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NARROWING THE GAP BETWEEN CLASSROOM SCIENCE AND RESEARCH SCIENCE: WHAT ARE THE BENEFITS FOR STUDENTS AND TEACHERS?

By

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ABSTRACT

NARROWING THE GAP BETWEEN CLASSROOM SCIENCE AND RESEARCH SCIENCE: WHAT ARE THE BENEFITS FOR STUDENTS AND TEACHERS?

By

Angela Lynn Forte

This project documents the meaningful outcomes that arise from pairing secondary, science students and teachers with mentoring scientists in a research environment. It dissects the experiences of nine teachers and ten students along their journey through an intensive summer research experience called STARS. The objectives of this paper are to 1) identify the authentic elements of science that are missing from classroom science, 2) evaluate the changes in scientific perception of participants from the STARS Summer Research Program, and 3) discuss how to bring authentic science into the classroom. A pre-inquiry questionnaire measuring subjects' prior scientific attitudes and beliefs was compared with journal entries, discussion group comments and interview responses, measuring new scientific attitudes and beliefs as a result of STARS. Students and teachers participating in the STARS Program showed enhanced awareness for the authentic culture that surrounds research science. Students expressed new desires to choose a career in the scientific field. Teachers rekindled their passion for science teaching. All subjects were engaged in true scientific inquiry.

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STATEMENT OF STUDY OBJECTIVE

After three years of teaching biology and biochemistry at a high school outside of Detroit, I felt the itch to go into the scientific field. For two years I worked as a biological research assistant with a coalition of scientists led by Noble Laureate, Dr. Alfred Gilman. The project, called the Alliance for Cellular Signaling, is a worldwide effort to map the entire cellular signaling network of a mammalian cell. I was fortunate enough to work within the Alliance's headquarters at the University of Texas Southwestern Medical Center of Dallas (UTSW).

My job doing experiments was a precursor step in a complicated chain reaction of Alliance objectives. I helped establish a protocol for obtaining large quantities of pure Primary B Lymphocytes from mice. Every morning for a year I extracted a dozen mouse spleens, magnetically separated the B cells from other spleen cells, counted the B cells, and used antibody staining to test the purity of my extraction. To my surprise, tweaking this protocol to perfection took the Alliance more than a year. Things never ran smoothly - like they had in my college labs and even in my own classroom labs.

Every day at 12:30 pm I handed off my purified B Cells to a symphony of local Alliance laboratories (our Antibody Lab and Protein Lab), outside university laboratories (Cal Tech, UCSF and Cornell) and pharmaceutical companies – all working in harmony on pieces of the project. At 1:30 pm my local coworkers would stimulate the cells by adding ligands (molecules or compounds that initiate cellular responses) at specific time intervals. The cells were handed back to me. I finished my day by extracting RNA from the stimulated B Cells for microarray chip analysis (a technique that allows researchers to see which genes are turned on or off in a cell).

The highlight of researching with the Alliance did not come from the opportunity to purify B Cells or extract RNA. It came from my encounters with a Nobel Prize winner, Dr. Gilman, and his well-published team of scientists. The best scientists – such as Dr. Gilman himself – had to look up subject matter (content) like the rest of us. They, therefore, were not walking encyclopedias as I had previously thought. Their brilliance came from their foresight, heedfulness, creativity and problem solving abilities – all things I consider to be true scientific inquiry skills.

While working on the Medical Center's campus and observing the inquiry skills of my mentors, I began sensing a "culture" surrounding science that I had not previously known as a science teacher. It consisted of the manner in which researchers carried out "true scientific inquiry." On the surface, it appeared to be different than the scientific inquiry (hands-on activities) being performed by my students. For example, the scientific method did not flow into neat fifty-five minute time packages as it did in my classroom. Scientists navigated their way through conflicting constraints (unanticipated problems solved by utilizing high-level thinking skills) and setbacks in nearly every experiment. Students did not – the textbook company and teachers already did the debugging for them.

Scientists relied on repeated trials, peer review and statistical significance to determine the accuracy of their data. Again, students did not. They relied on the teacher's knowledge of a cut-and-dry, right answer (refer to "Part 1" for an analysis of "true scientific inquiry" versus "classroom scientific inquiry").

Fortunately, I had the chance to further test my ideas about "the culture surrounding authentic science" and "true scientific inquiry" verses "classroom scientific inquiry." A program called Science Teacher Access to Resources at Southwestern (STARS) operated downstairs from my laboratory. It is a summer science program that pairs Dallas area students and science teachers with UTSW researchers and medical professionals. Volunteering my summer as a STARS assistant coordinator, I set out to accomplish the following objectives:

1) identify the authentic elements of science that are missing from my own teaching (PART 1), from the STARS teachers' teaching, and from the STARS students' learning (PART 2);
2) evaluate the changes in perception of participants from the STARS Summer Research Program (PART 3) with specific relation to
    - the authentic culture of science
    - the nature of true scientific inquiry;
3) discuss the constraints of bringing these authentic elements of science into the classroom (PART 4); and
4) seek to create an educator's guide for connecting authentic science to classroom science (PART 5).

RATIONALE FOR STUDY OBJECTIVE

"Leaders in research intensive, high-technology industries increasingly complain that the graduates they recruit lack vital knowledge and skills they will need in the workplace" (National Research Council, 1996). This problem may be blamed on the evolution of formal schooling over the past century. "One of the most common features of relegating education to schools is that skills and knowledge have become abstracted from their uses in the world" (qtd. in Barab & Hay, 2001). In other words, teaching "skills and knowledge as abstract entities" exposes children to the "culture of schools" but not to the "cultures outside of schools" (qtd. in Barab & Hay, 2001).

> Over the last twenty-five years, most of the programs funded by the United States Government for developing modern instruction for the elementary and secondary schools have stressed student involvement in discovery – or inquiry – oriented activities (Trowbridge & Bybee, 1990).

However, "95% of professional development of science teachers remains workshop-based rather than being based on scientific research experience" (qtd. in Westerlund et al., 2002).

Programs attempting to bridge the gap between real science and classroom science are popping up all over the country. One such program in North Carolina called itself, VISION (Vision of Industry and Schools Initiating an Ongoing Network). It was developed to help secondary teachers "experience the real-world applications of science and mathematics in an industrial setting" and "get a better understanding of the type of skills necessary for a technologically oriented work force" (Carter et al., 1998). Teachers engaged in twenty-five days of guided tours through industry facilities. They observed cutting-edge, technical processes, witnessed presentations from management about the importance of coordination and team building, and visited research and development sites. Although teachers did not directly perform science with industry personnel, they were lead through follow-up lessons (i.e. circuit-building activities) by a university science educator. The university science educator then helped teachers digest their industry experiences into classroom lesson plans (Carter et al., 1998).

Programs like the one mentioned above may provide teachers with an exposure to the culture surrounding industry (among other benefits), but they fail to engage teachers in their own true inquiry experience. One may argue that the follow-up, circuit-building activities did allow the teachers to have their own true inquiry experience. Such activities, however, neglect the nuances involved in real research such as generating an idea for a problem that needs to be studied, or solving a problem in which there is no presently known answer to refer to. "Teachers who have learned science facts from textbooks and lectures, but lack scientific research experiences, may have difficulty teaching science by inquiry methods" (qtd. in Westerlund et al., 2002). Another approach is to have students actively participate in scientific investigations directly guided by real scientists.

The National Science and Education Standards state that, "For students to develop the abilities that characterize science as inquiry, they must actively participate in scientific investigations, and they must actually use the cognitive and manipulative skills associated with the formulation of scientific explanations" (2002). In 2000 Barab and Hay published a paper called, *Doing Science at the Elbows of Experts: Issues Related to the Science Apprenticeship Camp*. During this two-week camp, middle school students worked with scientists for two hours each day. For these two hours, campers engaged in discussions with scientists, collected data, and eventually handed over the data for analysis. For the rest of the day, campers discussed their data with peers, e-mailed questions to their scientist, searched the World Wide Web for relevant data and prepared for their final presentations. Evaluators of the two-week camp studied its effectiveness by videotaping and interviewing the campers, and collecting field notes. The data was kept in its natural, qualitative form for analysis (2001).

This study suggests that its participants were doing, "domain-related practices" and "engaging in authentic scientific discourse [...] along with expert scientists who modeled scientific practices and valued the outcomes" (Barab & Hay, 2001). Additionally, its participants perceived "themselves as doing legitimate science and as contributing in meaningful ways to the work of the scientist" (Barab & Hay, 2001). The Barab and Hay paper admits, however, that the short, two-week duration only allowed students to work within a pre-defined structure "supporting someone else's research" (Barab & Hay, 2001). Had the campers' interactions with scientists been longer, students may have had "opportunities to develop and advance their own research agenda" (Barab & Hay, 2001). The paper goes on to suggest that in order to "experience the work that contributes to the creation of a research question" and engage in "long-term, and open-ended investigations" participants should be given longer time frames to work with scientists (Barab & Hay, 2001).

The third example encourages students to engage in their own long-term, "spin-off" investigations. A program in New England called Forest Watch involved students as "active participants in a scientific research collaboration between students, teachers and research scientists" (Evans et al., 2002). Students from one hundred schools used Forest Watch protocols to collect annual growth data from white pines. Data were sent to the University of New Hampshire for analysis. Throughout the research, real-time interaction between classrooms and scientists was encouraged through classroom visits, field trips, or teleconferencing. This leads to one of the program's strengths – leaving students feeling empowered and excited about science (Evans et al., 2002).

In Field Watch, students gain confidence knowing that the data they are providing scientists will be of scientific value. It, however, may leave students "with the perception that science consists only of data collection or that the role of the students is only one of 'data collector'" (qtd. in Evans et al., 2002). Although the program claims to be inquiry-based, it does not allow for students to observe a problem to solve, synthesize a hypothesis, design a protocol, decide what measurements to take, pick proper controls or acquire the correct tools to perform the analysis. If the teacher is highly motivated, he/she can encourage students to conduct their own spin-off projects that may have some value. However, most teachers - including myself - do not have room in their curriculum for such deviation, nor the knowledge and confidence to pull it off.

THE STARS PROGRAM

The STARS (Science Teacher Access to Resources at Southwestern) program seeks to promote sustained reform in science education by linking the educational community of North Central Texas with the scientific community of The University of Texas Southwestern Medical Center in Dallas. Introduced in 1991, its goals include (www.utsouthwestern.edu/stars):

- increasing science awareness
- stimulating an appreciation of health related careers
- providing ongoing support for science teachers and students
- improving science education by broadening the knowledge base of teachers, and
- assisting science education by providing instructional aids.

Reaching out to 850 schools in the Dallas / Forth Worth area, STARS offers several free programs. It invites teachers to participate in hands-on, inquiry-based workshops encompassing topics such as gel electrophoresis and exercise physiology. It disseminates current biomedical developments through symposia presented by UTSW faculty encompassing topics such as surgery and epidemiology. STARS also offers UTSW faculty and staff for science fair judges, tours of UTSW medical and research facilities, and video-conferencing between practicing scientists and secondary classrooms. The heart of STARS, however, remains their summer program for teachers and students – the focus of this study.

This study, in particular, centers on two programs: The Summer Research Program for Teachers, and Summer Research Program for Students. Open to all secondary Texas teachers, Dallas Independent School District juniors and Dallas County Community College District students, these programs seek to immerse participants in real scientific research. Their objective is to offer opportunities to work one-on-one with UTSW faculty researchers on an investigative project in a laboratory setting (STARS, 2002). Every summer nearly twenty different labs agree to mentor a STARS participant. The eight-week programs run simultaneously from June to July. Participants present their research at the end of the summer and are paid a stipend. Major funding for STARS is provided by the state of Texas. Teachers receive $4000 plus a $500 grant for classroom supplies. Students receive $2000. In addition, teachers are asked to write an exclusive, inquiry-based, action plan based on their research. Students are asked to present a power point presentation at their school based on their research (STARS, 2002). Enrollment in other programs [similar to STARS] continues to increase across the country. These programs have been discussed as being “a paradigm for systemic change” in science education (qtd. in Johnson, 2002).

THE UNIVERSITY OF TEXAS SOUTHWESTERN MEDICAL CENTER

The University of Texas Southwestern Medical Center at Dallas (UTSW) contains three degree-granting schools (The Southwestern Medical School, Southwestern Graduate School of Biomedical Sciences and Southwestern Allied

Health Sciences), three hospitals, and one children's medical center. Since all of these institutions are within walking distance of one another, the UTSW atmosphere is congenial to the cooperative links that exist among medical professionals, research scientists and graduate students. Study participants were encouraged to explore this unique relationship.

UTSW also prides itself on being congenial to local area K-12 schools. Its STARS program continues to be a dynamic bridge connecting students and teachers to real-world science. This project attempts to clarify and document the benefits of building that bridge.

PEDAGOGICAL LITERATURE REVIEW

Before attempting to clarify the benefits of the STARS program, it is first necessary to clarify the terminology that will be used throughout this study. The first two definitions are taken from Gott, Duggan and Johnson's 1999 paper entitled, "What do Practicing Applied Scientists do and What are the Implications for Science Education?" They make the distinction between "**conceptual understanding**" and "**procedural understanding.**" Conceptual understanding is "a knowledge base of substantive concepts such as the laws of motion, solubility or photosynthesis which are underpinned by scientific facts, e.g. that distance can be measured in centimeters." Procedural understanding is "the thinking behind the doing of science and includes concepts such as deciding how many measurements to take, over what range, how to interpret the pattern in the resulting data and how to evaluate the whole task" (Gott et al., 1999). In this study, the "culture of science" is heavily rooted in and influenced by scientists' procedural understanding of their research.

The third and fourth definitions aim to unscramble the misinterpretations of inquiry teaching. In their book, Becoming a Secondary School Science Teacher, Trowbridge and Bybee distinguish between **discovery teaching** and **inquiry teaching**. In their terminology, "discovery" occurs when an individual is mainly involved in using his mental processes to mediate (or discover) some concept or principle. It can include observing, classifying, measuring, predicting, describing and inferring (Trowbridge & Bybee, 1990). Grade school students, for example, could use a thermometer, measuring skills and graphing skills to discover the boiling point of water. The scientific community already knows the boiling point of water. These students, however, do not and can discover it rather than being told it by their teacher. Notice the teacher supplied the original problem. The students should run into few logistical difficulties since the teacher has already supplied the materials and pre-tested the lab ahead of time.

On the other hand, Trowbridge & Bybee define "inquiry" as the process of defining and investigating problems, formulating hypotheses, designing experiments, gathering data, and drawing conclusions about problems. It can include originating problems, formulating hypotheses, designing investigative approaches, testing out ideas, synthesizing knowledge and developing certain attitudes (e.g., objective, curious, open-minded, desires and respects theoretical models, responsible, suspends judgment until sufficient data is obtained, checks results) (Trowbridge & Bybee, 1990). A Science Olympiad team (a team that competes in extra-curricular science competitions), for example, could try to build the most efficient model of a steam-propelled car. A blueprint of this car is not available to them. The boiling point of water in this case is a known fact that the team may need to incorporate into the design. Unlike the grade school students, the Science Olympiad students will probably run into many logistical problems. They may have to scrounge around for inexpensive materials, try many different prototypes, and even go the library to research. The odds of building a functional car on the first try are very slim and the students will need to problem solve their way out of glitches. In this case, the teacher cannot give them a clear answer, only guide them with advice.

