jars showed correlating corrosion to the 'before' measurements [graph 4.2]. The correlation was also similar in the C jars [graph 4.3].

Conclusion

In conclusion, corrosion occurs more in higher temperatures. Possibilities for further testing include more jar tests for more accurate information or a longer cycle time to observe full corrosion in each jar. Also, temperature could be better regulated.

Results
Cycle One: A1 and A2

Date	Observation
4/16	Bending, stratification, shorter, thinner
4/17	Further corrosion
4/18	"
4/19	Significant deterioration
4/20	Shorter strip
4/23	Fully corroded
4/24	"

Table 1.1

Results
Cycle One: B1 and B2

Date	Observation
4/16	No change
4/17	"
4/18	"
4/19	Lighter color, layers start to separate
4/20	"
4/23	Some visible corrosion at top
4/24	"

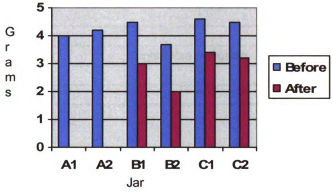
Table 1.2

Results
Cycle One: C1 and C2

Date	Observation
4/16	No settling, no visible corrosion
4/17	"
4/18	"
4/19	"
4/20	Thinner strips
4/23	No change
4/24	"

Table 1.3

Results
Cycle One



Test Cycle One:4/13-4/24

Graph 4.1

Results
Cycle Two: A

Date	A3 observation	A4 observation
5/7	Lighter color, significant corrosion	Lighter color, significant corrosion
5/8	Small copper piece on bottom, not fully corroded	Half of piece left. Light color
5/9	"	"
5/10	"	"
5/11	Fully corroded	Slight more corrosion
5/14	"	"
5/15	"	"

Table 2.1

Results
Cycle Two: A

Date	A3 observation	A4 observation
5/7	Lighter color, significant corrosion	Lighter color, significant corrosion
5/8	Small copper piece on bottom, not fully corroded	Half of piece left. Light color
5/9	"	"
5/10	"	"
5/11	Fully corroded	Slight more corrosion
5/14	"	"
5/15	"	"

Table 2.2

Results
Cycle Two:B1 and B2

Date	Observation
5/7	No change
5/8	"
5/9	"
5/10	Lighter color, layers start to separate
5/11	"
5/14	Some visible corrosion at top
5/15	"

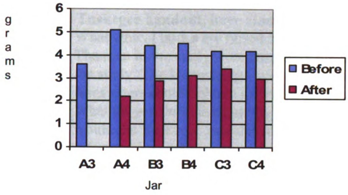
Table 2.3

Results
Cycle Two:C1 and C2

Date	Observation
5/7	No corrosion or stratification
5/8	No change
5/9	"
5/10	"
5/11	Lighter color
5/14	C3-slight bending, C4-build up of $FeCl_3$
5/15	"

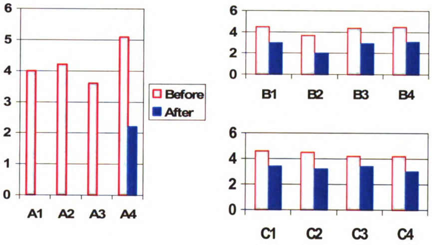
Table 2.4

Results
Cycle Two



Graph 4.2

Overall Results



Graph 4.3

Appendix H: Lessons in Experimental Ethics

Ethics-1

AIM: How and why did ethical concerns become so important in research?

Materials/ Format: Tuslegee and Milgram readings

After reading the Tuskegee handout, have students discusss the following questions:

1. What ethical issues are raised by this case?
2. The men in the study were purposely misinformed about the goal of the study. The Nuremberg Code and Belmont Report both state that researchers should obtain *informed consent* from research participants. What do you think is meant by the term *informed consent*? What would the Tuskegee researchers have had to do in order to obtain *informed consent*?
3. If the researchers had obtained informed consent(by making sure participants understood the purpose of the study and the potential risks involved), would you have any additional ethical reservations about the study? (coercion due to a status imbalanced between the researcher and participants, coercion due to the men's poverty had payment for participation or other monetary incentives been offered.)

Next, have students read the handout on the Milgram experiment and discuss the questions:

1. While no one was *physically* harmed by the Milgram experiment, it is considered the prototypical example of an experiment that could cause participants psychological harm. What harm could participants be reasonably expected to experience as a result of this study?
2. Did the Milgram participants give informed consent? Why or why not?
3. How could you alter the design of Milgram's study and/or add ethical safeguards to reduce the risk of harm to the participants' involved?

Summary: What do the Tuskegee and Milgram studies tell us about the need for ethical guidelines in research?

The Tuskegee Syphilis Study*

Syphilis was a widespread but poorly-understood disease until shortly after the turn of the century. Many cases were incorrectly diagnosed as syphilis, while in other cases patients who would now be recognized as victims of the disease were missed. As the etiology of the disease was better understood, it became increasingly urgent to understand its long-term effects. The early treatments that predated the discovery of penicillin involving the use of such poisons as arsenic and mercury were dangerous, and sometimes even fatal. Thus, it was vital to learn about the likelihood that the disease itself would result in serious or mental disability in order to make sure that the potential benefits of treatment exceeded the risks.

A discovery that the incidence of the disease was higher among African- Americans than among whites was attributed by some to social and economic factors, but by others to a possible difference in susceptibility between whites and non-whites. In 1932 the PHS decided to proceed with a study in Macon County. The specific goal of the new study was to examine the progression of *untreated* syphilis in African- Americans. Permission was obtained for the use of the excellent medical facilities at the teaching hospital of the Tuskegee Institute and human subjects were recruited by spreading the word among Black people in the county that volunteers would be given free tests for *bad blood*, a term used locally to refer to a wide variety of ailments. Thus began what evolved into "The Tuskegee Study of Untreated Syphilis in the Negro Male," a project that would continue for forty years. The subject group was composed of 616 African-American men, 412 o whom had been diagnosed as having syphilis, and 204 controls.

The participants were never explained the true nature of the study. Not only were the syphilitics among them not treated for the disease—a key aspect of the study design that was retained even after 1943 when penicillin became available as a safe, highly effective cure—but those few who recognized their condition and attempted to seek help from PHS syphilis treatment clinics were prevented from doing so.

The nature of the study was certainly not withheld from the nation's medical community. Many venereal disease experts were specifically contacted for advice and opinions. Most of them expressed support for the project. In 1965, 33 years after the Study's initiation, Dr. Irwin Schatz became the first medical professional to formally object to the Study on moral grounds. The PHS simply ignored his complaint. The following year, Peter Buxton, a venereal disease investigator for the PHS began a prolonged questioning of the morality of the study. Bothered by the failure of the agency to take his objections seriously, Dr. Peter Buxton contacted the Associated Press, which assigned reporter Jean Heller to the story. On July 25, 1972 the results of her journalist investigation of the Tuskegee Study of Untreated Syphilis in the Negro Male were published. The response to Heller's revelations was broad-based public outrage, which finally brought the Study to an immediate end.

***The description above was excerpted from onlineethics.org**
(http://onlineethics.org/edu/precol/classroom/cs3.html)

The Milgram Obedience Experiment

After WWII a Yale psychologist named Stanley Milgram became fascinated by people's willingness to harm other people just because they were ordered to do so. He ran a series of experiments that explored obedience to authority.

Participants were recruited from all over New Haven, CT. When they arrived, they were greeted by an experimenter and another man who was supposedly another subject but who, in reality, was a confederate of the experimenter. Participants were told that the study was on learning and, in a rigged drawing, they were assigned the role of teacher while the confederate was assigned the role of learner.

The confederates were then led to another room where they were strapped to a shock generator. The participants' job was to administer a memory test to the confederate and give him a shock each time he gave an incorrect answer. The shocks began at 15 volts and increased to 450 volts. The shocks on the panel were labeled: slight, moderate, strong, very strong, intense, extreme intensity, danger: severe, XXX.

As the shocks increased in strength, the confederate yelled out in pain, began to demand that he be let out of the experiment, and eventually fell silent, giving the impression that he had lost consciousness. If participants expressed hesitation to continue, the experimenter would tell them a sequence of four stock responses (e.g., "the experiment must continue"). Many participants exhibited signs of stress (e.g., sweating, pacing) during the experiment. The experiment was over once the participant gave the highest degree of shock or refused to continue.

The results of the experiment were surprising to Milgram and shocking (pun intended) to society at large. Nearly two-thirds of the participants delivered the maximum lever of shock, a level that would have killed the other person. NO SHOCKS WERE ACTUALLY ADMINISTRATED, AND NO ONE WAS PHYSICALLY HURT.

After the experiment the participants were debriefed. That is, the true purpose of the experiment was explained to them. They were introduced to the confederate and given the opportunity to ask any questions they might have.

Ethics-2

AIM: What is important to include in a code of ethics?

Format: Divide students into groups. Give the groups half the period to creater their own Code of Ethics, a list of 5-10 rules to encourage ethical research. Use the second half of the period to allow the groups to present and discuss the various codes.

Discussion Questions:

1. Do the groups' codes protect against psychological as well as physical harm?
2. Would the groups' codes allow the problematic Tuskegee and Milgram studies/
3. Would the groups' codes allow for medical research to test a new treatment for a deadly disease that might have significant side effects?
4. How do the codes deal with research on animals?

Summary: What are the most important facets of a code of ethics?

Ethics-3

AIM: What are the major ethical issues in doing research?

Format: Discussion

Questions:

1. Ethical research protects the rights of human participants. The Nuremberg Code (see handout) was an early description of these rights that followed the abuses of WWII. The more recent Belmont Report distills ethical concerns into three major issues involved in using human participants (see handout). The principles it discusses underlie the U.S. federal laws that regulates research on humans. To what extent and in what ways did the Tuskegee and Milgram experiments discussed earlier violate these principles.
2. Ethical research limits the dangers to animal subjects. The handout lists some of the major guidelines for research that involves animals Despite these rules, some people believe it is unethical to do research on animals, particularly vertebrates, because they are sentient beings and are unable to consent. What are the advantages of using animals for research? Do the potential benefits outweigh the rights of the animals?
3. Ethical research involves reporting accurate data. There have been cases where researchers reported data that did not exist, failed to report all their data. What might cause researchers to be tempted to report inaccurate data? Why is it important that researchers repot their data accurately?
4. Ethical research does not endanger the welfare of the researchers. What are some of the possible dangers involved in conducting research and what steps can we take to minimize them?

Summary: What are the major ethical issues involved in doing research?