Now that "inquiry" has been defined, it is necessary to outline the **steps of inquiry** as it relates to a scientific investigation. For these steps I turned to the National Science Education Standards 9-12 grade, Abilities Necessary to do Scientific Inquiry. The following were taken verbatim from part one of Content Standard A.

1. <u>Identify questions and concepts that guide scientific investigations</u>. Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design on an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understandings of scientific investigations (National Science Content Standards, 2002).
2. <u>Design and conduct scientific investigations</u>. Designing and conducting a scientific investigation requires introduction to the major concepts in the area

being investigated, proper equipment, safety precautions, assistance with methodological problems, recommendations for use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also require student clarification of the question, method, controls, and variables; student organization and display of data; student revision of methods and explanations; and a public presentation of the results with a critical response from peers. Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations (National Science Content Standards, 2002).

3. Use Technology and Mathematics to Improve Investigations and Communications. A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results (National Science Content Standards, 2002).

4. Formulate and revise scientific explanations and models using logic and evidence. Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, or mathematical. In the process of answering the questions, the students should engage in

discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation (National Science Content Standards, 2002).

5. Recognize and analyze alternative explanations and models. This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understandings, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students should be able to use scientific criteria to find the preferred explanations (National Science Content Standards, 2002).
6. Communicate and defend a scientific argument. Students in school science programs should develop the abilities associated with accurate and effective communication. These involve writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments (National Science Content Standards, 2000).

EXAMINING MY PREVIOUS TEACHING METHODOLOGIES FOR TRUE INQUIRY (PART 1)

By comparing my previous teaching methodologies to 1) my research experience at The Alliance for Cellular Signaling, and 2) the steps of inquiry as listed above, I began identifying the misconceptions I held about the nature of "procedural science." For example, the experiments in which I was engaged at UT Southwestern could not be contained within neat fifty-five minute packages. In fact, the Alliance for Cellular Signaling spent over a year determining the best approach for their main procedure alone. At times it was hard to even decipher what step of the scientific method was being performed at a given time. This is why the "scientific method" we teach in schools feels artificial to many scientists. As the project ran into constraints, new experiments with their own protocols were being carried out within the framework of the original design.

To my surprise, the Alliance experienced more constraints than success. The technology we needed to use lagged behind the science we were performing. Alliance experiments often did not present clear-cut results to the questions they were designed to answer - unlike my classroom experiments. The Alliance designed inquiries that had no "answer key" and no black and white explanation. In some cases, we did not know how to interpret our data. Was it both accurate and precise or just precise? To my bewilderment respected members of the research team, many of whom had been hand picked by the Nobel Laureate himself, didn't know the answer to this question. This was not due to a lack of intelligence on the part of my overseers, but merely due to the nature of a scientific endeavor itself. Experiments usually had to be tweaked and repeated several times, as well as attacked from different angles. The project is successfully advancing, however, due to Dr. Gilman's exceptional "procedural understanding" of science – his ability to perform a true scientific inquiry.

Ninety-five percent of the biology labs I used as a classroom teacher were completed in a fifty-five minute class period. Equal time was spent on each category of the scientific method (problem, observation, procedure, data collection, data analysis, results and conclusions). There wasn't time in the day, nor room in the curriculum to experiment with "conflictive constraints" or failures. All labs had been previously tested and known to work. Students knew that the answer key (from which a grade would be awarded) had been written ahead of time.

Students received lab equipment and supplies that were meticulously prepared by the biology teaching staff. To ensure the students would finish their lab before the bell rang, concentrations of solutions were already calculated. Exact quantities of materials were presented neatly at students' desks.

Students had the freedom to confer with other students and decipher if their measurements were within an acceptable range. The following day, students were asked to present their data on the overhead projector. We discussed some results as a class. I stood by and watched the kids burn through their erasers trying to enter the "correct" data. After all, I wouldn't want students to misinterpret the concept I was trying to teach. Then the class turned in their labs for a grade. A lecture and/or homework assignment would further reinforce the concept that was "discovered" by the students during their laboratory investigation.

We didn't encourage students to perform an entire lab more than once to solidify his/her findings. Students were too bogged down by after school sports, clubs and jobs. We as teachers did not have space in an already overcrowded curriculum to devote precious class time to the practice of tweaking and repeating experiments for the sake of verifying results. On top of that, we didn't have enough consumable supplies.

While teaching, I became comfortable with the fact that the objective of the lab was to teach a concept (respiration or photosynthesis, for example) that had already been discovered by another scientist. Along the way - as a sub objective – labs modeled a procedural understanding of science. Modeling the procedure of science, however, is extremely different than being "submerged" in it. As shown in the analysis below, my labs never took inquiry science to the next level.

The new paradigm, gained from researching at the Alliance, allows me to analyze my previous teaching methodologies from a scientist's point of view – instead of a teacher's point of view. A lab I chose to analyze is called, *A Chemical Reaction of Living Systems* and can be found in Appendix A. It represents the pedagogical style of close to 95% of the laboratory exercises for my sophomore Biology classes during the years of 1997-2000. The following is a comparison of this lab with Content standard A of The National Science Education Standards - Abilities Necessary to do Scientific Inquiry (2002).

In it's Report of Convocation, the National Research Council states that, "Many classes rely on textbooks heavy on "coverage" but weak on example, so that students are exposed to encyclopedias of fact without ever engaging in the process that is science" (1996). I was sure my biology classes didn't fall into this category. I did not rely on textbooks. In fact, our science department prided itself on stepping into the realm of "inquiry" learning by injecting more labs into the curriculum. I had the misconception I was teaching a "procedural understanding of science" through these labs. In reality, I was modeling the process of science but not truly teaching it. For example, *A Chemical Reaction of Living Systems* fails to engage students in the main process that is science - true scientific inquiry.

First, this lab teaches "content" over "process." Its main objective is to teach about enzymes' roles in regulating cell processes – an objective found on most standardized high school tests. By nature of teaching "content" over "process," students are never requested to synthesize their own problem of study. The curriculum itself initiates the problem to study – never the student.

In Procedure B, students are asked to choose from three possible hypotheses after observing the reaction between hydrogen peroxide and Catalase enzyme solution. Again, students did not formulate their own hypothesis – it was modeled for them. They did not get go to the library, read journal reviews and engage in the investigative background research that a scientist does before developing a hypothesis. In the interest of getting finished before the bell rang, my students randomly circled one of the three.

Question four asks students to design an experiment to test if their hypothesis is right. Although this question attempts to teach experimental inquiry, my students may not take it seriously. They already know that no matter what they write down, it will not be tested in class – unless their experiment matches the upcoming experiment in Procedure D. Even if I emphasized the importance of this question by assigning it for homework, I did not have the time or equipment to have large classes of students all testing a different procedure. Question four left my students feeling disempowered and, therefore, they didn't take it seriously.

In Procedure D, students are asked to follow a procedure that tests which of the three proposed hypotheses is correct. Following an established procedure prohibits students from engaging in the conflictive constraints that often plague researchers. Students are prohibited from asking essential inquiry questions such as: Does my experimental design actually test my hypothesis? What assay should I use? What is the proper equipment to use? What controls are appropriate to use? What criteria should I select in order to accept or reject my data?

Questions six and seven ask students to formulate a scientific explanation using logic and evidence. They ask, "Does hydrogen peroxide, the enzyme, or both change after the reaction?" and "What does this tell you about what an enzyme does in a chemical reaction?" Both questions engage students in formulating an explanation or model based on evidence from their investigation. Most of my labs ask these types of questions. Students are very skilled at developing these types of explanations.

"Is there an alternative scientific explanation for the one we proposed?" "Should we do the investigation over?" Again, students were disengaged from questions like these. Even if they did come up with a brilliant answer, they know we would never use valuable class time to further investigate an alternative. I often shied away from this question for fear of complicating the original concept I intended to convey. Finally, this lab does not ask students to defend a scientific argument. Because this lab teaches a "concept," students know there are predetermined answers to the conclusion questions. Since the lab has been revised several times by the textbook editors or previous teachers, there is usually little to question. Had the students all synthesized and carried out their own experimental design, a peer review (such as one preformed by scientists) would be appropriate. Overall, this lab gave attention to, and modeled the scientific method to students. However, it lacked efficient strategies for teaching scientific problem solving in order for students to develop their own problem-solving process.

In 2000 researchers in the Netherlands characterized the least and most effective strategies for teaching scientific problem solving. The least effective tactic was "merely giving attention to" knowledge of a problem solving strategy – such as merely modeling the scientific method for students. The most effective tactics were "providing the learners with guidelines and criteria they can use in judging their own problem-solving process" and "providing immediate feedback" (Taconis et al., 2000). Unlike the biology labs I had taught, the STARS program appeared to give students the initiative to develop their own problem-solving process. The student/scientist intimacy also appeared conducive for students to receive both criteria for judging their own problem-solving process and immediate feedback.

The following documents the outcome of student/scientist and teacher/scientist pairings in the STARS Summer Research Program. Part 2 identifies the elements of authentic science that were missing from the STARS teachers' teaching, and from the STARS students' learning before entering the program. Part 3 evaluates the changes in perception of STARS participants as they underwent the program. Part 4 discusses the teachers' constraints for bringing their newly discovered elements of authentic science back to the classroom. Finally, Part 5 offers educators a guide for overcoming the constraints of bringing authentic science to students.

METHODOLOGY

RECRUITMENT OF SUBJECTS

The 2002 STARS Summer Research Program participants underwent an intense selection process. High School Juniors from the Dallas area, Dallas ISD and Dallas County Community College District submitted applications in February of 2002. Students were selected on the basis of their class rank, standardized test scores, autobiographical essay, letters of recommendation and personal interview (STARS, 2002). Students were also selected on their interest in science, strong willingness to learn, and an enjoyment of the process of discovery. A strong background in biological science was not emphasized in the selection process (STARS, 2002).

Secondary Science Teachers (grades 7-12) employed in the state of Texas also submitted applications in February of 2002. Teachers were selected on the basis of their classroom performance, enthusiasm, and willingness to develop and incorporate new ideas into the science curriculum (STARS, 2002). A strong background of previous scientific research experience was not emphasized in the selection process (STARS, 2002). Teachers with at least 2-3 years of classroom experience were favored. The selection process was completely independent from this study.

Student and teacher STARS participants reported for an orientation on June 3rd of 2002. After listening to a detailed presentation of this study, subjects were recruited on a voluntary basis. Recruitment strictly followed both IRB guidelines from The University of Texas Southwestern Medical Center at Dallas and UCRIHS guidelines from Michigan State University (Appendix D).

DEMOGRAPHICS OF SUBJECTS

Of the fifteen 2002 STARS students participants, ten agreed to be part of this study. The group was ethnically diverse with two African-Americans, one African-Hispanic, three Asians, one Hispanic and three Caucasians. Seven were female and three were male. Nine of the students were entering into their senior year of high school. One had completed a year of community college. Four of the ten students attended a science and engineering magnet school. Two students attended inner city schools. Two attended prosperous suburban schools. One student attended a small, rural school.

Of the ten 2002 STARS teacher participants, nine agreed to be a part of this study. The group was not ethnically diverse, as all nine teachers were Caucasians. Four were women and five were men. Although the program was open to all Texas secondary teachers, all nine teachers taught in the Dallas / Fort Worth area where the STARS program is based. Four taught middle school science and five taught high school science. The range of professional teaching experience varied from two to eighteen years with a group average of nine years. The range of teaching subjects also varied among the study subjects. Three taught middle school science (advanced, honors and/or regular), one taught middle school earth science, three taught Chemistry (advanced placement, and/or regular), three taught Anatomy/Physiology, two taught biology (advanced placement, pre advanced placement and/or regular), and one taught physics. A majority of the teachers (six of the nine) taught at least one advanced science class (honors or advanced placement).

The STARS program selection committee preferred to pick teachers with little or no previous scientific research experience. Two, however, had participated in smaller programs similar to STARS but less intense. Two others had actually participated in the 2001 STARS program. The returnees were allowed to come back for a second year, but they were required to work on new research projects. Although this subject group was not ethnically or geographically diverse, it appeared to contain a dynamic spectrum of teaching philosophies and competencies.

DATA COLLECTION

In their book, *Qualitative Evaluation and Research Methods*, Michael, Quinn and Patton discuss "Triangulation" as being a valid research approach. In this study, "Triangulation of Qualitative Data Sources" was used. This includes, "(1) comparing observational data with interview data; (2) comparing what people say in public with what they say in private; (3) checking for the consistency of what people say about the same thing over time [...] " (Michael, Quinn, Patton, 467). Multiple sources of information were collected in order to statically evaluate qualitative data by triangulation.

Initially these data collection methods were designed to include the mentoring scientists, in addition to students and teachers. However, because of their busy schedules, most mentoring scientists were reluctant to become involved to the degree necessary to collect sufficient data for this study. Any data that references the mentoring scientists was obtained from student and teacher comments. All data was collected from students and teachers using the following multiple sources:

1) Pre- and Post-Inquiry Tests (Appendix C1, C2, C4 and C5)

The Pre- and Post-Inquiry Tests were designed to measure changes in subjects' perceptions of the culture of authentic science. Most of the questions were centered on the misconceptions I maintained as a teacher, but that dissolved after becoming a researcher. For example, one question asks, "How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?" As a teacher I thought scientists used repeated experimentation and statistical analysis. As a researcher I learned scientists also rely heavily on peer review. Another question asks, "What skills do you need to have in order to set up and perform a scientifically sound experiment?" As a teacher I would have answered, "knowledge of the content." As a researcher I learned one also needs the abilities of synthesizing creative experiments and problem solving around conflictive constraints (more inquiry related skills). I used The National Science Education Standards (excluding content standards) as a tool to refine the questions. Most questions were repeated verbatim from the Pre-Inquiry to the Post-Inquiry tests. Students and teachers completed Pre-Inquiry tests during the first two days of the STARS program. The Post-Inquiry tests were completed eight weeks later on the last day of the STARS program.

2) Weekly Journal Collections (Appendix C3)

I established a weekly dialogue with all nineteen subjects using journal writing. Subjects handed in their journals each week at the beginning of their mandatory STARS discussion group. Journals were copied and given back to participants before the end of the meeting. Subjects were given a new journal prompt to write about each week. Most journal prompts encouraged subjects to reflect upon their feelings, surprises, misconceptions, etc. (see Appendix C3).

3) Weekly Discussion Groups

Weekly discussion groups were a mandatory component to the STARS program. For two to three hours a week students and teachers met (in separate groups) to discuss concerns or reflect upon their experiences. Participants enjoyed mingling and hearing about others' laboratories. The STARS program coordinator and I facilitated the discussions.

4) One-on-One Interviews

Each participant had at least one interview with the STARS program coordinator and myself. Subjects were asked to explain their project, and reflect upon their experience thus far. Interviews were performed during the middle of the program. Aside from formal interviews, I frequently ate lunch with subjects and visited their laboratories. Most informal conversations were recorded after the conversation took place. These informal conversations were also considered interviews.

5) Presentation Evaluations

During the last day of the eight-week program, participants presented research posters. The ten-minute presentations were similar to a mock, peer-editing session. Scientists from each mentoring lab participated, and in some cases, questioned participants on the validity of their research methodologies. Subjects took this occasion seriously, as it was the culmination of their summer experience. During these presentations, I recorded notes. These notes proved helpful in later determining the level of inquiry in which the subject participated.

DATA ANALYSIS

Quotes of significance from all subjects were extracted from all five data collection methods. Each comment was entered into a computer. The quotes of significance included comments from subjects pertaining to "the culture of science" (including feelings about mentors, initial surprises, previous misconceptions, impressions of scientific meetings, changes in attitudes, etc.). They also included comments pertaining to "inquiry" (day-to-day events, encountering problems, navigating around problems, performing steps of the scientific method, questioning results, experiencing failures, the process of coming to a conclusion, etc.). Comments pertaining to an explanation of "content" (such as, "The film detects the amount of SoD1 protein needed for depression of an aggregate that causes FALS.") were not included. Comments irrelative to science (such as "I went to the cafeteria to get a turkey sandwich.") were also not included.

The quotes of significance used for data analysis totaled 384 (165 from the students and 219 from the teachers). Quotes were then clustered into patterns of significance. These patterns of significance can be found in Appendix C (labeled as "Student Quotes" and "Teacher Quotes"). Student and teacher quotes were kept separate from one another.

One may argue that these patterns of significance should have been cross-examined by a second observer to avoid the interpreter effect. "The interpreter effect occurs when two or more individuals observe the same phenomenon, but evaluate the results differently depending on their prior knowledge" (McComas & Moore, 2002). Including a second examiner into this study was not possible. Internal Review Board (IRB) standards regarding subject confidentiality required me to keep all data private. Second observers within the STARS program would easily figure out which participant wrote which quote. Second observers outside the STARS program would introduce inaccuracy into the study interpreting quotes out of their intended context.

The two goals of the data collection were to 1) determine whether the STARS experience changed students' and teachers' perceptions about the culture surrounding authentic science and 2) determine whether the STARS experience engaged students and teachers in true scientific inquiry. To determine the results of the goal 1, the students and teachers were asked the following questions on the Pre-Inquiry test, Post-Inquiry test and randomly during journal prompting, group discussions and interviews. Their responses (quotes of significance and answers to Pre/Post Inquiries) were scored using a scoring rubric (see Figures 1 & 2). A subject's rubric score, therefore, represents a blended composite of journal entries, interview responses, discussion group comments and Post Inquiry answers.

> What are your career aspirations after having experienced the STARS Program? (for students only)
>
> In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do his/her job well?
>
> How often do you keep up with the latest developments in science and technology? What sources do you enjoy using?
>
> Do you see yourself as a scientist as well as a student (or science teacher)? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to be a scientist?
>
> How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?
>
> Describe the qualities of a good scientific notebook. Explain why these qualities are important.
>
> Do you think most scientists follow the scientific method? Do you think most scientific knowledge was acquired by using the scientific method?
>
> What is an experimental control? Is a control necessary in every scientific experiment? What is an experimental standard?
>
> How important are good communication skills to a scientist?
>
> What skills do you need to have in order to set up and perform a scientifically sound experiment?
>
> From the previous question: Which of these skills do you feel you possess? Which of these skills do you need to work on?
>
> What is the difference between science and technology?
>
> Do you feel you now have new links to the scientific community? If so, how will you utilize these new links in your classroom next year? (for teachers only)

Will you feel more confident supervising independent, student research projects or science fair projects? (for teachers only)

After having the STARS experience, do you feel it is more important to incorporate disciplines other than science into your classroom? (for teachers only)

To determine the results of goal 2, I used the following question:

To what degree did students and teachers participate in true scientific inquiry?

To answer this question, subjects' clusters of significance relating to "inquiry" (see Appendix C) were scored using a third scoring rubric (see Figure 3).

The scoring rubrics (as shown in Figures 1,2 and 3) scored answers on a scale of 1-5. A score of five indicates that the subject underwent a change in perception about the culture of science (Figures 1 & 2) or experienced true inquiry science (Figure 3) as a result of their STARS experience. A score of one indicates that the subject developed further misconceptions about the culture of science (Figures 1 & 2) or the nature of true inquiry science (Figure 3) as a result of their STARS experience. Because Pre-Inquiry questions did not have a right or wrong answer, all Pre-Inquiry answers were scored at a baseline of two. A score of two on the rubric scales represents no change.

Figure 1: Student's Triangulation Rubric – The Culture of Science

Measuring Changes in Perception
Relating to "The Authentic Culture of Science"

Subject's Pre- and Post-Inquiry test answers changed significantly. **And / or** Subject reflected upon the change in journal, group discussion, interview or final presentation twice or more.	5
Subject's Pre- and Post-Inquiry test answers changed slightly. **And** Subject reflected upon the change in journal, group discussion, interview or final presentation once.	4
Subject's Pre- and Post-Inquiry test answers changed slightly. Subject did not, however, reflect upon the change in journal, group discussion, interview or final presentation. **Or** Subject's Pre- and Post-Inquiry test answers did not change. Subject did, however, reflect upon the topic in journal, group discussion, interview or final presentation.	3
Subject showed no change in answer from Pre-Inquiry test to Post-Inquiry test. **And** Subject did not reflect upon the topic in journal, group discussion, interview or final presentation.	2 Base- line
Subject shows change in answer from Pre-Inquiry test to Post-Inquiry test, but the change further increases misconceptions or confusion about the topic. **And / or** Subject reflects upon the topic in journal, group discussion, interview or final presentation, but the reflection indicates further misconception or confusion about the topic.	1

Figure 2: Teacher's Triangulation Rubric – The Culture of Science

Measuring Changes in Perception
Relating to "The Authentic Culture of Science"

Subject's Pre- and Post-Inquiry test answers changed significantly. **And / or** Subject reflected upon the change in journal, group discussion, interview or final presentation twice or more. **And / or** Subject made an attempt to bring this change into the classroom by creating or updating teaching materials.	5
Subject's Pre- and Post-Inquiry test answers changed slightly. **And** Subject reflected upon the change in journal, group discussion, interview or final presentation once. **And / or** Subject discussed the necessity of bringing the change into their classrooms.	4
Subject's Pre- and Post-Inquiry test answers changed slightly. Subject did not, however, reflect upon the change in journal, group discussion, interview or final presentation. **Or** Subject's Pre- and Post-Inquiry test answers did not change. Subject did, however, reflect upon the topic in journal, group discussion, interview or final presentation. **And** Subject did not connect this topic to their teaching methods.	3
Subject showed no change in answer from Pre- Inquiry to Post-Inquiry test. **And** Subject did not reflect upon the topic in journal, group discussion, interview or final presentation. **And** Subject did not connect this topic to their teaching methods.	2 Base- line
Subject shows change in answer from Pre-Inquiry test to Post-Inquiry test, but the change further increases misconceptions or confusion about the topic. **And / or** Subject reflects upon the topic in journal, group discussion, interview or final presentation, but the reflection indicates further misconception or confusion about the topic.	1

Figure 3: Student and Teacher's Triangulation Rubric – True Scientific Inquiry

Measuring the Degree to which True Scientific Inquiry was Experienced

Subject was able to develop and advance his/her own research agenda. Subject self-directed their own inquiry activities to further their research agenda. Scientist only served to give advice and support subject's research. Scientist developed trust in subject's ability to work on a self-directed project. Subject experienced conflictive constraints, but was able to problem solve around these constraints.	5
Subject was able to advance the research agenda of the mentoring lab. Subject's participation in inquiry activities was half self-directed and half scientist-directed. Scientist developed trust in subject. Subject experienced conflictive constraints and was able to problem solve around these constraints with the help of the scientist.	4
Subject was able to advance the research agenda of the mentoring lab. Subject participated in or observed inquiry activities that were mostly scientist-directed. Scientist did not fully trust subject's ability to self-direct experiments, however, scientist and subject had a positive working relationship. Subject was able to observe the scientist problem solving around conflictive constraints.	3
Subject was not allowed to develop his/her own research agenda. Subject was not allowed to develop or advance the research agenda of mentoring laboratory. Subject was scientist-directed. Subject mostly participated in predetermined procedures that required the following of others' directions. Subject was not able to witness or observe conflictive constraints because subject was mostly unattached from the research problem.	2 Base-line
Participation in research increased or created misconceptions about the "process of science" and the nature of an authentic inquiry investigation.	1

After qualitative data was transformed into quantitative data (using the scoring rubrics), the mean of the student group and the mean of the teacher group was determined for each question (see Tables 1, 2 & 3).

RESULTS

In line with what Michael, Quinn and Patton spoke of in their book, *Qualitative Evaluation and Research Methods*, Triangulation proved to be a "powerful solution to the problem of relying too much on any single data source or method, thereby undermining the validity and credibility of findings because of the weakness of any single method" (1990). Of the five data sources (put into one of three rubrics), the subjects' journal entries provided me with the most intimate and detailed accounts. Teachers uninhibitedly wrote about their feelings, struggles, day to day work and impressions of their mentors. Because I couldn't observe all nineteen labs at the same time, journal entries acted as a substitute video camera recording day-to-day laboratory events as seen through the lens of the participant.

Weekly discussion groups and oral interviews became the second most valuable pieces of data. Accounts were often passionate and descriptive. Topics, however, were often initiated by myself or the STARS Program Coordinator. Some subjects preferred talking over journal writing, while others felt intimidated by talking in front of people.

Pre- and Post-Inquiry test answers proved to be less beneficial. Although I tried to ask open-ended questions, subjects still were obliged to comment only about the topics being asked. Answers proved to be general in nature – unlike journal entries, discussion groups and interviews. Subjects completed the Post-Inquiry test after presenting their final presentations. Most subjects were exhausted and eager to say one last goodbye to their laboratories. Consequently, some subjects wrote quick and non-descriptive answers. Lastly, the subject's final presentations became useful reiterations and further reinforcement of the previous four methods of data collection.

BEFORE STARS –IMPRESSIONS OF SCIENCE AND SCHOOL (PART 2)

Perhaps the most powerful rationale for this study can be found within the voices of the STARS' teacher and student participants. Two of the nine teachers categorized their previous school labs as being cookbook in nature. Six teachers categorized their previous school labs as being a mixture of cookbook and inquiry. Seven teachers expressed the desire to bring more inquiry science into their classrooms. Five said their goal in STARS was to develop more inquiry labs for school. Five said their goal in STARS was to learn new "real-world" or "cutting-edge" science techniques.

Nine of the ten students participating in this study (90%) were critical of their previous school science education. Students were eager to share these previous classroom science experiences during all weeks of the study. Teachers' reflections of how they taught paralleled what the students were saying (refer to the clusters of significance found in Appendix C).

Student One best summed up the laboratory experience of most students in this study:

> At school a lab was set up with everything. All I basically had to do was fill in some basic blanks. The problem / hypothesis was

> always started, the materials were set out on the table. The procedures were already included. All I had to do was replicate the experiment and get data. Even for the conclusion I was given questions that would lead me to what was to be the accepted outcome to get a 100% or to understand the outcome. Even through it isn't a very effective way to learn or to proceed in research I believe that those experiments were not truly experiments but rather just examples. Thanks to them I learned such things as how different elements behave, about phase changes. In a real experiment I feel I would be better prepared to recognize such characteristics that would allow me to distinguish what is causing what in my data. (S1 – journal)

Above, Student One believed that her "experiments were not truly experiments [involving inquiry] but rather just examples" from which important "concepts" (element behaviors, phase changes) were learned.

Many other student quotes suggested their previous school labs were strong on conveying concepts, but weak on conveying the abilities necessary to perform true scientific inquiry. Under "The Abilities Necessary to do Scientific Inquiry (Content Standard A)" the National Science Education Standards require students to, "formulate a testable hypothesis." For Student Three, formulating a testable hypothesis was not emphasized in her previous science classes. She wrote:

In my Chemistry and Biology classes when we were doing labs, the procedure seemed to be the most important part to the students. Even though the results and conclusion were what the teachers actually cared about, the procedure was what the students worried about. If you didn't follow the right procedure, your results would not be accurate which made a difference in the grades. (S3 – journal)

Student Three's statements are backed up by Teacher Eight's statement:

I suppose my students participate in the procedure portion more than the other steps. Let's face it – it's easier. (T8 – journal)

Student Eight indicated that in his science class the experiments were assigned for the week and he mainly participated in just data collection. This indicates that the student does not use the opportunity to observe a problem, formulate a hypothesis to that problem, or even make sure that the design of the experiment fits the hypothesis. He wrote:

Last year at TAMS [a science and engineering magnet school], I mainly participated in the "Experiment" part of the scientific method (since the whole class was devoted to doing the experiments)…All the lab time was devoted to performing the experiments assigned for that week…So, much of the time, lab was just data collecting and occasionally some minor math calculations. (S8 – journal)

Only allowing students to focus on data collection does not give students the opportunity to initiate a problem to be tested, formulate their own hypothesis or develop procedures to test the hypothesis. Teacher Six admitted:

> Students – usually have trouble formulating the hypothesis, they enjoy the experiment part the most. (T6 – journal)

Sadly, one student even wrote:

> Last year in AP Biology, we did not do any labs. We just read the book and took tests…We did nothing but read other individuals' results. (S5 – journal)

Students also appeared to not have practice at designing and conducting scientific investigations – another requirement of Content Standard A -, since the procedures were already prepared for them.

> In classes, science is often black and white. The teachers already have a set way of performing the experiments. There is usually not much (if any) room for questioning the way the procedure has to be done. However, real life science is often full of surprises and that way a researcher believes something should be is often different from the way it actually is. (S3 – journal)

"In school the procedures are already there," confirmed S6 in her interview. Student Nine agreed as she stated, "Our teacher would tell you exactly what to do and measure" (S9 – interview). It appears the study teachers are aware of this problem and trying to fix it. Teacher Seven wrote, "I know I would like to reach a point where my students are writing out the labs instead of these recipe labs."

Content Standard A also requires students to recognize and analyze alternative explanations and models (NSES, 2002). This appears hard to accomplish when the teacher grades lab results using a predetermined answer key. For example Student Four wrote:

> In school, I mainly just did experiments. We often did not analyze the data answers or if we did we would often be wrong and the teacher would have to tell us the correct answer anyway. (S4 – journal)

Teacher Three's students did not even really perform a data analysis, "Students are usually involved in data collection the most. Most analysis is left out or done independently."

Lastly, Content Standard A requires students to communicate and defend a scientific argument (NSES, 2002). In Teacher One's opinion, students are never asked to defend the "whys" of how an experiment was run. In reality, defending a scientific argument is a large part of a scientist's job. She wrote:

> I felt that my students participate in actually doing for the experiment. The theoretically / logically system in which a scientist goes through finding the answer - i.e. the set up of the experiment, is lost on my students. I feel that they just see the results instead of the whys (why did you pick this chemical instead of that chemical) and how (why did you run a spec 20 instead of calorimeter). Here,

> you did the actual set-up of the system to carry out your experiment. Thus, this could answer the question: Why students do not understand what they did in lab even though they performed the experiment. (T1 – journal)

Overall, student and teacher comments consistently demonstrated that lab experiences prior to STARS were slightly rooted in discovery learning but not rooted in inquiry learning.