The Nuremberg Code

1. *The voluntary consent of the human subject is absolutely essential.*

This means that the person involved should have legal capacity to give consent; should be so situated as to be able to exercise free power of choice, without the intervention of any element of force, fraud, deceit, duress, over-reaching, or other ulterior form of constraint or coercion; and should have sufficient knowledge and comprehension of the elements of the subject matter involved, as to enable him to make an understanding and enlightened decision. This latter element requires that, before the acceptance of an affirmative decision by the experimental subject, there should be made known to him the nature, duration, and purpose of the experiment; the method and means by which it is to be conducted; all inconveniences and hazards reasonably to be expected; and the effects upon his health or person, which may possibly come for his participation in the experiment.

The duty and responsibility for ascertaining the quality of the consent rests upon each individual who initiates, directs or engages in the experiment. It is a personal duty and responsibility which may not be delegated to another with impunity.

2. *The experiment should be such as to yield fruitful results for the good of society, unprocurable by other methods or means of study, and not random and unnecessary in nature.*

3. *The experiment should be so designed and based on the results of animal experimentation and acknowledge of the natural history of the disease or other problem under study, that the anticipated results will justify the performance of the experiment.*

4. *The experiment should be so conducted as to avoid all unnecessary physical and mental suffering and injury.*

5. *No experiment should be conducted, where there is an apriori reason to believe that death or disabling injury will occur; except, perhaps, in those experiments where the experimental physicians also serve as subjects.*

6. *The degree of risk to be taken should never exceed that determined by the humanitarian importance of the problem to be solved by the experiment.*

7. *Proper preparations should be made and adequate facilities provided to protect the experimental subject against even remote possibilities of injury, disability, or death.*

8. *The experiment should be conducted only by scientifically qualified persons. The highest degree of skill and care should be required through all stages of the experiment of those who conduct or engage in the experiment.*

9. *During the course of the experiment, the human subject should be at liberty to bring the experiment to an end, if he has reached the physical or mental state, where continuation of the experiment seemed to him to be impossible.*

10. *During the course of the experiment, the scientist in charge must be prepared to terminate the experiment at any stage, if he has probable cause to believe, in the exercise of the good faith, superior skill and careful judgment required of him, that a continuation of the experiment is likely to result in injury, disability, or death to the experimental subject.*

[*"Trials of War Criminals before the Nuremberg Military Tribunals under Control Council Law No"*, Vol.2, pp. 181-182. Washington, D.C.: U.S. Government Printing Office, 1949.]

Available online at: http://www.med.umich.edu/ethics/Nuremberg/NurembergCode.html

The Belmont Report (1979)

Three basic principles involved in conducting ethical research are: the principles of respect of persons, beneficence and justice. The job of the Institutional Review Bond (IRB) is to examine proposed research to make sure that human participants will be treated ethically in line with these principles.

1. **Respect for Persons**- People should not be forced into research and should understand what the research will involve.

2. **Beneficence**- The goal of research should be to do good- - to better the individuals involved and/or the larger society. In the pursuit of this good, every effort should be made to protect participants from harm.

3. **Justice**- Neither the costs not the benefits of research should fall on only some parts of the population.

The entire Belmont Report is available at http://ohrp.dhhs.gov/humansubjects/guidance/belmont.htm

Some Ethical Principles Guiding Research on Animals

All research involving animals must first be reviewed by an institutional care and use committee (IACUC). The members must include a veterinarian.

Whenever possible, alternatives to using animals (e.g., tissue studies, computer simulations) should be used.

The number of animals used should be limited to the minimum that will allow a valid conclusion

Everything feasible must be done to ensure the animals; humane treatment

Ethics – 4

Aim: To apply ethical principles to specific research proposals.

Format: Divide students into groups. Give each group 15 minutes to discuss the three research projects described on the hangout and recommend changes/ask for more information in order to approve it. Use the rest of the period to discuss the answers as a class. Some of the issues that you should expect to come up are:

A-Zoe and the impact of sexually explicit television
-Because participants are minors and the topic is a sensitive one, the researcher would need to get parental consent. Alternatively, Zoe could work with an older population or could show the students clips from primetime shows that are deemed appropriate for their age.
-Zoe needs to debrief her participants after the experiment in order to prevent the clips from having any long-lasting, negative effects on the participants.
-Zoe needs to make clear to her participants that their participation is voluntary and that they can withdraw from the study at any time for any reason.

B- Dr. Mortimer's new Alzheimer's drug
-Because the participants are elderly and unwell, they are also unable to give informed consent. Therefore, Dr. Mortimer also needs to get consent from their relatives.
-Dr. Mortimer must monitor the participants' health over the course of the year rather than take a baseline measure and return a year later. If the drug is found to be harmful to participants, the study should be discontinued immediately.
-Conversely, if, before the year is out, it becomes obvious that the drug is helpful, the experiment should be ended and the participants in the placebo group given the opportunity to take the drug.

C- Lorenzo's rat learning study
-A veterinarian must certify that the two types of food are sufficiently nutritious and unlikely to harm the animals.
-One hundred animals is more than Lorenzo needs for his research to be valid. The experiment could be done with one-third that number. It would be possible to use even fewer animals if the experimenter counterbalanced.
-In all likelihood, Lorenzo would not be permitted to keep the animals in his basement but rather would need a controlled laboratory environment at a university.
-Cats can live for 15-20 years. After a year-long experiment, it would be entirely unethical to put the animals to sleep.

Evaluation: Before reviewing the answers in class, collect one copy of the handout from each group to grade.

Apply Your Knowledge

Directions: Each of the following research proposal involves ethical issues. With your group you will act as the IRB/IACUC to identify how the proposed study would need to be changed and /or what additional information you would need to know in order to approve it.

A.Zoe wants to study the impact of watching sexually suggestive/explicit television on people's attitudes toward sex. She plans to test ninth graders because she believes they are still young attitudes enough to be highly impressionable. She will solicit volunteers to come after school. Half will be assigned to watch one house of *Sex and the City* clips that focus on sex, wile the other half will view an hour of clips from the same show that deal with non-sexual topics. After watching the t.v. shows, all participants will fill out a questionnaire about the attitudes toward sex.

B. Dr. Mortimer has invented a new drug to treat Alzheimer's disease. He proposes to go to local nursing homes to ask residents who suffer from Alzheimer's if they would like to be in his study. Half the people would be assigned to get the new drug and the other half would be assigned to get a placebo. Dr. Mortimer plans to take baseline measures of the people's health before they begin the treatment and return one year later to test for changes.

C. Lorenzo wants to see if premium cat foods will improve the animal's performance on a learning task. He proposes to get 100 young animals from local shelters and to the house them in his lab. Half will eat the least expensive cat food on the Markey, while the other half will eat the most expensive. Every week for one year the cats will be given the same task – essentially an obstacle course with a food reward at the end – and the time it takes them to complete it will be timed. AT the end of the experiment, the cats will be put to sleep.

Appendix I: Presentation Peer Feedback Rubric

RATING SHEET FOR PRESENTATION OF AN ARTICLE

Rater Name: ____________________ Presenter Name: ____________________________

Date: _____________ Topic: ____

Rating Scale: 4 = excellent; 3 = good; 2 = fair; 1 = unacceptable

Section	Rating (Circle One)	Comments
Inrtoduction: Captures the audience's interest. Clearly introduces the main idea or purpose of the presentation.	4 3 2 1	
Review of the Literature: Indicates an adequate search of periodical literature. Presents references in logical order. Shows a 'funnel effect'.	4 3 2 1	
Problem Statement or Hypothesis: Clearly states a problem and/or hypothesis.	4 3 2 1	
Methods and Materials: Shows a concise and reproducible series of steps.	4 3 2 1	
Results: Results are easily understood. Visuals are accurate, clear, and effective.	4 3 2 1	
Discussion: The results are well explained. There is a clear statement of whether the hypothesis is proven.	4 3 2 1	
Conclusion: This summarizes the presentation. It relates to the stated hypothesis or problem. It is clearly and concisely stated.	4 3 2 1	
Delivery: The presentation is well organized. The presenter is comfortable with the topic. The presenter uses appropriate voice, eye-contact, posture, and body language.	4 3 2 1	

Appendix J: Data and Analysis Part I Questionnaire

Entrance/Exit Survey: Methodology
Research Seminar

For each of the seven goals, please rank your ability level on a scale of 1 (the worst) to 5 (the best).

I. USE OF THE SCIENTIFIC METHOD

1. Stating a research problem
2. Generating hypotheses
3. Stating hypotheses
4. Testing hypotheses
5. Design an experiment
6. Execute an experiment
7. Building theories

1 2 3 4 5

II. SCIENTIFIC THINKING

1. Drawing conclusions based on data
2. Indicating future research that the present completed research suggests

1 2 3 4 5

III. CONDUCTING LITERATURE SEARCHES

1. The use of the internet to find/retrieve scientific information
2. The use of the library network to retrieve desired journals
3. The review of all pertinent literature to determine the present state of knowledge in the topic of research

1 2 3 4 5

IV. CONDUCTING AUTHENTIC EXPERIMENTATION

1. Experimentation which addresses the hypotheses
2. Experimentation which is reproducible
3. Experimentation which has appropriate controls
4. Experimentation which is complex, compound, and state of the art

1 2 3 4 5

V. WORKING WITH DATA

1. Collecting data
2. Organizing data
   a) Using graphs
   b) Using charts
   c) Using tables
   d) Using figures
3. Storing data
4. Analyzing data
   a) Conducting statistical analyses
5. Interpreting data analyses
   a) Distinguishing valid from invalid Interpretations of data

1 2 3 4 5

VI. PARTICIPATING IN THE SCIENTIFIC COMMUNITY

1. Locating professors and professionals to serve as mentors
2. Contacting professors and professionals to serve as mentors
3. Working with professors and professionals

1 2 3 4 5

VII. WRITING A SCIENTIFIC PAPER

1. Writing a research abstract
2. Using economy of language
3. Writing a scientific paper which includes:
   a) Review of the literature
   b) Statement of purpose (or hypothesis)
   c) Methods and materials
   d) Results
   e) Discussion of results
   f) Conclusions

1 2 3 4 5

Appendix J: Data and Analysis Part I Data Results

In the charts below, each of the seven goals is treated independently. This data is gleaned from all 17 members of the pilot year of the research program.