DURING STARS – IMPRESSIONS OF SCIENCE AND SCHOOL (PART 3)

Stepping into the culture of research lead to a mixture of initial surprises for both students and teachers. Four of the ten students commented about the scientists' work ethic. For example, Student Five was shocked at the absence of a clock-in, or set time schedule. Four of the students were taken aback by the amount of freedom they were given in the laboratory. Three of the nine teachers were alarmed by the cost of doing research. Teacher Four couldn't believe that ten milliliters of a substance cost $280. Three students and three teachers held misconceptions about the time-line of research. "I thought things progressed a lot more smoothly and quicker – not the case in science," said Teacher Three. Finally, three of the ten students were surprised at the diversity of jobs within the medical center. Several of them enjoyed reading the title plaques over each door as we walked to lunch. Student Three wrote:

> In hospitals you see doctors and nurses working on their patients. Medications are prescribed and treatments are under-went. This is

> what people expect to see in hospitals. However, since there are many different kinds of doctors that work in the hospital, there are many different kinds of jobs they do (besides signing for a prescription). In the pathology department, doctors specialize in many different kinds of treatment that a regular physician may not ever have to worry about…(S3 - journal)

After the initial surprises wore off, subjects began interacting with the laboratory personnel (including Ph.D.'s, M.D.'s, lead scientists, medical students, graduate students and laboratory technicians). Students' impressions of researchers began to change. Five of the ten students were able to dissolve their previous misconceptions about scientists. As Student Seven bluntly put it, "Research isn't just a bunch of nerds who have no life, it's just normal people." Student Four is reassured about the number of young people in research. Students One and Three are surprised that their mentors don't have all the answers. "I thought before scientists came up with ideas miraculously," said Student Three. Teachers, on the other hand, did not hold these same previous misconceptions.

Six of the students commented on having positive interactions with the researchers. Student Eight wrote:

> The people at the office labs and General Clinic Research Center are very nice. They are very helpful and extremely patient with a novice like myself. They laugh at mistakes more than I do. I am very fortunate to work with all these nice yet sophisticated people.

On the same note, Student Ten wrote, "Everyone in the lab seems to be extremely helpful and talkative. They seem to be people who would give me advice on any issue." Three of the nine teachers, on the other hand, fixated on the fact that the researchers seemed almost too busy to help. Teacher Five expressed the most extreme point of view:

> When I visited with the PI [Principal Investigator] before the summer began, I thought he was going to be more hands on with me than he is. He was to leave (go out of town) a couple of days after I first began work and seemed very distracted and didn't have time to talk to me. He frankly seemed annoyed that I was there – one more thing to deal with.

In this case, the teacher was able to befriend and learn from other laboratory personnel. In fact, almost all subjects experienced a setting similar to Teacher One. In her interview, Teacher One said she learned two different perspectives by working with both lab technicians [usually at the lower end of the hierarchy] and doctors [at the higher end]. In her interview Teacher Eight said, "I didn't realize the techs were people that do the procedures…the techs know every protocol but don't know the "whys" to the problem."

Subjects further observed the world of scientists' at weekly meetings, where they began to peek into the "culture of science". Six of the students and four of the teachers commented on their impressions of these meetings. Student Six witnessed the value of peer review in science. She told me in her interview, "There was a paper being published and I got to see them pick it apart." Student

One also caught a glimpse of a peer review session. She wrote during a meeting in her journal:

> The data was controversial in the sense that the outcome had been unexpected and there was speculation on why that followed. The reasons that caused me to write that the data was a bit controversial. The words that followed were "weird results", "are you sure?" and "how was your experiment carried out?" The last question was asked several times and gone over in great detail. [Her mentor] was asked to review the data and replicate the experiment.

Teacher One was surprised by the "hush-hush attitude" at these meetings. Teacher Four witnessed the devastation his lab felt when their paper was initially rejected by the Journal of Neuroscience.

Observing the "culture of science" also included the viewing of surgeries and other procedures involving patients. Three of the ten students commented on this. Student Ten wrote, "One thing I did not expect to do this summer was watch surgeries. My mentor allowed me to stand right behind him as he operated. I got to experience the life of a surgeon…" Teachers had similar experiences, but did not comment as extensively as the students did.

Observing the culture that surrounds science was not the only favorable outcome of being involved in the STARS program. Subjects also found themselves involved in "true scientific inquiry" (as discussed above, the standard used to measure true inquiry was taken form The National Science and

Education Standards). The following paragraphs discuss how subjects used inquiry skills to navigate their way through the scientific method.

The National Science Education Standards require learners to be engaged in scientifically oriented questions (NCR, 2000). At the highest level, students would pose a question based on their previous observations of the natural world. At the very least, students would sharpen, clarify or engage in a question provided by the observations of a teacher, mentor or other source (NCR, 2000). Only Student Three posed her own research problem to study. She observed and felt impassioned by the lack of African American blood donors for Sickle Cell Anemia patients and wanted to study the problem.

Most subjects adopted the research question of their assigned lab. For this same reason, an equally low number of subjects developed their own hypotheses (only one student and one teacher). For example, since her laboratory was still in the beginning stages of their project, Teacher One was able to advance her own hypothesis. She wrote, "At this point in the lab – I expect from the articles that I am reading that my cells will convert to osteoblasts. I also expect that once they achieve that level then they will not stay osteoblasts long."

AFTER STARS – IMPRESSIONS OF SCIENCE AND SCHOOL AS A RESULT OF STARS

Table 1: Student Triangulation Results – The Culture of Science

Questions (Corresponding with Figure 4 below)	**Sample Number**	**Mean Composite of Triangulated**

		Triangulated Data
1. What are your career aspirations after having experienced the STARS Program?	9	4.4
2. In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do her/his job well?	8	3.1
3. How often do you keep up with the latest developments in science and technology? What sources do you enjoy using?	8	3.6
4. Do you see yourself as a scientist as well as a student? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to be a scientist?	8	2.8
5. What percentage of scientific endeavors and experiments are failures or involve conflictive constraints?	8	4.0
6. How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?	8	2.7
7. Describe the qualities of a good scientific notebook. Explain why these qualities are important.	8	2.6
8. Do you think most scientists follow the scientific method? Do you think most scientific knowledge was acquired by using the scientific method?	8	2.6
9. What is an experimental control? Is a control necessary in every scientific experiment? What is an experimental standard?	8	2.9
10. How important are good communication skills to a scientist?	8	3.1

11. What skills do you need to have in order to set up and perform a scientifically sound experiment?	7	3.6
12. From previous question: Which of these skills do you feel you possess? Which of these skills do you need to work on?	5	3.6
13. What is the difference between science and technology?	7	2.2

Figure 4: Student Triangulation Results Graph – The Culture of Science

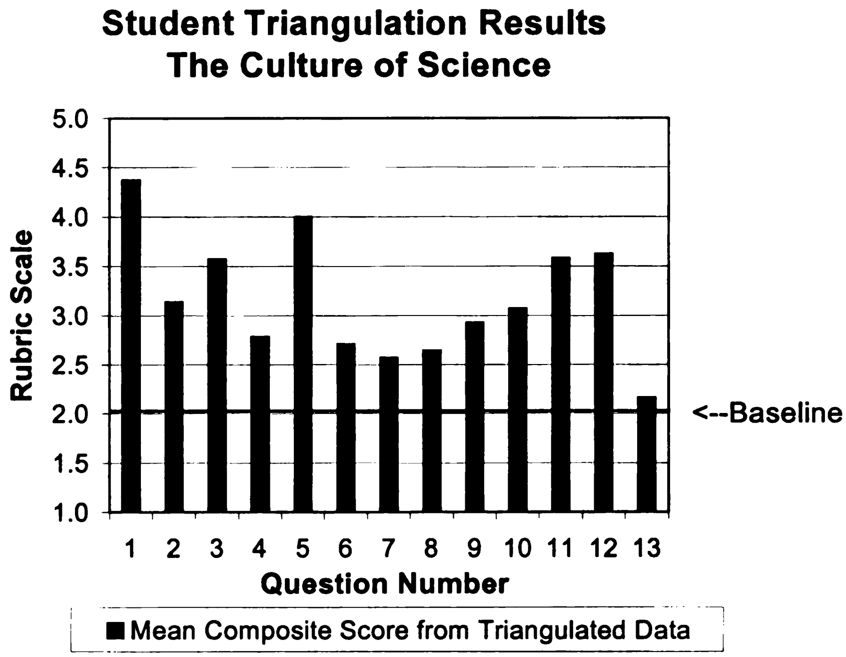

Figure 4 shows the extent to which students were affected by the culture of science experienced at STARS. All composite mean scores were above the baseline of 2. The baseline of 2 from the rubric scales represents no change. Question One demonstrates (with a mean composite of 4.4 out of 5) that the STARS Program significantly affected students' career aspirations. A mean of 4.4 indicates that students' Pre- and Post-Inquiry answers changed more than slightly, and students reflected upon the change in their journal entries, group discussions, interview responses or final presentation comments between one to two times (see Rubric, Figure 1). Student Seven stated the following in her Post Inquiry:

> STARS has really opened my eyes up to pursuing a career in research. This program has reiterated to me the importance that

> science has [working to find a cure for Multiple Sclerosis]. I will most definitely be pursuing a career in the sciences, this program has solidified that thought. (S7 – Post-Inquiry)

Student One echoed Student Seven's thoughts:

> There are lots of career paths and fields opened most that had it not been for STARS I would never known existed. I mean a whole lab concentrated on the study of how just one single protein interacts…(S1 – Journal)

Question Five – resulting in the second highest mean of 4.0 – shows that students were surprised at the amount of conflictive constraints or failure involved in real science. A mean of 4.0 indicates that students' Pre- and Post-Inquiry answers changed slightly, and students reflected upon the change in their journal entries, group discussions, interview responses or final presentation comments once. When asked what the most profound thing learned in STARS was, Student Eight responded, "I learned that failure is an option, mistakes will happen and are acceptable only if one learns from THEM!" Likewise, Student Three wrote, "Things often go wrong in science and no one can do anything about it but go on and learn form your mistakes."

In a tie for third and fourth highest means are Question Three and Question Eleven with a 3.6. A mean of 3.6 indicates that students' Pre- and Post-Inquiry answers changed slightly, but students probably did not reflect upon the change in their journal entries, group discussions, interview responses or final presentation comments (or vise-versa). Question Three demonstrated that students will now be more likely to keep up with the latest developments in science and technology as a result of being in the STARS program. Student Nine wrote:

> I have seen so many awesome developments in which science and technology work hand in hand to make human life more comfortable. This has sparked an interest in me and I am going to keep up with more developments by watching the news and discovery channel, reading scientific journals and keeping in touch with my lab people and doctor!. (S9 – Post Inquiry)

Finally, Question Eleven indicates students changed their perspectives concerning what skills are necessary in order to perform a scientifically sound experiment. For example, students cited careful handling of a substance, meticulous and accurate measurements, knowledge of past related studies, a background on the equipment and how it works, money management, being able to write a grant, and being a logical person as the skills they now feel are important to perform a sound experiment (Post-Inquiry answers from various students).

The lowest student mean of 2.2 resulted from Question Thirteen, "What is the difference between science and technology?" A mean of 2.2 indicates that students showed little change from their Pre- to Post-Inquiry answers, and didn't reflect upon the topic in their journal entries, group discussions, interview responses or final presentation comments. As discussed below, the difference between science and technology question also scored the lowest mean for teachers (Table 2).

Table 2: Teacher Triangulation Results – The Culture of Science

Questions (Corresponding to Figure 5)	**Sample Number**	**Mean Composite of Triangulated Data**
1. In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do her/his job well?	7	2.8
2. How often do you keep up with the latest developments in science and technology? What sources do you enjoy using?	6	3.3
3. Do you feel you now have new links to the scientific community? Is so, how will you utilize these new links in your classroom next year?	7	5.0
4. Will you feel more confident supervising independent, student, research projects or science fair projects?	6	3.6
5. After having this STARS experience, do you feel it is more important to incorporate disciplines other than science into your classroom?	6	3.3
6. Do you see yourself as a scientist as well as a science teacher? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to be a scientist?	6	2.5
7. What percentage of scientific endeavors and experiments are failures or involve conflictive constraints?	9	4.3
8. How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?	7	2.9
9. Describe the qualities of a good scientific notebook. Explain why these qualities are important.	6	3.3

10. Do you think most scientists follow the scientific method? Do you think most scientific knowledge was acquired by using the scientific method?	6	2.3
11. What is an experimental control? Is a control necessary in every scientific experiment? What is an experimental standard?	7	3.4
12. How important are good communication skills to a scientist?	6	2.6
13. What skills do you need to have in order to set up and perform a scientifically sound experiment?	7	3.4
14. From previous question: Which of these skills do you feel you possess? Which of these skills do you need to work on?	6	2.4
15. What is the difference between science and technology?	6	2.1

Figure 5: Teacher Triangulation Results Graph – The Culture of Science

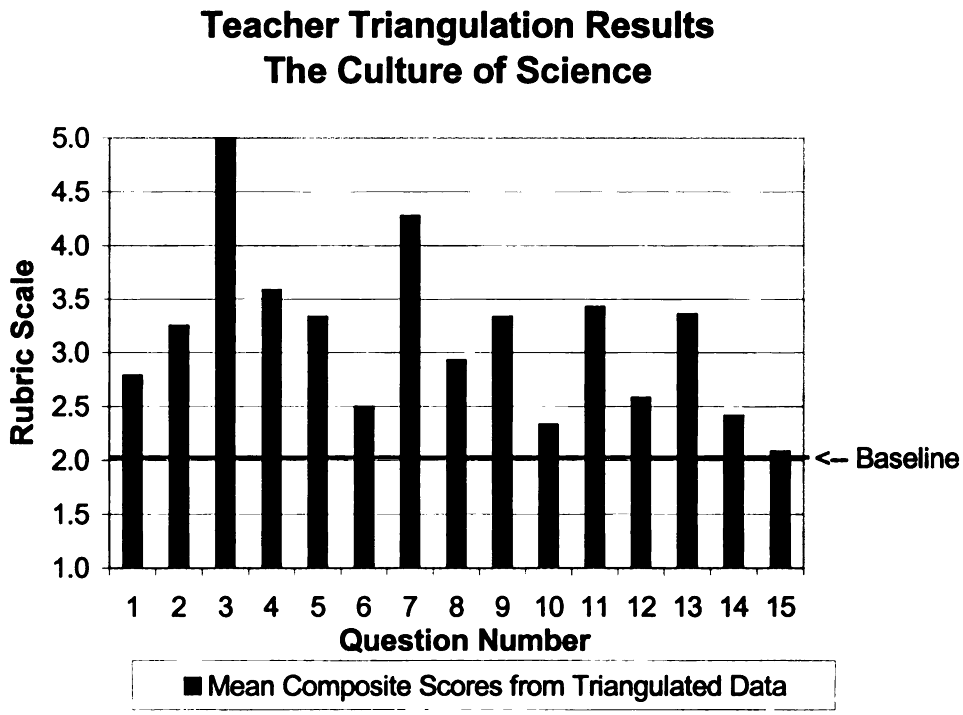

Figure 5 shows the extent to which teachers were affected by the culture of science experienced at STARS. Like the students, all teacher composite mean scores were above the baseline of 2. Again, the baseline of 2 from the rubric scales represents no change (Figure 2). All teachers felt they had new links to the scientific community. This topic, Question Three, had the highest teacher rubric score mean of 5 out of 5. A mean of 5.0 indicates that teachers' Pre- and Post-Inquiry answers changed significantly, and/or teachers reflected upon the topic in their journal entries, group discussions, interview responses or final presentation comments twice or more, and/or teachers made an attempt to bring this change into the classroom by creating or updating teaching materials (Figure 2). Teacher Eight stated, "I will not hesitate to call for science fair info, judges, etc. I also plan on becoming a regular fixture at the warehouse [where teachers can take used UTSW equipment]." Teacher Seven stated, "I will take my students here [UTSW] to show them the research world."

Like the students, teachers were also surprised by the amount of conflictive constraints or failures involved with scientific research. This question, Question Seven, resulted in the second highest teacher rubric mean of 4.3. A mean of 4.3 indicates that teachers' Pre- and Post-Inquiry answers changed slightly, and/or teachers reflected upon the topic in their journal entries, group discussions, interview responses or final presentation comments once or more, and/or teachers discussed the necessity of bringing the change into their classrooms (Figure 2). For example, when asked what the most profound things learned as a result of STARS were, Teacher One wrote, "failure is a guarantee…my failure to gain results is amazing." Teacher Eight wrote:

> Yesterday we were reviewing some data on some double blind dissections and cultures, but there was a big problem. Our data <u>consistently</u> was the opposite of our hypothesis. If the data is consistently wrong, it might mean that a previous research study was wrong. That means starting over again (T8 – journal).

Teacher Six also voiced his labs' concerns during the weekly discussion group, "Everything came back wrong, probes not reading, [we] gathered RNA and it was degraded, had a week of failure, we will re-grow the culture now to increase the number of cells to use."

The third highest rubric mean (3.6) resulted from Question Four, "Will you feel more confident supervising research projects or science fair projects?" A mean of 3.6 indicates that teachers' Pre- and Post-Inquiry answers changed slightly, or teachers reflected upon the topic in their journal entries, group discussions, interview responses or final presentation comments once (or vise versa), and teachers did not fully discuss the necessity of bringing the change into their classroom (Figure 2). Teacher One wrote, "yes – more exposure to science taught me that I can handle cutting edge research so I can handle explaining the harder concepts better to my students."

Tied for fourth and fifth with a mean of 3.4 (similar to Question Four) were questions Eleven and Thirteen. Question Eleven indicates that teachers felt differently about experimental controls after STARS. For example, Teacher Two wrote, "I have also learned the importance of having both negative and positive controls in an experiment…I have some good examples of what happens when your negative control turns out to be positive after testing." Teacher Nine agreed with Teacher Two by saying, "I intend to take positive and negative controls into my classroom." Finally, like the students, teachers had a change in perception about defining the skills necessary to perform a scientifically sound experiment (see Question Thirteen). They now cited patience, using good and clean equipment, being precise and accurate, and paying attention to small details, etc (Post-Inquiry answers from various teachers).

The lowest results for teachers, regarding the culture of science, were from questions Ten (mean of 2.3) and Fifteen (mean of 2.1). Means of 2.3 and

2.1 indicate that there was little to no change in the teachers' Pre- and Post-Inquiry answers, and teachers did not reflect upon the topic in their journal entries, group discussions, interview responses or final presentation comments (Figure 2). Question Ten asked teachers their thoughts regarding the scientific method and the extent to which it is followed in a research laboratory. Question Fifteen asked teachers to identify the difference between science and technology.

The most overwhelming positive change occurring in teachers was not directly asked on the Pre-Inquiry, but it is worth discussing. Journal Entries, Discussion Group Comments and Interview Responses were flooded with teachers' ideas for bringing the UTSW culture back into their classrooms. For example, eight of the nine teachers stated they would increase the amount of conflictive constraints or failures for students in lab. When asked what the biggest student misconception was, Teacher Six responded, "Students don't realize the error and failure associated with science." Teacher Four wrote, "I plan on designing more open ended labs that do not work for the purpose of increasing problem solving." Teacher Two agreed:

> We always set students up to make them successful. I'm learning that's not the best way to go with my students. I've had to start over with 250 samples 3 times…I learned how to really sit down and analyze data.

Three teachers confirmed they will now place more emphasis on the use of student notebooks. Three teachers expressed the need for better student accuracy in lab. Four teachers wanted to now emphasize new techniques (such as micro pippeting and sterile procedure). Three teachers expressed the need for more data analysis and interpretation in their classes (such as a focus on statistics and graphing, and refraining form making faulty conclusions).

Table 3: Student and Teacher Triangulation Results – True Scientific Inquiry

Questions	**Sample Number**	**Mean Composite Of Triangulated Data**
1. To what degree did **students** participate in true scientific inquiry?	10	3.3
1. To what degree did **teachers** participate in true scientific inquiry?	9	4.1

The most encouraging data in this study centers on the subjects' submersion within true scientific inquiry during their STARS experience. Table 3 demonstrate that most students either participated in or observed inquiry activities. Their Rubric mean was 3.3. A mean of 3.3 indicates that the student was able to advance the research agenda of the mentoring lab, participate in inquiry activities that were mostly scientist-directed, and have a positive working relationship with the scientist (Figure 3). Although most of these inquiry activities were mentor-directed as opposed to self-directed, students benefited from seeing and helping their mentors problem solve on a daily basis.

Teachers were submerged within inquiry to an even higher degree than students. Their rubric mean was 4.1. A mean of 4.1 indicates that the teacher was able to advance the research agenda of the mentoring lab, participate in inquiry activities that were half self-directed and half scientist-directed, develop trust with the scientist, and problem–solve around conflictive constraints (Figure

3). Many teachers acquired their own research projects from their mentors and, therefore, engaged in more self-directed projects than the students.

Overall, the above results parallel the statements of a teacher, Milton Johnson, who participated in a program similar to STARS at Arizona State University. In his article, *Teacher as Researcher*, Johnson analyzes the benefits of working for three summers in the Research Experience for Teachers (RET) program. He stated:

> Here I learned the process of actually doing science – truly using inquiry and the scientific method. Researching literature, asking questions, preparing the experiment, analyzing and interpreting data, and peer review are all as critical to the experiment as the actual test run. I was also reminded that in doing actual research, failure is more common than success (Johnson, 41).

Johnson also states the program has helped him "become more confident in managing students' science fair projects" (Johnson, 42). Every year his students tour the labs and meet the scientists. He also began to stress the importance of measuring skills, teamwork and peer review with his students – all similar to the comments made by STARS participants.

CONSTRAINTS OF BRINGING AUTHENTIC SCIENCE INTO THE CLASSROOMS (PART 4)

In their book, *Becoming a Secondary School Science Teacher*, Trowbridge and Bybee point out the many reasons why a teacher might shy away from bringing inquiry into their laboratories:

> Among these include the necessity for a slower pace, more time consumption, the need for large quantities of materials, a more active and perhaps chaotic classroom, the urgency to "cover " material to prepare for the next grade level, high emphasis of most tests on factual memorization and other factors (208).

Many teachers in this study expressed similar viewpoints during informal "off the record" conversations. Their viewpoints became especially apparent as teachers wrote their final, inquiry-based action plans (lesson plans). They cited time (both teacher preparation time and classroom time), curriculum constraints (too many "concepts" to teach) and large class sizes (can't have everyone doing different procedures at the same time). During his interview Teacher Three said, "The hindrance is time, because we have so many objectives to teach." Teacher Nine expressed similar views, "…can't teach inquiry-based because there is no time…has to be a balance because they have no idea of the concepts." Teacher Four's main goal in the STARS program was to learn how to carry out inquiry-based labs with large class sizes. He wrote, "With class sizes of 30 it is hard to do labs that are inquiry based."

CONCLUSIONS

It is clear (from Tables 1, 2 and 3 above) that the STARS program exposed students and teachers to the authentic culture surrounding science, and engaged them in true scientific inquiry. Because of their STARS experience, students understand the need to keep up with the latest developments in science and technology. Teachers have new links to the scientific community. Teachers feel more confident about supervising science fair and research projects. Teachers acknowledge the need to distinguish between positive and negative controls while discussing experimental design. Students and teachers, together, understand the amount of conflictive constraints or failures experienced by scientists. Both groups better comprehend the skills necessary to perform a sound scientific experiment. Nearly all subjects feel a renewed confidence and excitement towards science – whether it is enthusiasm about perspective career paths, or passion about a rekindled love for science teaching. In his Post-Inquiry Teacher Four wrote:

> I can honestly say that this experience has given me the desire and aptitude to be a great science teacher. I now understand, all too well, the process of scientific discovery and how to start teaching my students about its techniques.

Teaching students the process of scientific discovery and its inquiry techniques does not have to be a daunting assignment for teachers. In fact, it can be an exhilarating challenge. The National Research Council's book, *Inquiry and the National Science Education Standards: A Guide for Teaching and*

Learning, is an excellent resource for teachers. It states that when implementing inquiry into a lesson plan, there are "many types of teaching strategies that make up an effective teacher's repertoire" (2000). After teaching biology, researching cellular signaling and analyzing the STARS program, I've formulated my own hypotheses for implementing inquiry and authentic science into my classroom.

SUGGESTION FOR BRINGING AUTHENTIC SCIENCE INTO CLASSROOMS (PART 5)

1) <u>If the objective is to teach "the process of science" or "true scientific inquiry," do not include a "concept" objective</u>.

Teaching inquiry should be unattached from teaching concepts. For example, during a laboratory exercise a teacher may take her students through points A, B and C to get to the final concept objective of D (photosynthesis, natural selection, enzyme activation, etc.) The teacher's success depends on whether all students reach point D (understanding the concept). Due to time constraints within the curriculum, the teacher hopes all students reach D at approximately the same time. Should the students inquire on their own and forgo points A, B and C, (possible try points G, F and E) the teacher cannot guarantee the students will reach the concept objective of D. Not worrying whether students reach point D (disattaching the concept objective) leaves students with the freedom to navigate to other letters in the alphabet. Students' ability to navigate (inquire) is the objective, not whether they reach point D. In true scientific inquiry, D is sometimes an unknown. Where D lies on the alphabet scale is also an unknown.

Teacher Nine, a second year STARS participant, suggested that animal behavior studies may be ideal for teaching inquiry in classrooms. She insightfully wrote:

> ... I keep thinking it would be great to reinforce scientific method and allow students to observe animal behavior and allow for open-ended inquiry all at the same time. What if I provided them with Planaria, egg yolks, batteries, ice, heating pad, dilute lemon juice, dilute detergent, various colors of transparencies, black paper, flash light, thermometers, and various other things (glassware, scopes)...Then I told them to set up an investigation, using the steps of the scientific method and delve into a behavior of Planaria? Have them take it from start to finish with a free write up on their methodology.

2) <u>If the objective is to teach "the process of science" or "true scientific inquiry," assess on the process, not the results – use performance-based assessments</u>.

If students construct labs similar to the Planarian lab, the teacher should assess students on their abilities to answer questions similar to the following (NSES, 2002):

> How do you know? How certain are you of those results? Is there a better way to do the investigation? If you had to explain this to someone who knew nothing about the project, how would you do it? Is there an alternative scientific explanation for the one you

proposed? Should you do the investigation over? Do you need more evidence? What are your sources of experimental error? How do you account for an explanation that is different from yours?

3) If the objective is to teach "the process of science" or "true scientific inquiry," create a teacher – student (or scientist – student) journal dialogue.

Throughout this study, I found journal dialogue with students was critical. Like the teacher who may undertake the Planarian experiments, I found I could not be with each student throughout every point in time. Through journals, I was able to ask questions like: How did you decide what measurements to take? How do you know that your measurements are accurate? Why did you decide to perform process A over process B? I also helped students steer around conflictive constraints and calm fears. Although not always practical, pairing students up with local scientists to journal dialogue would be ideal.

4) If the objective is to teach "the process of science" or "true scientific inquiry," assess students' ability to peer review.

After witnessing weekly peer review meetings, or as he called them "paper shreds," Teacher Four discusses the importance of peer review. He concludes he needs to "[have] more constructive criticism on their papers, model with students a 'paper shred,' evaluate each others' work paper, [and] more peer editing." Since peer reviews are often scientists' system of checks and balances, it may be useful to facilitate them in your classroom.

Modeling proper behavior and appropriate questioning techniques for peer review will be essential. This can be accomplished by bringing guest scientists into your classroom to help model correct behavior. Although local scientists usually want to help, I have found them to be extremely busy and, in some cases, intimidated by stepping into a classroom. The principal, other teachers or parents may be more available. Prepare them with questions such as the ones found in "suggestion 2" above.

5) If the objective is to teach "the process of science" or "true scientific inquiry," get students involved in Science Fair and Science Olympiad.

Science Fair allows students to formulate their own problem, hypothesis and experimental approach – all skills shown to be lacking from traditional classroom experiments. Science Olympiad also provides students the chance to become involved in inquiry thinking. Events such as "Cow-A-Bungee (where students design a bungee cord system for dropping a bottle without having it touch the ground)" and "Write Stuff (where students design paper airplanes with specific flying specifications)" force students to use problem solving skills.

6) If the objective is to teach "problem solving skills" – incorporate an experimental design class into the curriculum.

This class would be the culmination of all science classes and taken in the Senior year. Scientific concepts would not be taught, but used as a stepping stone for further scientific investigation. The success of the class may depend on the establishment of communication links between the school and a major research facility (university, industry or medical center). To ensure scientific authenticity, the teacher should have participated in a self-directed, scientific research project in the past – such as the STARS program.

In conclusion, “Educators need evidence drawn from research to help them implement and justify inquiry-based approaches to teaching and learning science” (NCR, 2000). This project - through its numerous participant comments - documents the meaningful outcomes that arise from pairing secondary, science students and teachers with mentoring scientists in a research environment. In particular, it 1) demonstrates that a program like STARS enhances students and teachers’ awareness for the authentic culture that surrounds science, and 2) engages students and teachers in true scientific inquiry.

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APPENDIX A

ENZYME LAB **Hour** _____ **Name** ____________________

A Chemical Reaction of Living Systems

ENZYMES: Enzymes are proteins that speed up chemical reactions in living cells. This speeding-up is necessary for the cell to live. Chemists could not make some reactions happen in the laboratory until they could separate enzymes from living organisms. You will now work with an enzyme in this lab.

Hydrogen Peroxide Reacts in the Presence of Catalase (an Enzyme)

PROCEDURE A: Put **20 drops of Hydrogen Pereoxide** in a small, clean test tube. Put the tube in the rack. (**CAUTION**: If you spill any peroxide on you or your clothes, wash it off immediately!) **Add 5 drops of catalase enzyme solution** to the peroxide. Mix with a straw.

1. Record your observations:
   Solution bubbled as soon as it touched the peroxide.

PROCEDURE B: Feel the **bottom** of the test tube.

2. What temperature changes do you feel?
   An increase in heat.

   Why do you think this happens?
   Heat is liberated during the breakdown of hydrogen peroxide.

3. What are some possible explanations for the bubbles?
   - *The bubbles suggest that a gas (O_2) is released.*
   - *The heat produced by the reaction might create the bubbles.*

Hypotheses Which Might Explain the Chemical Reaction:

PROCEDURE C: The catalase solution was made by crushing a piece of liver in a small amount of water. This released many molecules of the enzyme from liver into the water. The reaction mixture in your test tube contained hydrogen peroxide and the enzyme. The enzyme in this reaction is called **catalase** (CAT ul lace). To explain the reaction, three hypotheses are possible:

<u>Three Possible Hypotheses:</u>

1. Catalase and hydrogen peroxide react together and are both changed to form one or more new products;
2. The hydrogen peroxide is changed in the presence of the enzyme, but the enzyme does not change;
3. The enzyme is changed in the presence of hydrogen peroxide, which does not change.