Sophomore Year in Program

Goal #	1	2	3	4	5	6	7
Pre-Pilot Year	2.25	2.5	2.0	1.63	2.25	1	1.4
Post-Pilot Year	4.25	4.4	4.5	3.75	4	4	3.9
% Increase	89	75	125	131	78	300	182

Figure 5

Junior Year in Program

Goal #	1	2	3	4	5	6	7
Pre-Pilot Year	2.3	2.9	2.14	1.86	2.3	1.3	1.14
Post-Pilot Year	4.3	4.6	4.6	4	3.9	4.7	4
% Increase	87	60	114	115	69	265	251

Figure 6

All Students

Goal #	1	2	3	4	5	6	7
Pre-Pilot Year	2.27	2.67	2.1	1.7	2.27	1.13	1.27
Post-Pilot Year	4.3	4.47	4.53	3.87	3.93	4.3	3.9
% Increase	89	67	119	128	73	281	207

Figure 7

Appendix K: Data and Analysis Part II Student Response
Student: A
Year in School: Junior
Date of Interview: September 2006 (Pre-test) and June 2007 (Post-test)

Science Perspectives

1. Do you read books or articles about science? If yes, please describe which ones and how often you read them.

Pre-test: *I read articles/books about science usually only for school purposes. That means once a day on whatever topic we covered in class.*
Post-test: *I definitely read articles and scientific journals. The entire year I have focused on nutrition and its effects on the body.*

2. Do you talk about science with your friends? If so, what exactly is the content of your discussion? What specific topics?

Pre-test: *I talk about science with my friends if something is really big in the news or again if it deals with homework. An example may be the bird flu or Pluto not being a planet anymore.*
Post-test: *When I talk about science with my friends, it is usually my research buddies. We talk about our latest findings on our topic or just something in general that we know they would appreciate.*

3. Have you ever been to a science museum? Please be specific with dates. Did you initiate the visit, or did someone ask (or demand) that you go with them?

Pre-test: *I have been to a science museum. I went to the Museum of Science and Industry in Chicago about 5 years ago. I also went to the Smithsonian museums including the Museum of Natural Science about 3 years ago. My parents suggested these museums, and I thought that they sounded interesting and wanted to go.*
Post-test: *I have been to the science museum in Chicago a few years ago. My parents asked if it would be something that I'd want to do, and it definitely appealed to me.*

4. Do you have a science related hobby? If so, what is it?

Pre-test: *I do not have a science related hobby.*
Post-test: *I would have to say that my science related hobby would be the research class. I actually enjoy reading up on my topic outside of class.*

5. Are you, or have you ever been, involved in a science club? Please give specifics.

Pre-test: *I have not been involved in a science club, but during junior high I wish I would have been able to join the science Olympiad team.*
Post-test: *I have not been involved in a science club even though I really wish I would have done Science Olympiad.*

6. When you surf the internet, do you frequently visit science-oriented sites? If so, please list.

Pre-test: *I do not frequently visit science oriented sites.*
Post-test: *I visit the science news website or Google something on my topic.*

7. What are your top three favorite TV shows?

Pre-test: *Survivor, The Cosby Show, and anything on the Food Network.*
Post-test: *Survivor, Mythbusters, and anything on the Food Network.*

8. Do you regularly watch the news? Read a newspaper?

Pre-test: *I usually watch the news a few times in a week, and I skim the headlines of the paper and anything that sounds interesting I will read.*
Post-test: *I occasionally watch the news and only read the articles that interest me in the paper.*

9. Do you like to cook or bake? If so, what exactly intrigues you about cooking or baking? Do you always follow the recipe?

Pre-test: *I love to cook and bake. I love the fact that different ingredients taste different when separate, but when added together, one can make a fantastic dish to eat, with a completely different flavor. I usually follow the recipe, but it is always fun to add whatever you want or what you think would go well with all the ingredients.*
Post-test: *I love to cook and bake. The idea that different components can be put together to make something completely different and delicious intrigues me. I do not always follow the recipe; sometimes I just like to add a little of my own ideas to the mix.*

10. Do you have a science related toy (telescope, chemistry set, etc.)? If so, please name.

Pre-test: *I do not have a science related toy.*
Post-test: *I do not really have any science related toys.*

11. Do you like to try to fix things that are broken? If so, please give a specific example.

Pre-test: *I do like to try and fix things that are broken. An example would be that I just recently replaced a door knob and lock that was broken on one of our doors.*
Post-test: *I do enjoy trying to fix things. Again, it is a sense of accomplishment of making something out of a bunch of pieces that I find fascinating.*

12. Do you like to tear things apart that aren't broken? If so, please give a specific example.

Pre-test: *I do not like to tear things apart, but I do like to put things back together.*
Post-test: *No, I do not really like to break things.*

13. Are you considering a career as a scientist?

Pre-test: *I am considering a career as a scientist, specifically in the medical field.*
Post-test: *I am considering a career in medicine.*

Experimental Methodology

1. Why did you take this class?

Pre-test: *I took this class because I love science. Science is my favorite class and I thought this would be a great opportunity to be surrounded with others that felt the same way I did.*
Post-test: *I took this class because I have always really liked science. It has always come pretty naturally, and I wanted a class where I could study whatever interested me the most, which is exactly what this class is.*

2. What image comes to mind when you think of a researcher? A scientist?

Pre-test: *A researcher is someone who is passionate about a certain topic and wants to learn as much about his topic as possible. I can see a researcher being someone who tests using experimentation and a computer to find the information they need. I see a scientist being someone in a lab, testing out different theories to try and prove what they believe is right.*
Post-test: *When I think of either of these occupations, I think of men or women studying something they are passionate about. They start with a very general topic and work their way to a specific idea. They then perform numerous experiments to try and support a hypothesis.*

3. What are your strengths and weaknesses as a scientist?

Pre-test: *My strengths are my dedication and love for science. I do not mind looking up information, and I love to learn. My weaknesses are sometimes I draw blanks as of how I should proceed when researching a certain topic. I always think it can be hard to get started, but once I have started, I go all out to learn as much as possible.*

Post-test: *I think my strengths include the fact that I am a hard worker and a dedicated person. I keep to what I have started and I am not afraid to go out of my way to get the job done right. I am also very passionate about what I study. My weaknesses would have to include procrastination and sometimes not using my time as well as I can during the class. I am always able to accomplish my work, though.*

4. Why might it be difficult to describe a "typical" researcher?

Pre-test: *It would be difficult to describe a typical researcher because they are all different. They all research different topics, they all go about their research in different ways, and they are all looking for different results.*

Post-test: *It is difficult to describe a researcher because every researcher is different. A researcher could be in a lab all day, running experiments or at home looking up numerous journals on the computer. There are so many different aspects to being a researcher that to have a "typical" researcher would be almost impossible.*

5. Einstein once said that his success was due to 1% inspiration and 99% perspiration. What do you think he meant, in terms of scientific experimentation?

Pre-test: *I think he meant that results come from hard work and determination. One has to be willing to work, to experiment, and to truly want what he or she is trying to find. An idea is not that hard to come by, but the work to research this idea and truly understand it can prove more difficult.*

Post-test: *I think that this means that a lot of experimentation is in the experiment itself. Yes, it is great to come up with a great idea, but the experiment is needed to support it. The background research, forming of the hypothesis, and running an experiment to get the results and make conclusions is what gives off success.*

6. In movies, we often see the image of a scientist randomly mixing chemicals to come up with a "eureka" type of discovery. Is this realistic? Please explain.

Pre-test: *I believe that there is such a thing as a eureka discovery, but I do no think that one can come across it in so little a time. These discoveries take time and tons of research before they can become realistic.*

Post-test: *I guess anything is realistic. Some types of great discoveries, though, don't exactly always happen like this. I do think, though, that scientists can spend numerous days or even weeks stumped on one idea when all of a sudden it hits them. The answer seems so obvious and clear. Mixing chemicals to get this result would be very rare; this would more come with reading and hard core thinking.*

7. How does a researcher develop an experiment where the *conclusion* will be reliable?

Pre-test: *The researcher must do multiple, multiple tests and use different conditions before the conclusion can be reliable.*

Post-test: *The experiment has to take into account many different variables. To perform one experiment and look at the results to make a conclusion is not sufficient. Also, the data set has to be quite large.*

8. What does it mean to do statistical analysis of experimental data?

Pre-test: *Statistical analysis of experimental data means to test how accurate and consistent the data from one's tests really are.*

Post-test: *This simply means to put the information you have obtained into a graph and find values such as mean and median. This way, it is easier to interpret the results.*

9. When designing an experiment to determine the pattern of heredity of different characteristics in fruit flies, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *Different variables would be: size, weight, color, appetite, favorite foods. The statistical analysis should be to see the average say weight or size to see how consistent and accurate one's tests were.*

Post-test: *Some different variable would include different ages of fruit flies, different environments, different diets, and even male and female. Finding the average of the data would be the key.*

10. When designing an experiment to test the quality of a river, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *The variables could be: pH level, different minerals/chemicals in the water. The statistical analysis could maybe include testing a different river to compare and contrast one's results.*

Post-test: *Different variables could be the spot of the river, temperature, surrounding vegetations, how strong the current is, location in the city, how deep the water is. Again, finding the average would be the key to determine the best results for the experiment.*

11. Distinguish between causality and correlation in experimentation.

Pre-test: *The causality shows the results of the experiment and the correlation determines how the results compare and contrast to other experiments.*

Post-test: *Causality is basically just cause and effect: this happened so that occurred. Correlation shows how two different variables are similar or related, but one does not cause the other.*

12. What is the purpose of a control in the experimental method? Distinguish between a control and a variable in an experiment.

Pre-test: *The purpose of a control is to make sure that the experiment is under the conditions one needs to obtain the results one wants. A control is something that stays the same throughout the experiment, and a variable changes with time to yield different results.*

Post-test: *A control always gives you something to compare your results with. For example, if one was testing how different liquids reacted with an object, it would be good to have a neutral liquid like water to compare it to. By only testing with variables, the results would not have anything to be compared with.*

Exit Interview

1. How/why did you choose your topics of research?

I chose my topics simply by what I found most interesting. There were certain topics that I could not stand to read, and others that I could not read enough about.

2. Why, do you think, our school offers this program? What benefits does the program provide that other classes don't?

This school offers this program to satisfy the needs of those students who are in need of answering their questions. This program allows students to set their own deadlines, and pick their own curriculum. It keeps the love for science alive and really allows for some awesome experiences and different learning environments.

3. What specific skills have you learned?

I have learned how to conduct and come up with my own experiment. I have learned about different types of experiments, how to graph the results. I have also learned how to work well with others, meet my own deadlines, and manage my time to accomplish everything that I need to.

4. What could be done to make the program better?

I think starting as early as possible will make the program better. It was hard this year to cram everything in, but overall, the more prepared and aware the incoming students are, the better.

5. If you are a junior, do you feel ready/prepared to start on your summer research project?

I do feel that I am prepared. I know that I do not know everything that will happen or understand every single concept, but I think that my mentor and summer project will help me with that. I am apprehensive and excited to start my project. I know that all of my hard work and research over the year will definitely pay off.