Circle the hypothesis you think is correct.

4. How could you test your hypothesis to see if you are right? (Be specific!! Design an experiment)
   Answers will vary

Testing the Hypotheses:

PROCEDURE D: To test all three hypotheses, use raw liver instead of the catalase solution. Use two test tubes in your rack. Put a small piece (about the size of a grain of rice) of liver into one of the test tubes. Use a straw to push the liver all the way to the bottom of the test tube. Put the tube in the rack and **add 20 drops of hydrogen peroxide** (should fill about ¼ inch of the test tube).

Allow the reaction to continue until all the bubbling stops. Stir gently with the straw **until the bubbles disappear**. Pour this reaction liquid into the other test tube. Put another piece of liver (about the same size) into this liquid. Observe. **Put 20 drops of hydrogen peroxide onto the liver in the first tube**. Observe.

5. Record your observations about **both** tubes:
   A) New liver and old hydrogen peroxide:
   No reaction: the liquid is water now and not hydrogen peroxide.

   B) Old liver and new hydrogen peroxide:
   Bubbling and heat: the enzymes in the liver have not changed.

6. Does hydrogen peroxide, the enzyme, or both change after the reaction? Explain the reason for your answer.
   Hydrogen Peroxide: a reaction between the new liver and old solution with hydrogen peroxide did not take place.

7. What does this tell you about **what an enzyme does** in a chemical reaction?
   An enzyme may cause a change in the compounds with which it reacts, but the enzyme is not changed or used up.

8. Which of the three hypotheses on page 1 is supported by these results?
   The hydrogen peroxide changes in the presence of the enzyme, but the enzyme does not change.

APPENDIX B

B1. STUDENT PRE - INQUIRY TEST

This survey is deigned to examine what you already know about science and how you currently feel about science.

Please do not ask anyone for help, or use any type of reference material while answering these questions. Doing so will create inaccurate data for this research project.

You may relax because your answers will not be graded. Your name will not be associated with your answers in any way. Angela Alexander will be the only person to read this survey once you have completed it.

Remember, participation in this study is voluntary. There is no penalty for your withdrawal.

Student Pre-Inquiry

My identification number is _______________ (please do not write your name).

1. Please draw a flow chart and/or describe the steps a scientist would go through in order to conduct a thorough scientific investigation. Pretend that this investigation will be published in the scientific journal *Nature* when it is finished. Be as descriptive and detailed as possible. If it helps, you can use an example of a scientific question you would like to investigate. There is no right or wrong answer here.

2. What are your career aspirations? What factors have influenced you towards these aspirations?

3. What grade will you be in next year?

4. What is your goal in this program? What do you hope to learn? How will you utilize what you learned in the upcoming school year?

5. Outside of the classroom, have you ever participated in a research project before? A science fair? If so, briefly explain.

6. In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do her/his job well? Please elaborate as extensively as possible on this question.

7. How often do you keep up with the latest developments in science and technology? What sources do you enjoy using?

8. Do you see yourself as a scientist as well as a student? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to think like a scientist? (aside from a degree)

9. What percentage of scientific endeavors and experiments are failures? What information led you to write down your answer?

10. Do you like to participate in open-ended projects or more structured projects? To what extent do you hope your mentor will tell you what to do next as opposed to letting you decide what to do next?

11. How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?

12. Describe the qualities of a good scientific notebook. Explain why these qualities are important.

13. Are you familiar with the scientific method? If so, do you think scientists need to follow the scientific method? Why or why not? Do you think most scientific knowledge was acquired by using the scientific method?

14. What is an experimental control? Is a control necessary in every scientific experiment?

15. How important are good communication skills to a scientist? How did you come to this conclusion?

16. What skills do you need to have in order to set up and perform a scientifically sound experiment? Which of these skills do you feel you possess? Which of these skills do you need to work on?

17. What is the difference between "science" and "technology"? Use an example to explain your answer.

18. In your science class, have you ever recorded data according to "what you thought you should get" as opposed to "what you really observed" just to get a good grade? How often does this occur?

19. Read the following experiment and answer questions a. and b. on the next page.

PROBLEM

Which beverage cooler is better for keeping drinks cold?

HYPOTHESIS

Styrofoam coolers keep drinks colder than plastic coolers.

MATERIALS

2 cans of soda pop
1 Styrofoam beverage cooler (containing small hole for thermometer)
1 plastic beverage cooler (containing small hole for thermometer)
2 thermometers

METHODS

1. Take the two cans of soda pop from refrigerator. Open cans.
2. Simultaneously place a thermometer into each can.
3. Simultaneously place a can with thermometer into each cooler.
4. Shut coolers allowing thermometers to stick through holes in coolers (this allows experimenter to read the thermometer from the outside).
5. Seal thermometer holes to prevent heat from entering the coolers.
6. Record the beginning temperature and the temperature after every 5 minutes until the soda pop reaches at least 30° C.

RESULTS

	Styrofoam Container (^{0}C)	Plastic Container (^{0}C)
0 Minutes	10	10
5 Minutes	12	14
10 Minutes	13	18
15 Minutes	15	21
20 Minutes	18	25
25 Minutes	20	28
30 Minutes	22	32
35 Minutes	24	-
40 Minutes	26	-
45 Minutes	27	-
50 Minutes	29	-
55 Minutes	31	-

CONCLUSION

Styrofoam coolers keep drinks colder than plastic coolers.

a. Identify three weaknesses in the methods used for this experiment.

b. Describe how you would improve upon this experiment to obtain more accurate results.

Thank you for your participation. Have a good day in the lab!!!

B2. TEACHER PRE - INQUIRY TEST

This survey is deigned to examine how you think about the "process of science" and how you currently teach this in your classroom.

Please do not ask anyone for help, or use any type of reference material while answering these questions. Doing so will create inaccurate data for this research project.

You may relax because your answers will not be graded. Your name will not be associated with your answers in any way. Angela Alexander will be the only person to read this survey once you have completed it.

Remember, participation in this study is voluntary. There is no penalty for your withdrawal.

Teacher Pre-Inquiry

My identification number is _______________ (please do not write your name).

1. Please draw a flow chart and/or describe the steps a scientist would go through in order to conduct a thorough scientific investigation. Pretend that this investigation will be published in the scientific journal *Nature* when it is finished. Be as descriptive and detailed as possible. If it helps, you can use an example of a scientific question you would like to investigate. There is no right or wrong answer here.

2. What classes and grade levels do you currently teach?

3. How many years have you been teaching?

4. What is your goal in this program? What do you hope to learn? How will you utilize what you learned in the upcoming school year?

5. Have you ever participated in scientific research before coming to UT Southwestern? If so, how did this research change your teaching methodologies?

6. How would you describe the nature of the labs that you taught during the last school year (inquiry labs, cookbook labs, etc.)? What would you change about the way you teach laboratory investigations?

7. In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do her/his job well? Please elaborate as extensively as possible on this question.

8. How often do you keep up with the latest developments in science and technology? What sources do you enjoy using?

9. During the last school year, did you have any links to the scientific community? If so, how did you utilize these links in your classroom?

10. Do you feel confident supervising independent, student, research projects or science fairs projects?

11. How often did you incorporate disciplines other than science into your classroom last year? Please explain.

12. Do you see yourself as a scientist as well as a science teacher? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to be a scientist?

13. What percentage of scientific endeavors and experiments are failures? What information led you to write down your answer?

14. Do you like to participate in open-ended projects or more structured projects? To what extent do you hope your mentor will tell you what to do next, as opposed to, letting you decide what to do next?

15. How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?

16. Describe the qualities of a good scientific notebook. Explain why these qualities are important.

17. Do you think scientists need to follow the scientific method? Why or why not? Do you think most scientific knowledge was acquired by using the scientific method?

18. What is an experimental control? Is a control necessary in every scientific experiment? What is an experimental standard?

19. How important are good communication skills to a scientist? How did you come to this conclusion?

20. What skills do you need to have in order to set up and perform a scientifically sound experiment? Which of these skills do you feel you possess? Which of these skills do you need to work on?

21. What is the difference between “science” and “technology”? Use an example to explain your answer.

22. Read the following experiment and answer questions a. and b. on the next page.

PROBLEM

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HYPOTHESIS

Styrofoam coolers keep drinks colder than plastic coolers.

MATERIALS

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METHODS

1. Take the two cans of soda pop from refrigerator. Open cans.
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5. Seal thermometer holes to prevent heat from entering the coolers.
6. Record the beginning temperature and the temperature after every 5 minutes until the soda pop reaches at least 30^{o} C.

RESULTS

	Styrofoam Container (^{0}C)	Plastic Container (^{0}C)
0 Minutes	10	10
5 Minutes	12	14
10 Minutes	13	18
15 Minutes	15	21
20 Minutes	18	25
25 Minutes	20	28
30 Minutes	22	32
35 Minutes	24	-
40 Minutes	26	-
45 Minutes	27	-
50 Minutes	29	-
55 Minutes	31	-

CONCLUSION

Styrofoam coolers keep drinks colder than plastic coolers.

a. Identify three weaknesses in the methods used for this experiment.

b. Describe how you would improve upon this experiment to obtain more accurate results.

Thank you for your participation. Have a good day in the lab!!!

B3. JOURNAL QUESTIONS

Possible journal topics for week #1 (for Students and Teachers):
Write about your first impressions of your laboratory and mentors. Explain how your first impressions were different than what you had imagined them to be.

Describe your feelings as you worked in the laboratory on the first day.

Write down the question that you would like to investigate for your research project. Write down the question that your mentor would like you to investigate. Do the two of you see eye-to-eye?

Outline what you need to do in order to start your project this week.

Possible journal topics for week #2 (for Students):
Write about the things that you discovered this week, regarding your learning style and the way you learn science the best.

Is there anything else that surprises you about science, scientists or the way science is performed?

Possible journal topics for week #2 (for Teachers):
Write about the things that you learned this week, which you can directly use in your classroom this fall.

Is there anything else that surprises you about science, scientists or the way science is performed?

Possible journal topics for week #3 (for Students):
Identify the parts of the scientific method that you have participated in during your experience here. Explain by giving examples of what you have been doing.

Which part of the scientific method do you feel you participate in the most during school labs last year?

How did you gain an adequate knowledge base to support the investigation you are undertaking?

Possible journal topics for week #3 (for Teachers):
Identify the parts of the scientific method that you have participated in during your experience here. Explain by giving examples of what you have been doing.

Which part of the scientific method do you feel your students participate in the most when they do labs in your classroom?

Possible journal topics for week #4 (for Students):
Free write!

Possible journal topics for week #4 (for Teachers):
Do you have time to ponder…What explanation do you expect to develop from your data? Do your students have time to ask this question?

Were you surprised by your data this week?

How confident do you feel about the accuracy of the data you have collected so far? Give an example of how you knew the data that you collected might not have been accurate (if this happened to you)?

What "conflicting constraints" did you encounter when you tried to solve your problem this week? How often do your students encounter a "conflicting constraint" when they do a lab?

Possible journal topics for week #5 (for Students and Teachers):
No discussion group or journal pick-up because of 4th of July break.

Possible journal topics for week #6 (for Students):
If you could clear up any misconceptions your high school (or college) classmates have about "science" and "the way science is practiced," what would you say?

After having this STARS experience, would you change anything about the way science is taught in high school (college) today?

Possible journal topics for week #6 (for Teachers):
What difficulties did you face when preparing your action plan?

Are the teaching methodologies used in this action plan similar to the teaching methodologies you have used in the past?

Possible journal topics for weeks #7 and #8 (for Students and Teachers):
Free write!

B4. STUDENT POST - INQUIRY TEST

This survey is deigned to examine what you know about science and how you currently feel about science after completing the STARS Program.

Please do not ask anyone for help, or use any type of reference material while answering these questions. Doing so will create inaccurate data for this research project.

Angela Alexander will be the only person to read this survey once you have completed it.

Remember, participation in this study is voluntary. There is no penalty for your withdrawal.

Student Post-Inquiry

My identification number is _______________ (please do not write your name).

1. Please draw a flow chart and/or describe the steps a scientist would go through in order to conduct a thorough scientific investigation. Pretend that this investigation will be published in the scientific journal *Nature* when it is finished. Be as descriptive and detailed as possible. If it helps, you can use an example of a scientific question you would like to investigate. There is no right or wrong answer here.

2. What are your career aspirations after having experienced the STARS Program? What factors have influenced you towards these aspirations?

3. What were the most profound things you learned in the STARS program? How will you utilize what you learned in the upcoming school year?

4. In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do her/his job well? Please elaborate as extensively as possible on this question.

5. How often will you keep up with the latest developments in science and technology in the future? What sources will you use?

6. Do you see yourself as a scientist as well as a student? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to think like a scientist? (aside from a degree)

7. What percentage of scientific endeavors and experiments are failures? What information led you to write down your answer?

8. To what extent did your mentor tell you what to do next as opposed to letting you decide what to do next? You can give examples to help explain your answer.

9. How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?

10. Describe the qualities of a good scientific notebook. Explain why these qualities are important.

11. Do you think scientists need to follow the scientific method? Why or why not? Do you think most scientific knowledge was acquired by using the scientific method?

12. What is an experimental control? Is a control necessary in every scientific experiment?

13. How important are good communication skills to a scientist? How did you come to this conclusion?

14. What skills do you need to have in order to set up and perform a scientifically sound experiment? Which of these skills do you feel you possess? Which of these skills do you need to work on?

15. What is the difference between "science" and "technology"? Use an example to explain your answer.

16. Describe the part(s) of the scientific method that you got to participate in while you were in STARS. What parts were preformed by another scientist beside yourself?

17. Compare and contrast learning science in a situation like the STARS program with learning science in school. Which one is more effective? Why?

18. Has this program increased your confidence in doing science? How about your interest in science? Please explain.

19. Read the following experiment and answer questions a. and b. on the next page.

PROBLEM

Which beverage cooler is better for keeping drinks cold?

HYPOTHESIS

Styrofoam coolers keep drinks colder than plastic coolers.

MATERIALS

2 cans of soda pop
1 Styrofoam beverage cooler (containing small hole for thermometer)
1 plastic beverage cooler (containing small hole for thermometer)
2 thermometers

METHODS

7. Take the two cans of soda pop from refrigerator. Open cans.
8. Simultaneously place a thermometer into each can.
9. Simultaneously place a can with thermometer into each cooler.
10. Shut coolers allowing thermometers to stick through holes in coolers (this allows experimenter to read the thermometer from the outside).
11. Seal thermometer holes to prevent heat from entering the coolers.
12. Record the beginning temperature and the temperature after every 5 minutes until the soda pop reaches at least 30° C.

RESULTS

	Styrofoam Container (°C)	Plastic Container (°C)
0 Minutes	10	10
5 Minutes	12	14
10 Minutes	13	18
15 Minutes	15	21
20 Minutes	18	25
25 Minutes	20	28
30 Minutes	22	32
35 Minutes	24	-
40 Minutes	26	-
45 Minutes	27	-
50 Minutes	29	-
55 Minutes	31	-

CONCLUSION

Styrofoam coolers keep drinks colder than plastic coolers.

a. Identify three weaknesses in the methods used for this experiment.

b. Describe how you would improve upon this experiment to obtain more accurate results.

Thank you for your participation.

B5. TEACHER POST - INQUIRY

This survey is deigned to examine how you think about the "process of science" and how you will teach this in your classroom after going through the STARS Program experience.

Please do not ask anyone for help, or use any type of reference material while answering these questions. Doing so will create inaccurate data for this research project.

Angela Alexander will be the only person to read this survey once you have completed it.

Remember, participation in this study is voluntary. There is no penalty for your withdrawal.

Teacher Post-Inquiry

My identification number is ________________ (please do not write your name).

1. Please draw a flow chart and/or describe the steps a scientist would go through in order to conduct a thorough scientific investigation. Pretend that this investigation will be published in the scientific journal *Nature* when it is finished. Be as descriptive and detailed as possible. If it helps, you can use an example of a scientific question you would like to investigate. There is no right or wrong answer here.

2. What were the most profound things you learned in the STARS Program?

3. How will you utilize what you learned in the upcoming school year? Is there any factor that would inhibit you from utilizing what you learned in the upcoming school year?

4. After having this STARS experience, what will you change about the way you teach laboratory investigations this year?

5. In your opinion, what are the most important things (tools, skills, concepts, habits, etc.) a scientist must have in order to do her/his job well? Please elaborate as extensively as possible on this question.

6. How often will you keep up with the latest developments in science and technology in the future? What sources will you use?

7. Do you feel you now have new links to the scientific community? If so, how will you utilize these links in your classroom next year?

8. Will you feel more confident supervising independent, student, research projects or science fairs projects?

9. After having this STARS experience, do you feel it is more important to incorporate disciplines other than science into your classroom? Please explain.

10. Do you see yourself as a scientist as well as a science teacher? If so, what things do the two disciplines have in common? If not, what skills or habits would you need to acquire in order to be a scientist?

11. What percentage of scientific endeavors and experiments are failures? What information led you to write down your answer?

12. To what extent did your mentor tell you what to do next, as opposed to, letting you decide what to do next?

13. How do scientists conclude that their data is right or wrong, accurate or not accurate, precise or not precise?

14. Describe the qualities of a good scientific notebook. Explain why these qualities are important.

15. Do you think scientists need to follow the scientific method? Why or why not? Do you think most scientific knowledge was acquired by using the scientific method?

16. What is an experimental control? Is a control necessary in every scientific experiment? What is an experimental standard?

17. How important are good communication skills to a scientist? How did you come to this conclusion?

18. What skills do you need to have in order to set up and perform a scientifically sound experiment? Which of these skills do you feel you possess? Which of these skills do you need to work on?

19. What is the difference between “science” and “technology”? Use an example to explain your answer.

20. What parts of your Action Plan were directly inspired by things you have learned in the STARS Program? (Remember I have read your Action Plans twice. You can use shorthand when referring to your plan. I should be able to follow what you are explaining.)

21. Has this program increased your confidence as a science teacher? If so, how?

Thank you for your participation!!!

APPENDIX C

C1. Student Quotes

On students being surprised at the time line of doing research
S4 – journal What surprises me about science is how slow everything is. It takes a whole day or even several days just to get one result that contributes to a bigger picture. I know that each individual process takes time but when put all together, I didn't realize just how long everything takes.

S10 – final presentation I thought this was an experiment in itself [finding a positive control group]. You could do that the whole summer.

On students being surprised at the advanced termonology used in the lab
S1 – weekly discussion surprised at advanced terminology

On students being surprised at the research work ethic
S1 – interview more cooperative work here

S4 – weekly discussion at how much they work all day

S5 – weekly discussion shocked at how there is no clock-in, no time schedule

S8 – weekly discussion they are always busy

On students being surprised at the amount of freedom given to them
S3 – weekly discussion they asked me what I wanted to do

S5 – weekly discussion freedom to do what you want to do, too much freedom

S7 – weekly discussion surprised they let me do stuff

S10 – journal Before coming here, I had expected not really to have a project but more doing random things in the lab. But contrary to my belief, I did have an excellent project which actually interested me…My mentor has allowed me to stay on through high school to finish my project.

On students being surprised at the amount of different cultures in the lab
S6 – weekly discussion how many ethnics are in my lab

S10 – final presentation I got to learn about many different cultures…

On students being surprised that the diversity of each deptment

S3 – journal Surprises – In hospitals you see doctors and nurses working on their patients. Medications are often prescribed and treatments are under-went. This is what people expect to see in hospitals. However, since there are many different kinds of doctors that work in the hospital, there are many different kinds of jobs they do (besides signing for a prescription). In the pathology department, doctors specialize in many different kinds of treatment that a regular physician may not ever have to worry about. In transfusion services (where I'm stationed at), the doctors attend many lectures and are able to visit many different patients. They specialize in the lab work running tests to uncover what may be wrong with a particular patient. This part surprised me very much because these doctors can be all over the place.

S5 – weekly discussion whole floor is the urology department

On dissolving previous misconceptions – about scientists

S1 – journal I disagree with the way science or research is portrayed in the movies. The rooms are all white and sterile. The people working inside have not seen the light of day for many weeks/years (*Independence Day*). I mean you do find people very dedicated to their work here but not to that great extent.

S1 – interview I thought before scientists came up with ideas miraculously.

S3 – interview I thought they were already doctors and they would already know.

S4 – journal Its really interesting how as I walk down the halls of the buildings, there are so many young people! Tons! That made me feel a little more at ease I think.

S7 – post test Research isn't just a bunch of nerds who have no life, its just normal regular people.

S9 – journal My first impression of the laboratory and my mentors was completely opposite to the picture I had in my mind. I expected them to be too serious to smile, too busy to explain, too absorbed in their research to explain to me anything. I was completely wrong! My mentors are fun and nice and smart. They really care if I learn and understand everything that is going on around me.

S9 – interview I thought scientists were serious but they are funny, smart and fun.

On dissolving previous misconceptions – about science being detached and boring

S4 – journal I know that I had the misconceptions that science was too detached from life. I used to think science was just a boring continuous cycle of some procedure after procedure that never really applied to us. But after having worked here, I see that what they are doing is really making advances in MSUD, small but worthwhile. It, in actually, is not detached from real life at all.

S5 – journal I would say science is not as boring as it may seem. I know in school since the labs are done over and over again, they get dull and boring. However, when you are continuously working in a lab, and you feel like you're actually contributing something you gain a whole new outlook on exactly what science is.

On dissolving previous misconceptions – about science being harder than previously thought

S8 – journal If I could clear up misconceptions, I 'd say, "Be more careful, it's not as easy as it looks." Science experiments sometimes look very easy when they're not! Take for instance, pipetting a sample into a container – sounds easy but actually isn't since you need strength, stamina, and especially concentration.

On the benefits of student submersion – inspiration to keep up with scientific developments

S9 – post test I have seen so many awesome developments in which science and technology work hand in hand to make human life more comfortable. This has sparked an interest in me and I am going to keep up with more developments by watching the news and discovery channel, reading scientific journals and keeping touch with my lab people and doctor!

On positive interactions with mentors and other laboratory personnel

S3 – journal While working in Transfusion Services, I have felt open to the assistance of many wonderful doctors and nurses. Any question I may have is easily answered for me…I have discovered that being one on one with a doctor is the best approach to learning about something new to me. This way I can feel as though a question is really being answered.

S3 – journal What also surprises me is the fact that these scientists are very open to helping me. Despite their very busy schedules, they make time to check up on me and make sure I am doing well.

S5 – journal Today I sat and talked with my PI (principal investigator). I assumed he would be very busy because he was out of town the first two days. However, after I ate lunch he attempted to just welcome me to the lab but he talked to me for an hour and a half. My thoughts were very incorrect. He took the time to explain all areas of research in the lab and asked me questions.

S7 – journal I met Sarah the graduate student and [her mentoring doctor]. She is really nice and cool too. She seems like she will be really helpful and I expect that I will have a lot of fun n the coming weeks.

S7 – final presentation "I concluded that", she thanked her mentors for treating her as an equal

S8 – journal I hung out with the graduate student and chatted about school, hobbies, movies, music and the usual…The people at the office labs and General Clinic Research Center are very nice. They are very helpful and extremely patient with a novice like myself. They laugh at mistakes more than I do. I am very fortunate to work with all these nice yet sophisticated people.

S8 – journal …I met Dr. Peter Snell, a researcher who conducts the testing. Through conversation, I found out that he was a 3-time Olympic Gold Medallist!! I had a great time with him. He showed me several of is computer programs that can calculate body fat percentages through non-invasive procedures. He also showed me several high-tech equipment, including a mass spectrometer, capable of measuring the percentage of a certain gas. I was inspired just by standing next to this living legend. I hope to get more chances to word with him and get his autograph.

S9 – journal The doctor I worked with and all of the lab techs I worked with didn't just explain a procedure to me, they showed me how to do it.

S10 – journal I am extremely lucky to have such a diverse lab. There are four research fellows from different countries as well as four students, one STARS teacher, and a lab technician…

S10 – journal Everyone in the lab seems to be extremely helpful and talkative. They seem to be people who would give me advice on any issue. My immediate mentor is extremely helpful but the only downfall is he is very busy…

<u>On the most important tools, skills, concepts, habits a scientist must have in order to do his/her job well.</u>

S7 – post test (what are the most important skills a scientist must posses) patience – projects are long and often reach an unwanted conclusion, knowledge – to come up with ideas for experiments, thinking outside of the box – to overcome hurdles in experiments

On the communication skills of mentors and lab personnel

S3 – post test ...doctors need plenty of communication skills...to give lectures, talk to patients, to talk to other colleagues. I found this out by observing the behaviors of all the doctors I've met recently. For the most part they are all very clear and concise speakers.

S7 – post test (how important are communication skills?) Important – scientists must be able to get along with their peers in the field, as well as, give presentations about their work, grants, etc., you just can't be a recluse.

On learning about brainstorming, peer review, journal publications and obtaining grants by observing mentors at weekly meetings

S1 – journal Last week, on Wednesday a meeting was held with all of the orthopedic staff...Well, this past Wednesday everyone was telling about their projects, progresses and research. During this meeting one person who works in the same lab I do presented his research on a project he did. The response from the group was that of excitement. The data was a bit controversial because those results were not expected. Someone mentioned that it was publishing material and another that it was a breakthrough. There I was sitting in what was obviously something very important, important enough to publish... The experiment is to be repeated. So, yes, I think this qualifies as something that is surprising regarding the way science is performed.

S1- journal Today I attended Cancer Center Thoracic Malignancy Conference case presentations...It gave me a peak of how doctors discuss their topics...The presenter would discuss how the patients were being treated and their progress or ask suggestions for diagnosis. After a brief summary the presenter would ask for suggestions regarding further treatment or diagnosis. Sometimes the suggestions were agreed upon by the group. Other times controversy was sparked about the way the person had been treated and the suggestions were disagreed upon.

S1- journal The data was controversial in the sense that the outcome had been unexpected and there was speculation on why that followed. The comments and the suggestions after the data were the main reasons that caused me to write that the data was a bit controversial. The words that followed were "weird results", "are you sure?" and "how was your experiment carried out?" The last question was asked several times and gone over in great detail. Herman was asked to review the data and replicate the experiment. My guess is that he is to repeat it and do more background research on it until he is sure that the data obtained is correct and that the chemical used is the cause of the changes in bone marrow cell growth.

S1 – interview Meetings are different – I asked them how they decide what research to do.

S3 – journal I attended a weekly meeting at Children's that gave doctors, nurses, social workers, etc. the chance to discuss the needs of certain Sickle cell patients.

S5 – interview I have a journal club meeting that I am going to in which people present papers

S5 – interview They publish papers and do tests a million times…if you get results one time, then it's good…but they repeat it.

S6 – interview There was a paper published, she got to see a meeting where they picked it apart.

S7 – journal This morning we had our first lab meeting since I have been here. Dr. [X's] was about the grant he already turned in. I didn't really understand it that much…We had a MS unit lab meeting today in the Neurology library.

S8 – journal Today was the first weekly lab meeting! All the lab members were present and discussed the ongoing studies and any concerns or problems we have.

<u>On students witnessing procedures and surgeries</u>

S2 – interview He got to see a breast augmentation.

S2 – journal I was able to follow the UT med. Students around Parkland and Zale Lipshy… On Friday I got to see 3 surgeries. 2 which were gastric bonding using laproscopic technology. The third was the best since I got to see a breast augmentation which was absolutely spectacular.

S3 – journal I've been able to observe a couple of procedures done on patients with Sickle-cell anemia…The first time I actually got to see where the donated blood was being stored was pretty exciting. I did not expect to see so much work being done to make sure the blood gets to the right patient at the right time.

S3 – journal When I got the opportunity to observe Red Cell Exchange being done, I was pretty nervous. I didn't know whether or not to speak to the patient or not.

S10 – journal One thing I did not expect to do this summer was watch surgeries. My mentor allowed me to stand right behind him as he operated. I got to experience the life of a surgeon shortly while being in the OR.

On following the scientific method straight through

S1 – post test ...many times it is not needed [the scientific method] I guess because some situations don't follow the problem, hypothesis...straight through. One may go in circles at a time (hypothesis, procedures, refined hypothesis, refined procedures, head in another direction) and sometimes in one's mind one doesn't say "okay" I am going to use the V step of the scientific method: but does it unconsciously with the knowledge already in one's head.

S7 – post lab (what profound things did you learn in STARS) What really goes on in a lab...how to work in a clean lab environment and to manage all the procedures and equipment in the lab

S7 – post test Maybe not exactly "THE" scientific method, but the same thought process

On being put into a situation where inquiry is required to determine a problem to be solved

S3 – interview I picked my own project.

On being put into a situation where inquiry is required to develop or rework a hypothesis

S3 – journal Hypothesis – If an effective campaign is planed out that includes the cooperation of churches, schools, organizations and any other black communities then more African American donors will be available to help with sickle cell treatments... I set up meetings with churches/organizations where we can speak about the safety of blood donation and answer any questions...My hypothesis is that education is the best solution to solving the minority blood donation problem.

On being put into a situation where inquiry is required to develop or rework a protocol / experimental design

S1 – interview Here most decisions are yours – like when to record data. Here it's your own initiative to do it.

S3 – journal I spoke to (name of speaker), who is a national speaker of sickle cell disease... It's hard enough to get into contact with people and once you do it's even harder to get them to really listen to what you have to say. I told her that I will defiantly keep trying. This is something I plan on doing for a long time...I have been trying to schedule drives at different areas around Dallas. I made out minority blood donation surveys and passed them out at the 11:00 am service at my church. Only 17 people were interested in filling it out...

S9 – post test A control is the source you change. Many times you need a control to test different experiments. (S9 – pre test) An experimental control is a section of the group that is not given the essential element. Like we did nerve injuries on rats. On our control, we cut them open, but did nothing, so that they would experience the same exact things.

S10 – journal To outline my project, I basically am receiving all my information form articles. – determine exactly what protocols to use – practice with the protocols before starting...