6. What skills/knowledge do you feel you are lacking that would better help you run a high level research project?

I think that just plain old experience. I have not worked with too high tech of equipment or really been put in a situation of running a high level project. I know the methods and procedures, I just need to experience everything first hand.

7. If you are sophomore, do you feel ready/prepared to design your own high level research project?

N/A

8. What specific aspect of the program do you feel is the best?

I love the fact that the student can decide what he or she wants to research. All other science courses require one to learn a specific, set curriculum. I believe that this class allows students to pursue their own interests, answer their questions, and potentially come up with stunning results.

9. What specific aspect of the program do you feel is the worst?

I do not like that the deadlines can be switched so easily. I completely understand when someone has no way of meeting it and it must be pushed back. It just seems that throughout the year, so many deadlines continuously got pushed back. This class entails a LOT of work, and for all of it to be completed, people must stick with the original deadlines.

10. How do you feel about the grading system (grades awarded based on deadlines and work, not on paper grades)?

I agree 100% with the grading system. I think that one should take pride in the work they accomplished and what they have researched. I do not think that it matters if there might not be a comma where necessary or if the format is a little off. There is always room for improvement. This class is completely based on how far you want to take it. You can do as much work or the least amount of work as you want. The students' dedication and continuous research and hard work should be enough to earn the grade.

11. Has your interest in science been changed by this experience? If so, how?

My interest has been changed. I now appreciate what researchers go through every day so much more. There is so much thought and hard work and amazing stuff involved in research. But after all the hard work, reading, background research, running the experiment, and supporting one's hypothesis....now it doesn't get much cooler than that. I used to like science merely because I found it interesting. It was a once a day class that I looked forward to. Now, it feels normal to go home and look up the latest info in the science community or read up more on my topic.

Appendix K: Data and Analysis Part II Student Response
Student: B
Year in School: Junior
Date of Interview: September 2006 (Pre-test) and June 2007 (Post-test)

Science Perspectives

1. Do you read books or articles about science? If yes, please write (describe) about which ones and how often you read them.

Pre-test: *Most of the books I read for pleasure are somehow related to science. I go through a book or so a week, depending on my schedule. Among my favorites: Sinclair Lewis's* Arrowsmith *(I love how medical research is described as "pure science," while medicine is regarded as a vocation for the uncreative), Bill Bryson's* A Short History of Nearly Everything *(this was just interesting in the scope of topics it covered), Brian Greene's* The Fabric of the Cosmos *(I loved having my brain hurt while reading it, and I started using physics principles in daily conversations for a week), Steven Levitt's* Freakonomics *(though this is more economics, it was really cool how it viewed the world differently), and Malcolm Gladwell's* Blink *(I think that thinking about thinking is just interesting). In terms of articles, I like keeping up with the latest science news. I have two science news modules on my "My Yahoo" home page (which I visit a few times daily), one from the Associated Press and one from the New York Times. I am a huge fan of* Discover *magazine and read it from cover to cover as soon as I get it. I even bring it to school to read.*

Post-test: *I read quite a few science related books last summer, listed in my pre-assessment. I read Discover magazine quite often, though our subscription has expired, and I follow science news as best I can online. I'd say I probably spend about an hour a week total just reading up on news in different fields.*

2. Do you talk about science with your friends? If so, what exactly is the content of your discussion? What specific topics?

Pre-test: *My friends don't like me talking about science because they generally have no idea what I'm talking about. However, when I just start talking about science to one of them, it's usually about a current piece of news that might interest them. For example, stem cells have come up once (briefly). Really, though, I don't have anyone I can talk to about science.*

Post-test: *I only talk science with my friends from research. I help out the AP Bio kids quite often when they have a question about a topic, but generally my science conversations are limited to research kids (with whom we talk about our own projects) and a good unnamed friend of mine who's simply brilliant enough to understand what I'm talking about without really knowing much of the science behind it.*

3. Have you ever been to a science museum? Please be specific with dates. Did you initiate the visit, or did someone ask (or demand) that you go with them?

Pre-test: *The Field Museum in Chicago is the closest I have ever come to going to a "science" museum. I'm usually the one that asks to go and am also the one who has to be dragged out at the end of the day. I can't be specific with dates because I frankly don't know, but for the sake of statistics every other Thanksgiving would be pretty close.*

Post-test: *Nothing besides the Field Museum in Chicago, and then I'm usually dragged out of the door by my family. We go there once every few years.*

4. Do you have a science related hobby? If so, what is it?

Pre-test: *I have a habit of standing out on my driveway on clear nights and finding constellations. I guess you could count reading about science as one of my hobbies, too.*

Post-test: *Does sailing count as physics? If so, then yes. If not, then driveway stargazing is about it.*

5. Are you, or have you ever been, involved in a science club? Please give specifics.

Pre-test: *I've been involved in Science Olympiad since 6th grade with a break in 8th grade because I lived in another state where it wasn't offered. That would be 4 years total. In 7th grade, I received two medals at Regionals: a 3rd place in "Reach for the Stars" (Astronomy) and a 5th place in "Weather or Not" (Meteorology). That year at States, I won 5th pace in Meteorology again. I haven't won any medals since, but I have had a big role in organizing our team here at Catholic.*

Post-test: *Of course- I'm a First-degree nerd. I participated in Science Olympiad during 6th and 7th grade, winning two medals at Regionals (Astronomy and Meteorology) and a 5th place at States (Meteorology). I then joined the team here at Catholic and won 3 medals at Regional competition this year without studying or even knowing what my events were about going into them (Epidemiology, Genetics, and a general science knowledge event). I actually think our epidemiology medal was for creativity. Case in point- my partner and I made up this elaborate model of the spread of mumps. We decided that it was a bacteria, with viral strain as well (borrowed from what we knew about meningitis), was spread through bodily fluid contact (borrowed from what we knew about mono), and the outbreak occurred in the beginning of April because the incidence was highest among people ages 18-24 and since the incubation time of mumps is 2-4 weeks, the infection time would correspond with many colleges' spring breaks.*

6. When you surf the internet, do you frequently visit science-oriented sites? If so, please list.

Pre-test: *Yes, I visit science related sites pretty frequently. In addition to the two modules I had mentioned before, I frequently visit MIT Admissions, arXiv.org, and Public Library of Science.*

Post-test: *I wouldn't say that I frequent any scientific site besides scholar.google.com. Over the last 6 months, my web traffic has generally shifted towards college admissions sites, unfortunately.*

7. What are your top three favorite TV shows?

Pre-test: *I really don't watch TV all that much because most of it is garbage. However, I will drop everything to watch "House." If I have to pick two others, I enjoy "That 70's Show" and "CSI" as well.*

Post-test: *I don't watch TV enough to have a favorite 3. "House" is honestly the only one worth listing.*

8. Do you regularly watch the news? Read a newspaper?

Pre-test: *I read the newspaper almost every afternoon when I get home (comics first, then news). As stated in the previous question, I don't watch TV very often, so no, I don't watch the news very often either.*

Post-test: *I listen to NPR more than is healthy for the average teenager and keep up on world news, mainly for Debate purposes.*

9. Do you like to cook or bake? If so, what exactly intrigues you about cooking or baking? Do you always follow the recipe?

Pre-test: *I absolutely love to bake. To be honest, I like it because the end product is usually very enjoyable and the process is relaxing. I do think the fact that almost the entire thing is a chemistry experiment is cool, but it's not the main thing I'm thinking about when I'm making cookies, for example. The main thing on my mind would be how good they're going to taste when I pull them out of the oven. While I might follow the recipe the first time I make something, from that point on I like to play with it to see if I can make it better.*

Post-test: *I love baking- the most intriguing thing about it is certainly the end product. Granted, the science is cool, but I honestly don't think about it when I have the smell of brownies wafting through the kitchen. I follow the recipe the first time around, then tweak it to fit my personal preferences the second time.*

10. Do you have a science related toy (telescope, chemistry set, etc.)? If so, please name.

Pre-test: *My family has a telescope. That's about it.*
Post-test: *No.*

11. Do you like to try to fix things that are broken? If so, please give a specific example.

Pre-test: *I love to fix things myself. The only specific example I can think of would be toying around with my bike when the gears stopped shifting and the thing was generally falling apart.*
Post-test: *Absolutely- I love tinkering with old bikes (I fixed the gears on mine), fooling around with computers in general, and the like.*

12. Do you like to tear things apart that aren't broken? If so, please give a specific example.

Pre-test: *I also like to pull perfectly good stuff apart just to put it back together. The most recent example would be opening my calculator to see the inside.*
Post-test: *Yes, much to the chagrin of the unfortunate owner. I can't think of an example off the top of my head, but I do remember taking apart my alarm clock when I was younger.*

13. Are you considering a career as a scientist?

Pre-test: *I am absolutely considering a career in the sciences. Actually, I'm almost positive that that's the field I'm going into. I'd like to be a research scientist and earn a doctorate in Molecular Biochemistry. I think my brain would get bored if I didn't stay on the leading edge of science.*
Post-test: *Claro que sí. I'm going to focus on getting into college first, though- one thing at a time.*

Experimental Methodology

1. Why did you take this class?

Pre-test: *I took the Research Seminar primarily because I love science and would like to pursue a career in research. By taking the Research Seminar in high school, I'll be able to be a step ahead of my peers from other schools and, because I know the methodology, will be able to land an awesome undergraduate research position early in college (hopefully MIT). Also, taking this class will hopefully help me get into RSI (the Research Science Institute) at MIT next summer. There, I'll be able to perform research with MIT scientists as my mentors for six whole weeks. At the end, I'll then get to present my findings. RSI would also help me fine-tune my* *research so that I can enter it into the Siemens-Westinghouse Science and Technology Competition senior year.*

Post-test: *I want to go into research and earn a PhD- this class was perfect in affording me the opportunities to give me a leg up in my field before I'd even graduated high school.*

2. What image comes to mind when you think of a researcher? A scientist?

Pre-test: *When I think of a researcher or a scientist, I imagine a brilliant and somewhat eccentric person. They bend over a microscope to study a slide and then go back to their office to pour over recent journals and lab notes. After some more thought, they head back to the lab to run a few more experiments, "just in case." This person is not unaccustomed to failure, welcoming it as an avenue to eventual success. Above all, they are determined, creative, and thoroughly in love with their work.*

Post-test: *When I try to come up with a manifestation of my idea of a "researcher," I imagine a single, aging red haired woman sitting in an arm chair in her living room pouring over the latest journals in her field at 2am in the morning when her peers are sound asleep dreaming of their grandchildren. It would be depressing if it didn't actually sound so comforting. I picture scientists as sleep-deprived grad students with gloves and goggles on and a micropipette in hand, painstakingly measuring out the necessary samples.*

3. What are your strengths and weaknesses as a scientist?

Pre-test: *My greatest weakness and strength is my hate of failure. I simply cannot accept being wrong. In a way, this may cloud my thinking so that I am unable to see other viewpoints or possible causes. On the other hand, it will also drive me to find an answer (assuming there is one). Another weakness/strength would be the fact that I am extremely self-critical. I become discouraged easily when something doesn't work out; however, it also means that I continually push myself to a level of perfection. Finally, my greatest strength would be my absolute love for science. Unlike other subjects, I enjoy doing work in it and am willing to do whatever it takes to succeed in it. As a scientist-in-training, I love what I do.*

Post-test: *Strengths: intelligence, curiosity*
Weaknesses: extremely short attention span, tendency to procrastinate

4. Why might it be difficult to describe a "typical" researcher?

Pre-test: *Different types of people research different things. While they all share a love for their subject and an innate sense of curiosity, they are normal people that differ in outside interests, work habits, and family life. Describing a "typical" researcher would be like describing a "typical" human being. It's impossible.*

Post-test: *Research in different areas entails different methods and demands upon each researcher, and different personal temperaments are better suited to different working environments. For example, someone who would not enjoy working with people and thus performing clinical studies might greatly prefer the individualized work of a lab.*

5. Einstein once said that his success was due to 1% inspiration and 99% perspiration. What do you think he meant, in terms of scientific experimentation?

Pre-test: *While inspiration is admittedly vital to scientific process, it means nothing if it is not tested continually and refined to the point of perfection. In terms of the actual work involved in successful scientific experimentation, inspiration is only the kick that gets the ball rolling. The rest is brute persistence in proving your idea.*

Post-test: *Scientific discovery begins with a great idea; however, great ideas hold no merit in science unless they can be proven. A typical scientist's career will be less than 1% inspiration- much of the rest will be spent in devoting their lives to proving his or her idea correct.*

6. In movies, we often see the image of a scientist randomly mixing chemicals to come up with a "eureka" type of discovery. Is this realistic? Please explain.

Pre-test: *Any scientist that would randomly mix chemicals on a regular basis would not have a job. Thus, the Hollywood conception of a scientist is totally off the mark. Scientific discoveries more often result from controlled experimentation and years of persistence. However, it would be nice if the "eureka" moment was common. Cancer would be cured by now.*

Post-test: *No- if it were, we'd have a cure to cancer and numerous dead chemists. As stated above, the majority of a scientists' career is labor of love in the lab.*

7. How does a researcher develop an experiment where the *conclusion* will be reliable?

Pre-test: *A researcher would design a controlled experiment to result in a reliable conclusion. Let's call our researcher Bob. First, Bob should have a hypothesis, stating what he thinks will happen and what must occur if his hypothesis is to be proven. Next, he'll need to design a procedure that is reproducible. He should specify a control group and a variable. He should repeat his experiment numerous times carefully recording his results. Then, he should perform a statistical analysis of them; this just gives his results meaning. At this point, he can see if his hypothesis was supported or not, and can draw a nice reliable conclusion.*

Post-test: *As many variables as possible must be eliminated, and sufficient experiments must be performed to rule out other conclusions and/or causations of the given conclusions.*

8. What does it mean to do statistical analysis of experimental data?

Pre-test: *Doing a statistical analysis of experimental data means interpreting the data so that it proves or disproves the hypothesis. Basically, it gives the raw data meaning. Fro example, this could mean find the average of the set of seeing if the data as a whole increases or decreases. My personal favorite from AP Biology would be the Chi-squared test.*

Post-test: *To statistically analyze data is to apply appropriate methods of presenting data.*

9. When designing an experiment to determine the pattern of heredity of different characteristics in fruit flies, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *I'm really not sure what you would consider a variable in this experiment. I know what you would DO, but...I mean, you'd breed flies with different traits. I suppose one variable could be eye color and another could be wing shape. In terms of statistical analysis, though, if you were a biologist you'd know your ratios for autosomal and sex-linked patterns of inheritance. You would then see if your numbers of flies with different traits (for example, red eyes vs. white eyes) matched any of the ratios (you would have to do this for multiple generations). If so, you have your pattern of inheritance.*

Post-test: *You could test eye color, wing structure, body color, the previously mentioned three in relation to gender, etc. I still don't understand different types of statistical analysis.*

10. When designing an experiment to test the quality of a river, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *Rivers generally have a ton of "stuff" in them, so you could test for a ton of variables. You could do E. Coli levels, sediment levels, and oxygen levels just for a few examples. For this type of experiment, you would definitely have to do multiple tests. You should take the average of all the tests for a certain variable, which would give you a solid idea of that aspect of water quality. This way, you account for differences on different days.*

Post-test: *You could test fecal coliform levels, algae levels, E. Coli levels, amount of silt present, etc. I still don't understand different types of statistical analysis.*

11. Distinguish between causality and correlation in experimentation.

Pre-test: *Causality indicates that one event directly results in another one. Correlation, on the other hand, means that two events are occurring at the same time and are related, but do not cause one another.*

Post-test: *Causality is when one factor in an experiment directly causes another; correlation is when one factor merely occurs at the same time as another.*

12. What is the purpose of a control in the experimental method? Distinguish between a control and a variable in an experiment.

Pre-test: *A control is an unaltered sample and serves as the basis for comparison in an experiment. The variable is essentially what is being altered by the scientist in the experiment.*

Post-test: *The control ensures that experimental procedures are working as planned- any deviation from expected results on controls indicates that something is wrong with the methodology. The control is the constant in the experiment, while a variable changes throughout.*

Exit Interview

1. How/why did you choose your topics of research?

   I'd always been interested in molecular biology, and I knew that that was an area that I could certainly research as the range of topic is almost endless. I began to focus on different aspects of molecular biology I liked, and then narrowed my topics until I was at extremely specific levels.

2. Why, do you think, our school offers this program? What benefits does the program provide that other classes don't?

   The tradition classroom simply isn't challenging for smart kids- we need something above and beyond rote memorization that challenges us to think and apply our knowledge to new and novel situations.

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3. What specific skills have you learned?

   The greatest skill I've learned this year is how to prepare a literature review- as long and as hard as it was, it really was beneficial and has helped my understand my own project better.

4. What could be done to make the program better?

   Increase accountability- I don't like how meetings really dropped off towards the end of this year.
   Deadlines- It would be really useful to set deadlines for everything at the beginning of the year and give out a calendar. Deadlines need to be non-negotiable, especially if such long notice is given.

5. If you are a junior, do you feel ready/prepared to start on your summer research project?

   Yes- in terms of knowledge, I feel extremely prepared. However, I really regret the fact that I have no wet-bench experience going into my internship.

6. What skills/knowledge do you feel you are lacking that would better help you run a high level research project?

   Wet bench experience.

7. If you are sophomore, do you feel ready/prepared to design your own high level research project?

   N/A

8. What specific aspect of the program do you feel is the best?

   Freedom of choice and independence- It's nice to be able to work on what you want when you want to, as long as you get the work done.

9. What specific aspect of the program do you feel is the worst?

   Lack of accountability outside of paper deadlines- As our one-on-one meetings dropped off this year, especially for juniors, I felt that we really missed out on being held regularly accountable for work. In addition, I felt that everyone (meaning, student, mentor, and teacher) wasn't always on the same page because of this.

10. How do you feel about the grading system (grades awarded based on deadlines and work, not on paper grades)?

    I think papers should be graded based on Intel judging guidelines, and work done in class should definitely play a role in the grade. Based on this, I'd probably have a B because I have the attention span of a gnat in class and work much better away from distractions at home, but if everyone had the extra incentive to use class time as work time instead of *study hall time (allowing for more work time at home), the class as a whole might be more productive. I still like my Intel idea much better, though.*

11. Has your interest in science been changed by this experience? If so, how?

Only strengthened.

Appendix K: Data and Analysis Part II Student Response
Student: C
Year in School: Sophomore
Date of Interview: September 2006 (Pre-test) and June 2007 (Post-test)

Science Perspectives

1. Do you read books or articles about science? If yes, please write (describe) about which ones and how often you read them.

Pre-test: *Yes, I do read magazines and articles about science. Every so often, I will read articles online. Some of them are from Scientific American, Discovery magazine, and NASA publications. I read them about once a week. I like Scientific American magazines and I read those about every month or so, along with National Geographic.*

Post-test: *Yes, I read many books and articles about science. I have read about 8 journals and 200 articles this year. I average about 3-4 articles a week.*

2. Do you talk about science with your friends? If so, what exactly is the content of your discussion? What specific topics?

Pre-test: *Occasionally I will talk about science with my friends. I mostly talk about science with the kids in my science class, and we have the best discussions, or with my dad. If I can't figure out how something works or why it does a certain thing, he supplies answers that satisfy me for the time being. With my dad, we talk about mechanical stuff because I'll be helping him fix something, and with my mom we talk about the body and health. These talks include what to do if you're sick or in an emergency.*

Post-test: *No, I don't talk about science with my friends.*

3. Have you ever been to a science museum? Please be specific with dates. Did you initiate the visit, or did someone ask (or demand) that you go with them?

Pre-test: *Yes, I have been to a science museum. My favorite museum is the Museum of Science and Industry in downtown Chicago. We go about once a year since I was 7 years old. We may have skipped a year in between, but usually we are avid science museum goers. The Field museum is always fun and we go there about once every two years. I have been to the Grand Rapids Science museum multiple times on school field trips; in the fourth grade we went to the Science museum multiple times on school field trips; in the fourth grade we went to the Lansing science museum. When I was younger, I was brought there by my parents, but as I got older and began to understand science, I was always the one who suggested we go.*

Post-test: *Yes I go to the Chicago Museum of Science and Industry every year. I love that museum and I find it interesting every time. I have initiated the visit some years, and others it was brought up by other people.*

4. Do you have a science related hobby? If so, what is it?

Pre-test: *My science related hobby for a while was Science Olympiad. Since that has ended, I have begun to read more articles about science and the latest news. The biggest science related hobby I have would be baking, which I do 2-4 times a week. I have learned a lot from it and defiantly do not regret my mistakes!*

Post-test: *Yes, my science related hobby includes working out and playing sports. I find it interesting to learn about the muscles that I use in athletics.*

5. Are you, or have you ever been, involved in a science club? Please give specifics.

Pre-test: *Yes, I was involved in Science Olympiad for three years. I did enjoy it a lot and I learned so much that has helped me in science classes. I competed at the state level for two years and my eighth grade year; I got a medal in "Awesome Aquifier," which deals with the natural water systems.*

Post-test: *Yes, I was involved in science Olympiad for three years at Immaculate Heart of Mary grade school. We had a very strong team, and I medaled in an event my 8th grade year.*

6. When you surf the internet, do you frequently visit science-oriented sites? If so, please list.

Pre-test: *Yes, I frequently visit science related sites when I surf the internet. My favorite is SA.com and NASA.gov and AmericanChemistry.com has also interested me. My passion is cars and what designs make them get better gas mileage, go faster, or have more torque, etc.*

Post-test: *Yes, I frequently visit science related sites to see if any interesting articles catch my eye. I enjoy discover and the Scientific American websites.*

7. What are your top three favorite TV shows?

Pre-test: *I don't watch television that much because I don't have the time, but I like Dirty Jobs on Discovery Channel, anything on the biography channel, and also Mythbusters, which is also on discovery channel.*

Post-test: *A. Grey's Anatomy*
B. Sports shows
C. Anything on Discovery

8. Do you regularly watch the news? Read a newspaper?

Pre-test: *I read or skim the newspaper almost every night and I watch the news about once or twice a week.*
Post-test: *Yes, I either read the newspaper or watch the news for about ten minutes a night.*

9. Do you like to cook or bake? If so, what exactly intrigues you about cooking or baking? Do you always follow the recipe?

Pre-test: *I love to cook and bake. I think that the thought of enjoying what you have produced is intriguing. What is also attractive is that other people usually enjoy what you have made. No, I do not always follow the recipe. I think that sometimes if you change the recipe depending on what you want, you will get results that you will enjoy, but sometimes, other people wouldn't.*
Post-test: *I like to cook and bake because I find that it pays off when I can see what I have created. No, I don't always follow the recipe because in order to learn some things, you need to step beyond the boundaries that you have been accustomed to.*

10. Do you have a science related toy (telescope, chemistry set, etc.)? If so, please name.

Pre-test: *I have a microscope that I got in the fourth grade and I have a chemistry set that I received in the fifth grade.*
Post-test: *Yes, I have a chemistry set that was given to me when I turned eleven by my grandpa.*

11. Do you like to try to fix things that are broken? If so, please give a specific example.

Pre-test: *Yes, I love to fix things that are broken. More so, I love to figure out why it broke, how you can fix it, and how to prevent it in the future.*
Post-test: *Yes, I love to fix things that are broken. Whenever the lawnmower or the pool is in need, I am always the first one to volunteer to help.*

12. Do you like to tear things apart that aren't broken? If so, please give a specific example.

Pre-test: *Yes. If there is a broken computer, I love to unscrew the cover and look inside. Things that are big are more exciting and complicated than the little things in my opinion. Smaller things lead to bigger things though!*
Post-test: *Yes, I like to tear pens or other small mechanical things apart just so I can see how they work. I find this very interesting.*

13. Are you considering a career as a scientist?

Pre-test: *Yes, I am seriously considering a career in science. I am particularly interested in chemical engineering or medicine. I hope that this research program can help me choose so that in college it will be easier.*

Post-test: *Yes, I am strongly considering a career in science. I am leaning more towards engineering or medicine, but that could change.*

Experimental Methodology

1. Why did you take this class?

Pre-test: *I took this class because I want to be an engineer and I think that it will help me get a jump-start on that. It also appealed to me because I enjoy science.*

Post-test: *I took this class so that I could learn about a specific topic of my interest. I love science and I thought that I would further that interest with this class, and so far, I have.*

2. What image comes to mind when you think of a researcher? A scientist?

Pre-test: *When I think of a scientist, I think of a very smart person who works hard at what they do to help the world and modify things. When I think of a researcher, I think of the background guy who does everything but doesn't get any credit, which he should.*

Post-test: *The image that comes to mind when I think of a researcher is an extremely smart hard working person that loves what they do a lot. They enjoy just looking up information because they know that it will lead to something useful. The image that comes to mind when I think of a scientist is one that uses the researcher's results to further it into something useful. I would rather be on the scientist end because you are actually seeing where the work goes and how it is being used.*

3. What are your strengths and weaknesses as a scientist?

Pre-test: *My strengths are that I have a math and science dominated brain and that I can think without getting caught up in emotions. My weaknesses would be my lack of artistry skills and my need to always be the best or win. My competitive drive could end up being my strength if I guide it in the right way.*

Post-test: *My strengths as a scientist include my ability to work well with others. I can communicate well, and that is very much needed in the science field today. Another strength is my hard work (not settling for anything but the best). My weakness is that I may rush through things sometimes that need more thought and patience.*

4. Why might it be difficult to describe a "typical" researcher?

Pre-test: *It may be difficult to describe the typical researcher because I don't believe they get enough credit. They deserve a lot, and yet we never hear of them on TV, getting prizes or awarded millions of dollars. Not many people know how to describe them because they are not broadcast and celebrated on TV or all over the paper.*

Post-test: *It is difficult to describe a typical researcher because they aren't very well known. Not too many people have met a researcher or know what they do for a living, even though it can be very interesting work.*

5. Einstein once said that his success was due to 1% inspiration and 99% perspiration. What do you think he meant, in terms of scientific experimentation?

Pre-test: *I think that Einstein meant that you have to work hard to get to what you want. You aren't just given success, you have to earn it. The harder you work, the more appreciative and better you feel because it paid off and you realize it. The inspiration part gets you started but the perspiration part makes it happen.*

Post-test: *I believe that Einstein meant that success only comes from hard work. If you work hard (and do a lot of experiments) you will see success sometime in the future.*

6. In movies, we often see the image of a scientist randomly mixing chemicals to come up with a "eureka" type of discovery. Is this realistic? Please explain.

Pre-test: *No, this is not realistic, because rarely you get a "eureka" discovery. There are a lot of smaller discoveries that always lead to the bigger ones. Yes, once in a while you will get a "eureka" discovery and then, it is realistic; usually there are always smaller ones that lead to the big ones.*

Post-test: *NO, this is not realistic. This is more of a dramatic characterization of a scientist. Every scientist is not curing cancer or making some huge discovery. They all have their jobs, and most of them are very specific, where at the end hopefully lots of jobs put together can be a big breakthrough, which makes is very "un-Eureka" like.*

7. How does a researcher develop an experiment where the *conclusion* will be reliable?

Pre-test: *A researcher can develop an experiment when the conclusion is reliable if he has seen proof. It's like he skipped a step and found out the results worked, he now has to go back and fill in the gaps with other conclusions. This is sometimes easier because you know that you have reached it, the only thing left is the little baby steps.*

Post-test: *The researcher develops an experiment where the conclusion will be reliable based on past studies and experiments. After learning proper knowledge, they state a testable hypothesis, test the hypothesis, and record large numbers of multiple data sets. They repeat the experiment to verify results. They have to use information that others have used and base their experiment of off that in order to get a reliable conclusion.*

8. What does it mean to do statistical analysis of experimental data?

Pre-test: *Statistical analysis of an experiment is the taking down of stats and recording them. This is usually done in the data and observations part of an experiment. It helps reach a conclusion at the end of the experiment.*

Post-test: *Statistical analysis means that you have to take data and observations and use calculations on the data to interpret what you found. You have to analyze your findings to the findings of others.*

9. When designing an experiment to determine the pattern of heredity of different characteristics in fruit flies, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *The variables could be habitat, diet, gender, size, and hereditary genes. They could note changes in the different variable in these then record. The statistical analysis would use the differences and similarities.*

Post-test: *There are many variables that could be tested. Some include habitat and eating patterns; along with their spot in the community (are they alone or how many fruit flies are there?) You could base this statistical analysis on the control group, which would have little, if any, variables. You would analyze the findings of each and contrast/compare the two.*

10. When designing an experiment to test the quality of a river, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *The variables in a river would be habitat, weather, living material, non-living material (both in and out of the river), what feeds into it and what it feeds into. The main variable would be what makes up the water; if it is filled with fish or more algae. The statistical analysis should be based on how all of the tests come back, either negative or positive. Your statistics would be the notes and results of all the tests.*

Post-test: *The variables that could be tested are weather, pollution, activity in the river, location of the river, etc. The statistical analysis that should be done includes comparing the variable groups to the control groups and seeing what is different or similar.*

11. Distinguish between causality and correlation in experimentation.

Pre-test: *Causality is the cause and effect of an experiment; the "if then, then this." Correlation is the relationship between two things. Scientifically, it is when two or more attributes or measurements on the same group of elements vary accordingly together. One is how they are different, and the other is how they have the same results.*

Post-test: *Causality is when one variable directly affects another variable in a system. Correlation is when two events and/or variable simply happen at the same time or at the same place, and scientists have to determine if they are related. Newspapers mess up this all the time.*

12. What is the purpose of a control in the experimental method? Distinguish between a control and a variable in an experiment.

Pre-test: *A control in an experiment takes the lead and is the guidepost for the experiment. The variable is there to affect the control to show difference between the two. The variable is something surrounding it and the difference is noted. You need both to run a well organized and reliable experiment.*

Post-test: *The purpose of the control is to compare and contrast the control factors to it. It is the most predictable out of all of the groups. A variable has something added to it to make it different from the control. The point of this is so that you can note the difference.*

Exit Interview

1. How/why did you choose your topics of research?

   I chose my topic in pediatric cardiology because I found it very interesting. It is a problem that is important and it has a use in the real world. You can see the results right before your eyes, and you are saving someone's life, which is very cool.

2. Why, do you think, our school offers this program? What benefits does the program provide that other classes don't?

   I think that our school offers this program because we are a talented student body that needed a more independent class. We also have the materials and resources, which made it easier. This program offers us more freedom during the school day and it also allows us to get a jump start on the work that we do in college.

3. What specific skills have you learned?

I have learned how to write a business letter that sells me and I have also learned a lot about how to design an experiment and write a paper based on the findings. This will especially be useful when we have to design experiments for our big project next year.

4. What could be done to make the program better?

   To make the program better, only a few small things could be done. It needs to be more appealing to other kids, so that they are encouraged and try out for it. Right now, I think that a lot of kids were scared of the prospect of this class, and that is why they didn't attempt to even try. We can do this by making more public what we do and how we do it. It doesn't necessarily have to be bragging or anything. The freshmen classes could be invited to see what we do for ten minutes during the research seminar class period.

5. If you are a junior, do you feel ready/prepared to start on your summer research project?

   N/A

6. What skills/knowledge do you feel you are lacking that would better help you run a high level research project?

   I believe that we are not missing any skills to run a project. If we are missing some, it is general knowledge that we just haven't gotten to in high school yet. For example, because I haven't taken AP biology yet, I don't know everything about the study of life. I also think that to be better prepared we should've have read for two years, instead of one. This is almost impossible to do, but we would have been more literate in our topic if we read twice the amount of articles and journals.

7. If you are sophomore, do you feel ready/prepared to design your own high level research project?

   As a sophomore, I feel ready and prepared to start my own project. I know that I can always ask the advice of the ones ahead of me, and that is more reassuring

8. What specific aspect of the program do you feel is the best?

   The part of the program that I think is the best is the resources. We do not let anything hold us back, and that is amazing. Money doesn't matter and if we get a once in a lifetime opportunity, we are highly encouraged to take it. You cannot find this support or encouragement in any other class, which is why that makes it so unique.

9. What specific aspect of the program do you feel is the worst?

   The part of the program that I think is the worst is the independence. I work better and achieve more when we get an assignment every night and the teacher lays out what needs to be done for us. The independence in this class is at an extremely high level, and it has been a challenge to adjust. This independent work ethic, however, I will be able to take with me to college, where it will be especially worthwhile.

10. How do you feel about the grading system (grades awarded based on deadlines and work, not on paper grades)?

    I think that the grading system is excellent. Everybody in the class works hard, and if they do what is told and turn in assignments on the due dates, then they are set.

11. Has your interest in science been changed by this experience? If so, how?

    Yes, my interest in science has grown since the beginning of this program. I find myself wanting to read more and more and always thinking about the future and my career in something in the science field. This has encouraged me to go into possibly medicine or engineering, because they are useful areas that are what I enjoy doing.

Appendix K: Data and Analysis Part II Student Response
Student: D
Year in School: Sophomore
Date of Interview: September 2006 (Pre-test) and June 2007 (Post-test)

Science Perspectives

1. Do you read books or articles about science? If yes, please write (describe) about which ones and how often you read them.

Pre-test: *No.*
Post-test: *I often read articles that show up on Yahoo! News about new research. Also, I do plenty of readings on tumor suppressor genes for Research.*

2. Do you talk about science with your friends? If so, what exactly is the content of your discussion? What specific topics?

Pre-test: *No.*
Post-test: *I talk about science when I find something really interesting. I'm not going to bore people with the correlation of pH and tree growth, but turning things invisible is a cool science breakthrough.*

3. Have you ever been to a science museum? Please be specific with dates. Did you initiate the visit, or did someone ask (or demand) that you go with them?

Pre-test: *No.*
Post-test: *I've gone to science museums for school field trips and I thought they were cool. I've rarely bone by my own volition, though.*

4. Do you have a science related hobby? If so, what is it?

Pre-test: *No.*
Post-test: *No.*

5. Are you, or have you ever been, involved in a science club? Please give specifics.

Pre-test: *I did Science Olympiad in 8^{th} grade. I competed in events involving fossils, weather, the human body, and bottle rockets.*
Post-test: *I joined Science Olympiad in eighth grade. However, at the competition, the weather was too bad to shoot our bottle rocket, and my partner went in to take our test on fitness too early, taking it alone without me. My only other events were tests on fossils and meteorology, which I didn't find interesting.*

6. When you surf the internet, do you frequently visit science-oriented sites? If so, please list.

Pre-test: *No, but I go to logic puzzle sites like griddlers.net and websudoku.com*
Post-test: *I visit Yahoo! News and read interesting science articles.*

7. What are your top three favorite TV shows?

Pre-test: *America's Got Talent, Survivor, and That 70's Show*
Post-test: *The Office, Grey's Anatomy, and Inferno III*

8. Do you regularly watch the news? Read a newspaper?

Pre-test: *I watch the news when someone else does, and I read the newspaper when it's in front of me.*
Post-test: *I watch the news almost every night, but I don't read the paper that often.*

9. Do you like to cook or bake? If so, what exactly intrigues you about cooking or baking? Do you always follow the recipe?

Pre-test: *Yes. I like using ingredients to make something new and different. I always follow the recipe.*
Post-test: *I don't really like cooking.*

10. Do you have a science related toy (telescope, chemistry set, etc.)? If so, please name.

Pre-test: *I used to play with a microscope, but I don't use it anymore.*
Post-test: *My grandma gave me a microscope a while ago, but I don't use it much.*

11. Do you like to try to fix things that are broken? If so, please give a specific example.

Pre-test: *I like to try to fix small things like staplers and pens, but nothing huge.*
Post-test: *I love trying to fix broken things. When a drawer doesn't open right, I look through it carefully to see what is blocking it. When my mom is trying to use one of her many appliances and it doesn't work, I will always take a look at it and give her my advice.*

12. Do you like to tear things apart that aren't broken? If so, please give a specific example.

Pre-test: *No.*
Post-test: *I don't really like to tear things apart much.*

13. Are you considering a career as a scientist?

Pre-test: *Yes. I am thinking of something with medicine.*
Post-test: *Right now, I think I want to be a surgeon, which is in the science field, but my interests constantly change as do my goals.*

Experimental Methodology

1. Why did you take this class?

Pre-test: *I took this class because I want a career in math and science, and I thought this would be a great start.*
Post-test: *I have always had a huge interest in science and I thought this class would further that interest. I know I want a career in science, possibly a surgeon, and I know this class will help me to meet that goal, or possibly change that goal to a more ambitious one.*

2. What image comes to mind when you think of a researcher? A scientist?

Pre-test: *I think of researchers as people who find how things work. Scientists figure out how to make things work.*
Post-test: *When I think of a researcher, I think of the scientific method and one experiment leading to another. There are no shortcuts to research, only hard work and well-designed studies. I see scientists more as more of people who apply what researchers learn into new technologies or new treatments.*

3. What are your strengths and weaknesses as a scientist?

Pre-test: *My strengths are my intellect and ability to remember information. My weaknesses are my slow work habits.*
Post-test: *My strength as a scientist would have to be my hard work. I stay up countless nights just to make my work a little bit better. I always have to make every assignment the best it can be. My weakness would have to be time constraints. Playing a sport every season and other obligations on top of that make it hard to find time for schoolwork, but I manage.*

4. Why might it be difficult to describe a "typical" researcher?

Pre-test: *Researchers work in many different fields so there isn't a "typical" researcher.*
Post-test: *There is no typical researcher. All researchers research new ideas and technology. If they didn't, they wouldn't be researchers. All new ideas are creative and unprecedented, making all researchers creative and unprecedented.*

5. Einstein once said that his success was due to 1% inspiration and 99% perspiration. What do you think he meant, in terms of scientific experimentation?

Pre-test: *You must work very hard. Hard work is almost all you need to be a good scientist.*

Post-test: *In science, you must be inspired to do your work. Otherwise, why would you do it? More important than that, however, is hard work. Every new theory is found through intense experimenting, testing, and retesting just so it can be supported. You can't find the cure for cancer in one experiment, but only through countless experiments on all of cancer effects, and all of the things that affect cancer.*

6. In movies, we often see the image of a scientist randomly mixing chemicals to come up with a "eureka" type of discovery. Is this realistic? Please explain.

Pre-test: *No, scientists find their theories slowly through observation and experimentation.*

Post-test: *Scientific breakthroughs are usually not achieved through just one experiment, but through countless experiments to support an idea, then more experiments to see its possible implications.*

7. How does a researcher develop an experiment where the *conclusion* will be reliable?

Pre-test: *The experiment must be set so only one conclusion can be drawn. Any more conclusions could have conflicting information.*

Post-test: *A researcher can get reliable conclusions only through lots of data in a controlled environment. There must be tons of data to prevent one or two outliers from ruining the final result. Also, the atmosphere must be controlled to the point that there is only one variable in the experiment. Any more than one could cause confusion as to what brought about the results.*

8. What does it mean to do statistical analysis of experimental data?

Pre-test: *Statistical analysis is writing down quantities of qualities of any given parts of an experiment.*

Post-test: *Statistical analysis of data is grouping data, finding averages, making graphs, and searching for trends. Data must be processed in every possible way to see every possible way that the variable in the experiment affected the subjects.*

9. When designing an experiment to determine the pattern of heredity of different characteristics in fruit flies, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *The flies' wing size or color could be tested. The amount of each color fly should be written for every stage of offspring.*

Post-test: *A variable such as mother carrying the gene vs. father carrying the gene as it is passed to offspring could be tested. The number of flies total must be counted and the number of flies who show the gene would be recorded. The flies would be split by if their mother or father had the gene. Then, the percent of flies that show the gene would be compared to find a significant difference between the groups.*

10. When designing an experiment to test the quality of a river, what kind of variables could be tested? What kind of statistical analysis should be done, and why?

Pre-test: *The presence of certain chemicals or materials could be tested. Percentages of waste or other materials should be taken at different points on the river.*

Post-test: *Variables such as temperature, pH, or proximity to a sewer drain could be tested. There should be plenty of test sites along the river, and between different rivers. Then, all the results should be divided according to temperature, pH, etc. Results could be placed on a bar graph to observe trends.*

11. Distinguish between causality and correlation in experimentation.

Pre-test: *Causality is when one thing causes another thing to happen. Correlation is when two or more things happen together and never separately.*

Post-test: *Causality is when one occurrence is the reason something else happens. If one thing happens, something else is sure to follow. Correlation, though, is when two things just coincidentally happened together. There may be no connection between the occurrences other than time.*

12. What is the purpose of a control in the experimental method? Distinguish between a control and a variable in an experiment.

Pre-test: *A control is used to see the effects on a group without a changed variable. A control could be a plant in normal soil. A variable could be a plant in soil with fertilizer.*

Post-test: *A control is to ensure that the variable is causing the change. A control has no variables changed so it is considered the normal case. The variable then has one variable changed so that the one different variable must be the reason for any change in the results. The control is there to compare to the variable group.*

Exit Interview

1. How/why did you choose your topics of research?

My first article readings pointed me in all different directions, but I naturally turned to what I found most interesting. My current area of research appeared immediately in those first readings and it has stuck with me since.

2. Why, do you think, our school offers this program? What benefits does the program provide that other classes don't?

   I think that our school offers this program to give students a better taste of the life of a researcher. Experiments are not lined up for researchers as they are for students in labs. This teaches students to design their own experiments to find answers to the questions they want answered.

3. What specific skills have you learned?

   I have learned much more about the finer details of research. I know that you need plenty of data. I used to consider plenty of data as about ten cases, but now I know fifty times that is a more appropriate answer.

4. What could be done to make the program better?

   More deadlines could be set on the students. During the winter, the sophomore students were pretty much on their own (juniors were recruiting mentors) to do article readings on their topic. I know that because there were so few deadlines, I slacked off a bit during this time. I rarely worked outside of class. More deadlines could help the natural tendencies of students to not work on their own.

5. If you are a junior, do you feel ready/prepared to start on your summer research project?

   N/A

6. What skills/knowledge do you feel you are lacking that would better help you run a high level research project?

   Most of the skills that must be known for such an individualized high level experiment must be taught to you by a mentor. A student can not learn how to perform polymerase chain reaction on cultures of cells, through just article readings. He/she must learn it by doing it with a mentor. All experiments are different, so each student needs different preparation. That is why each student has an individual mentor.

7. If you are sophomore, do you feel ready/prepared to design your own high level research project?

I don't feel too prepared to design my own experiment yet. There are still countless procedures I must learn from my mentor just to learn how to do an experiment in my field. On top of that, my exact specific topic has not yet been nailed down. I have a general idea of my area of research, but I do not know what I will test. This summer, with the assistance of my mentor, however, should change that and lead me to my experiment and the ability to design it.

8. What specific aspect of the program do you feel is the best?

   I think that the mentor recruitment is the best part of the experiment. First of all, the student could not perform an experiment without a mentor. However, I think the mentor idea gives the class a sense of mystery. The student knows that if he/she slacks off and tries to just sneak by in the class, they will not receive a mentor. This pushes the student to work hard for a mentor. Also, the students compete with each other to get a mentor.

9. What specific aspect of the program do you feel is the worst?

   The worst part of the program would probably be the time constraints on the class that make it hard for the teacher to meet with students regularly. These meetings are necessary to keep the students working and to ensure that they are working in the right direction. However, next year with two sections should solve this problem.

10. How do you feel about the grading system (grades awarded based on deadlines and work, not on paper grades)?

    The deadline grading system is good as long as there are a few more deadlines to keep the students working. Basing grades on paper grades is a bad idea. A good researcher with a well designed experiment may still have failed results. They just must look at what happened and try to fix it.

11. Has your interest in science been changed by this experience? If so, how?

    This has given me much more respect for scientists. I used to think their job was just like any other person's with a regular schedule. The only difference is that they work in a lab. This class changed my whole view of that. I've realized that no research is ever so orderly. Some days you will be done early and out the door at three in the afternoon. Other days, you may have to work at your experiment constantly until two in the morning. This gives research a different aspect than other jobs that are regular and predictable. Researchers never know what they will find, but they always use what they do find to guide future work.

Appendix L: Mentor Feedback for Future Planning

1. As of right now, you have committed to mentor a high school student through a research project, without actually having worked with them. What set of skills do you hope that they have?

***Mentor A**: It's helpful for the students to have a basic idea of experimental design methodology: generating a hypothesis, figuring ways to test the hypothesis, data collection and interpretation, and some ability to think through and rationalize less than clear results. Exposing them to successful and not successful research studies and pointing out design strengths and weaknesses through didactic sessions would foster that basic understanding and knowledge. It took me a while as a college student to pick up on those points because I had to learn on the job rather than through example. To me, sitting and thinking is far more important than sitting and doing.*

***Mentor B**: I hope that the student has interest, motivation, and guts. Interest, because progress is made in science when someone asks the right question, or asks it in the right way. Motivation, because there's too much drudgery in research to keep on going if you're bored. And guts, because we can't be afraid of breaking the instruments, even though they may cost a lot of money; instruments are tools, and time is valuable, so we think carefully first, and then get our hands dirty.*

***Mentor C**: The ability to work independently, a sense of enthusiasm, flexibility, knowledge that it's acceptable to ask questions, ability to work well with others and be a good representative in the community.*

***Mentor D**: The most important skills are mental. I like to see a student with good quantitative skills. They need to have had enough science that we can communicate effectively. Technical skills (i.e. use of pipettes, running electrophoretic gels, growing bacteria) are helpful, but are not really necessary. I am more interested in their having the intellectual underpinnings for science.*

2. The students learn basic research principles through discussions and the implementation of two small research projects (observational and experimental). Are there specific areas of research that you think high school students are particularly weak and/or have a misleading perception?

***Mentor A**: Since I'm new to teaching high school students, I'm not sure that I can address this issue confidently. The experimental projects to me are more difficult to comprehend and master. My guess also is that they have a harder time with research design problem solving and understanding that not much in research is black and white, mostly shades of gray (even though the protocols they see and design are black and white). Focusing on the discussion sections of papers may help them understand in what ways experimental design is limited and how infrequently definitive results are generated.*

***Mentor B**: I suspect that most high school students have a mistaken impression of what constitutes "experimental error," and this is important because it clouds the way that graduates – whether interested in science or not – think about what scientists do. When I was in high school, I'd measure something in the lab, and find that I was off from the "book value" by, say, 15%. I'd have to think of excuses for my 15% mistake – usually, my joke was that I had a 15% deficient lab partner. I wish that students approached their experimental work with the notion that something happened in their experiment, and it is their job to explain what it was, rather than to examine what they did wrong. It's a fundamentally different question, but a valuable one.*

***Mentor C**: I think all students—including college students and often even college faculty—have had very little experience with single-subject design and small N research. This is not a fault of the students, as the research field, in general, prefers large N research. In the field of autism and developmental disabilities it is common to conduct studies with only a few participants to account for the difficulties in obtaining research participants and the variability of the profiles displayed by these students. Additionally, it can also be difficult to understand the length of time that it takes to complete a research study. It is not unusual for it to take 8-10 weeks to write an IRB (Internal Review Board) proposal (including literature review and revisions), and then another month or longer to obtain approval through IRB. Then, participants must be identified and consent forms must be obtained. Data collection can also move quite slowly, as we are often only able to obtain 1-2 data points per day for any of our participants since we cannot remove them from the classroom for extensive periods of time. Collectively, these factors result in a slow and tedious research process, but one that can also be very rewarding.*

***Mentor D**: I don't really have a sense of this.*

3. I am considering teaching basic research lab techniques (electrophoresis, centrifuging, etc.) to students before they work with mentor. However, I have received feedback that the individual mentors would probably rather teach each of their students with their own particular method. What are your thoughts?

***Mentor A**: I spent three years in a molecular biology lab at U of M. Some prior exposure to bench top techniques would have prevented many failed experiments; I had no hands-on experience before then. Never hurts to learn "a" way before learning the mentor's way.*

***Mentor B**: I'd say that if you're going to teach centrifugation, do it for its own value in your class. We are going to have to start from the very beginning with our instruments, and that's probably fine.*

***Mentor C**: Understanding the process of research is critical, so it would certainly be valuable to have additional experiences, but I think the transfer of skills to my particular field would not be easy.*

***Mentor D**: I think that it is true that each lab does things its own way, so a student may be perplexed when they join a lab and find that the procedure that they have learned is not the way that they are going to be doing things. On the other hand, I think that there is value is performing lab techniques in your classroom. The students get an opportunity to apply scientific principles at the bench prior to joining a lab. This will give them a more sophisticated perception of new techniques that they will learn with their mentor. They also learn manual dexterity at the bench in performing these techniques, even if the details change when they join a lab. Even though I do not believe that a technical repertoire is necessary for a student to wok with me, there is value in these prior experiences. I think that it is simply important to let the student know that they will encounter different ways of performing similar procedures and that it is best to perform experiments in the manner that is established in the lab that they join.*

4. What kind of statistical analysis would you like the student to have already mastered before they work with you?

***Mentor A**: Very basic stats are enough to get started, i.e.: one and two tailed t-tests and understanding of confidence intervals, p values.*

***Mentor B**: Most of the statistics that we use in our research are things that we master in graduate school, if then. It's not that it's so hard (it isn't), but it only comes up when we have a large dataset for the first time. Most physicists never learn formal statistics, but just do what makes sense. This is perfectly satisfactory if one has good sense. I'd say that, for a high school student, it would be nice to have a sense of the difference between a mean, a median, and a mode.*

***Mentor C**: Once again, my research field (autism and developmental disabilities) tends to use fewer statistical analyses, but I think a basic knowledge of t-tests, ANOVA and correlation would be helpful for any student engaging in research.*

***Mentor D**: I use standard error of the mean and Student's T-test. If a student is familiar with performing these analyses, that is great, but I generally show students how to perform these analyses.*

Appendix L: Future Modifications/Requirements for Incoming Freshman

Experimental Methodology Checklist
Research Seminar

I. **Introduction to Research**
   A. What is research?
   B. Basic and Applied Research Comparison
   C. Scientific Method
      1. Outline the steps
      2. Narrowing the hypothesis
      3. Designing controls
      4. Selecting the sample size and/or number of replicates
      5. Independent and dependent variables
      6. Formulating and writing procedures
      7. Collection and analysis of data
         a. Collating data
         b. Table design
         c. Graphing
      8. Conclusions and inferences
   D. Review metric measurement
   E. Students are given examples of poor writing and are asked to correct the examples to make them clear and concise
   F. Writing Laboratory Reports
   G. Students learn how to use the library resources

II. **Statistics**
   A. Basic statistical analysis
      1. Students collect data regarding their test scores, coin flips, birth dates, class demographics, dart (plastic tip) scores, etc.
      2. Mean, median, mode, range
      3. Standard deviation
   B. Beyond the basics
      1. t-test
      2. Chi square analysis

III. **Types of Investigations**
   A. Surveys
      1. Students design and carry out a survey investigation
      2. Students collate and analyze data
      3. Students prepare a written report
      4. Students prepare and present a poster
      5. Use a rubric, similar to the one for assessment of the journal presentation, and have the students grade each other
      6. Grade all sections of the work – formation of questions, distribution methods, sample size, data analysis, conclusions, discussion, presentation

B. Field Observation
   1. Students choose a situation and make observations in natural setting
   2. Students manipulate one condition in the environment chosen above and make observations
   3. The results of the observations are compared
   4. Data is analyzed
   5. Reports and/or posters are prepared and graded
C. Experimental
   1. Students design an experimental to test a simple hypothesis
   2. Students submit their procedures and data tables for approval
   3. Students conduct their approved experiment
   4. Reports and/or posters are prepared and graded

IV. **Basic Laboratory Techniques** ***(Commercial lab kits are an easy way of introducing laboratory techniques)***
   A. Laboratory Safety (Review)
   B. Identification of major equipment
   C. Handling and mixing of chemicals
   D. Use of MSD (Material Safety Data) sheets
   E. Microscope use, slide preparation
   F. Pipette and micropipette use
   G. Centrifugation
   H. Spectrophotometry
   I. Aseptic techniques (microbiology)
   J. Electrophoresis
   K. Titration

V. **Applications**
   A. Current issues in science
   B. Students design experiments to solve real-life problems and if possible carry out these experiments
   C. Critical thinking exercises

VI. **General Knowledge and Appreciation of Research**
   A. Invite speakers in from all fields
   B. Field trips to local laboratories at universities, commercial industries, and government organizations
   C. Field trips to carry out ecological/environmental investigations
   D. Behind-the-scenes museum trips
   E. Students conduct simple experiments with elementary school students
   F. Students design a science resource center or activities center
   G. Students go to local science symposia and competitions
   H. Students read about a favorite research topic and present it to the class