S10 – interview to develop protocol by reading articles

On being put into a situation where inquiry is required to conclude that their data is right or wrong, accurate or not accurate, precise or not precise

S1 – post test One needs to know what one is dong and ask oneself if the experiment will satisfy what it is intended to perform...see if the experiment needs to be replicated or tuned

S1 – journal The bone marrow I obtained is in 5 flasks. Surprisingly I gathered a lot this time. It really surprised me and I think the data is incorrect but the marrow has already been "watered down." There's nothing to do but hope that there might be a chance the data was correct...When I was going to count the cells I shook the tube to get the cells diluted but then I went ahead and gathered a sample from the bottom. My guess is that the cells settled down and that's why I got a higher concentration of cells than I should have.

On being put into a situation where inquiry is required to conclude results form data

S3 – journal If students are taught about sickle cell disease and other illnesses such as cancers, that require constant blood transfusions, then when they are older they'll come to realize the importance...Conclusion – The best approach to increasing the number of minority blood donors in the community is through education.

On experiencing a mistake, road block or constraint in the research

S1- journal Recently just yesterday I had a terrible encounter with contamination....there are many reasons why flasks get contaminated and I spent all last night trying to trace where I make an error. I think I traced it to the handling of one of the apparatus which I use to suck out the medium. I am still worried about my other flasks on all of them. This morning nothing was evident but I will check later again.

S3 – post test Things often go wrong in science and no one can do anything about it but go on and learn from your mistakes

S5 – journal What surprises me about science is that it's just like math. Meaning if you mess up on one step, our whole product is different and may be wrong. You have to carefully do each step and check to make sure it is right.

S7 – journal The reason we were doing the sort AGAIN is because the last sort didn't work out.

S7 – post test 90% or more you don't find the answer you are looking for, but you may discover something unintentionally. If anything, you discover what NOT to do.

S8 – journal With my clumsy hands, I spilled a bit of the serum onto the counter (arrrg!). I cleaned the mess with some tissues. Luckily, I didn't spill it on myself or anyone else. This is the first major mistake I made.

S8 – post test (when asked what is the most profound thing learned) I learned that "failure is an option," mistakes will happen and are acceptable only if one learns from THEM!!!

<u>On what part of the scientific method the student participated in</u>

S1 – journal The parts of the scientific method in which I have taken part in I believe constitute of just the procedures. The problem had already been established by [her mentor] and so had the materials to use. I now mostly carry out the same procedures on different subjects, record and observe data, and maintain previous cell cultures. I think I will be taking part of the data analysis and conclusions (since I will have to compare these), but I believe my ability in these areas is a bit weak.

S1 – final presentation S1 examined the difference between two mediums, sacrificed 5 rats, removed bone marrow, tibia and fibula, was trying to determine if the way in which the rats were sacrificed (CO2 or injection) affected the cells, one day she got contamination, had to go back and figure out why she got it and what it was, said it was very spore like, wasn't able to draw conclusion form data but speculated that MEM medium was better, I learned a lot of techniques

S2- journal During these two weeks, I basically did paper work in the DACU at Zale (a hospital). This is by far the tedious task I have done yet. I have to get all the patients that we first tracked in the year 2001… I still do data entry. It seems that my hands and fingers hurt every day. But I know that my job is really important to the research going on. The last part of this study depends on me. It is up to me if it gets published or not.

S2 – final presentation S2 said he has seven studies going on in his lab – he is a part of one, explained the purpose of the study was to reduce the amount of drugs given to patients and minimize the side effects, his study had a control group, really important in this study to keep everything the same (age).

S3 – final presentation S3 wanted to increase African-American donation, she gathered information, observed treatments, visited Carter Blood, contacted churches, contacted Sickle Cell Anemia Association, contacted people in media, did a survey, conclusion: education is the most important way to get African-Americans to donate blood, people should be taught early on, media should be involved, included n=10 and pie graph in results

S4 – journal Here, mainly I have been involved in the experiment part and basically perform the experiment and collect data. All this I do by myself, however, my mentor often analyzes the data and allows me to listen in and know what's going on. I also prepare materials for future experiments (ex. prepare media).

S4 – interview I have been following my mentor growing the tissues.

S4 – final presentation S4 got fibroblasts cells from patients, grew them, did a Western Blot, got cDNA, sequenced the DNA, confirmed the mutation, found 5 new unpublished mutations, spoke in terms of "we".

S5 – journal I have participated in all parts of the scientific method. My PI first explained our problem. Then, my immediate supervisor explains what I do to contribute to the purpose / problem. Right now I mostly view my/our written protocol to do/redo my experiment. I really make LB broth and add a bacterial clone. I harvest the DNA, remove cells and eventually get the DNA to test the pH. I do the scientific method for "procedure." My protocol really helps me to know what steps come next because no matter how many times I do the process I sometimes forget what comes next. I have also made graphs and results but I believe at the end of the program I will write my conclusion.

S5 – final presentation S5 felt like she didn't contribute a lot but enough to where it would make an advancement in science, said she cloned a gene, she did an agarose gel, learned how to amplify DNA, incubated centrifuged, started to test concentration, read a lot of articles

S6 – interview In procedure part on the method

S6 – final presentation S6 told what she did in the methods section, appeared to have been guided through this experiment by her mentor, "We were actually in the laboratory, we learned a lot of techniques and had a good time"

S7 – journal We also did a PCR…Today I made check-gels and learned about heavy and light chains in a protein…We ran a sequence today that consists of coding our antibodies – it puts out a different color for each ATGC and ultimately will lead us to which gene that antibody is derived from…I cleaned check gel combs and put tips into empty tip boxes. Then I labeled each box with autoclave tape. At the end of the day I made wax pellets…I got to resuspend some cells as well…We got liquid Nitrogen to "flash freeze" the cells so they don't die…Nancy had me enter data into the computer after organizing and numbering the gene folder an MS patient…I organized by plate numbers, stapled and separated into possible clone pairs. Then we checked to see if they were actually clones. Again I did paperwork all day… Oh, I learned to wax plates today…Today I did my first PCR. Not just watching, I've come along way from just watching Sarah do one…Sarah showed me how to isolate the DNA by putting it in little square, hollow containers and then cutting off the extra agarose…We were preparing the DNA to be sequenced…We came back downstairs to resuspend the DNA – which is invisible to the human eye. It is nerve-racking to do this because sometimes there is a little dye that won't go back out of my pipet and I always worry that the DNA might be inside the pipet…I added all the DNA into the gel by myself…Then I took our isolated DNA and after spinning it took out all of the DNA in each tube and transferred it to the ones I had just labeled…I labeled all the extra primers we have so that we can find them easier…Today I did a special PCR that Nancy wanted me to do because another one that was done turned out bad. In it I tested 2 different magnesium concentrations using one set of primers…In the morning I was learning how to analyze the DNA that we sequenced…Sarah taught me how to read the CDR3 chain…basically I just analyzed data all day…This morning I was given the assignment of doing mutational analysis on my repertoire.

S8 – journal…they had to get blood drawn from their arms in intervals of 30 minutes…I visited the technician to do the technical part of the study (primarily consists of pipetting, labeling, and centrifuging). But this part is only the beginning step in creating data. Results of today's study will not be revealed for a week or two. These experiments are very fascinating and the methods very cleverly formulated…In the afternoon, I visited the lab tech and performed some experiments on the results from the past 4 patients. The main experiment was the "Free Fatty Acid Assay Test"... Setting up the experiment took a tedious 3 hours…Two patients came in this morning. The usual things happened…drawing blood, centrifuging, processing, freezing. All except for the analyzing part. The tech was busy and could not accommodate me…I also spent some time with the technician and tried to learn the basis of some of the procedures…This time, however, I got to do more stuff, such ans taking care of the blood and centrifuging without too much supervision…I'm curious about how the tech processes the blood afterwards. I have only seen two things: FFA counting and cell pelleting. I was allowed to do most of these steps, so that's why I actually recalled them. I'm so proud. Haha…This time, I really got to see how the study patients were booked…For next week I'm hoping to analyze some of the results and hopefully sit down with one of the PI's (if possible). As for the research, I have finished just about everything – I'm missing the analyzing of the data, which I will do with my mentor/supervisor tomorrow…

S8 – journal Problem – I have done some digging and inquiring abut the research on hand, including reading up on insulin and diabetes, and asking my co-workers with question that I have…Hypothesis – The PI's for this experiment had already decided on the hypothesis, which is: People of Asian decent are more insulin resistant than people of Caucasian decent…Experiment – I have been chatting with the patient while they get their blood drawn, and I have done some lab work with the tech. Some lab work includes: cell pelleting, FFA Assay test, Insulin Assay Test, and DNA test, which I'm so familiar with yet…Conclusion – I have not personally looked at the results yet, since the PI's have been quite busy lately. However, they did promise one-on-one time with them to discuss the results and their meaning.

S8 – final presentation S8 weighed patients underwater, processed the blood tests (glucose and insulin), did a statistical analysis (error bars and p value)

S9 – journal Well, the only part of the scientific method that I have participated in is the experiment part. But I have learned so much from that. I have been running gels, homogenizing tissue samples…

S9 – weekly discussion I learned how to organize data. I did a standard curve!

S9 – post test They conclude this information from the data they get. They can test the theories until they receive the information they want. (S9 —pre test) Through experiments

S10 – final presentation S10 ordered medium that was being tested, went to operating room and got tissue, had positive and negative control groups, went to library and found chemicals needed to turn fat cells into bone cells, showed what he wanted to do in the future (inspired by the model of another doctor)

On how students are inspired by trying to find a "real" cure solving "real" problems

S5 – weekly discussion researchers have the power to find a cure

S9 – journal I feel very fortunate to have had a hand in research that someday may help millions of women (and I'm only 17).

S9 – interview I see science at work and how it helps people

S9 - interview I never thought about science as helping people, I thought oh cool a DVD player.

School Science - On how students do not participate in inquiry involving developing experimental design

S3 – journal In classes science is often black and white. The teachers already have a set way of performing the experiments. There is usually not much (if any) room for questioning the way the procedure has to be done. However, real life science is often full of surprises and that way a researcher believes something that should be is often different from the way it actually is.

S4 – weekly discussion school – can just do the procedure and don't have to know what's going on

S6 – interview In school the procedures are already there, at the end the teacher puts up the numbers...In school you follow the procedures.

School Science - On how students do not participate in inquiry involving data analysis

S1- journal Data analysis, I believe, is not an area I am very strong in because I have not really been involved in true actual data analysis. In school the labs I participated in I was only expected to write my outcome. From observation and recent orientation in scientific writing I have found that one has to practice a higher level of analysis rather than writing an expected conclusion and leaving a teacher to guide one through the what, why and where. I believe I have been taught techniques and background that have make the procedures in STARS very easy. Maybe due to the fact that I don't have a strong background or practice in cell culture or real research knowledge I feel this way.

S3 – journal Mistakes are made and any questions a scientist has must always be answered for the sake of his/her research. In school, you may

have times when you doubt what is going on, but you may not always have time to start over.
S3 – interview The teacher knows the answer already

S4 – journal In school, I mainly just did experiments. We often did not analyze the data answers or if we did we would often be wrong and the teacher would have to tell us the correct answer anyway.

S4 – journal In school, I despised doing labs, like many other people in my AP Bio II class. It would seem like we would be learning something and then all of a sudden some lab that's supposed to fit in with the lesson shows up. But the teacher wouldn't really point how the lab fitted in. We would end up spending a couple days doing the lab, which basically disrupted what we were originally learning, and have the teacher spoon feed us the results and analysis because we would be too confused to get it.

School Science – how students are NOT participating in inquiry labs
S1 – journal At school a lab was set up with everything. All I basically had to do was fill in some basic blanks. The problem / hypothesis was always started, the materials were set out on the table. The procedures were already included. All I had to do was replicate the experiment and get data. Even for the conclusion I was given questions that would lead me to what was to be the accepted outcome to get a 100% or to understand the outcome. Even through it isn't a very effective way to learn or to proceed in research I believe that those experiments were not truly experiments but rather just examples. Thanks to them I learned such things as how different elements behave, about phase changes. In a real experiment I feel I would be better prepared to recognize such characteristics that would allow me to distinguish what is causing what in my data.

S3 – journal In my Chemistry and Biology classes when we were doing labs, the procedure seemed to be the most important part to the students. Even though the results and conclusion were what the teachers actually cared about, the procedure was what the students worried about. If you didn't follow the right procedure, your results would not be accurate which make a difference in the grades.

S3 – journal If I could change high school science I'd make it more experiencing science rather than just reading about it.

S3 – interview Our teacher would tell you exactly what to do and measure…Labs at school – we would just write down answers of other kids or what the teacher said. (S9 – interview)

When I'm doing labs in school, I'm scared I'm going to mess up and have a bad grade.

S5 – journal Last year in AP Biology, we did not do any labs. We just read the book and took tests…We did nothing but read other individual's results.

S5 – weekly discussion school – write it down, teacher knows outcome

S6 – weekly discussion school – just looking in books

S8 – journal Last year at TAMS, I mainly participated in the "Experiment" part of the scientific method (since the whole class devoted to doing the experiments)…All the lab time was devoted to performing the experiments assigned for that week. With an immediate supervisor (usually 1 per 30 students), little help was available to answer questions. So, must of the time, lab was just data collecting and occasionally some minor math calculations.

S9 – journal In all of my science classes at school, I have always had pen and plenty of paper ready for class because I know tht my teacher is about to spit out 30 letter long words for 55 minutes and I am going to have to memorize these words for my test. I never really learned science in that way. I passed my tests and got my homework done, but I never understood. This past summer, while working in the lab, I have developed an appreciation for science and all of the wonderful capabilities it possesses.

T10 – interview In school the outcome is already determined.

School Science – Positive comments
S2 – journal Actually I thought that science learned in school is almost the same as it is at the medical center, except that here science is explored more than finding canned answers. But much like college, you still do research, form hypothesis, and of course record the observations and data.

S8 – journal I must admit that the classes I took (Biology / Chemistry) both in high school and TAMS helped build a broad knowledge base for the understanding of the research I'm currently working on.

School Science – Miscellaneous comments
S3 – journal We may learn the concept in school, but there is not real time to master it. That's what may be the real problem along with a shortage of lab equipment due to the lack of funds provided for the district.

Anyhow, it's okay the way science is taught now, but unless you have real great, enthusiastic teachers you won't gain much from your classes.

S6 – interview In school my teacher makes a mistake in lab procedure and we have to figure out that he did wrong.

S8 – journal If I was a science teacher, I would spend more time one-on-one with my lab students to make sure that they understand the concepts behind the experiments and what the results mean. In other words, I would spend more time teaching the methods/explaining the results than done in today's class.

<u>On how STARS is different than school</u>

S1 – weekly discussion here – they show you once, you do it next

S1 – weekly discussion school – more structured, teachers hovering around

S1 – post test ...there is a chance that one may just get stuck learning and practicing one area of study, in school one has to study and learn about various subjects...

S2 – journal I think some of the misconceptions of my classmates would be just to find an answer. In school there is always an answer, nothing is left blank. At UT Southwestern I found that even my case lasted longer than a year. This would be unthinkable in school. Many of my classmates rush to a conclusion or expect to find one. In the research facility it is really different.

S2 – weekly discussion here – things are more long term, mentor has been working for two years just on first step

S3 – weekly discussion here – more hands on and free

S3 – weekly discussion school – just doing a lab (here more hands on and free)

S4 – interview In school you're doing it just cause. Labs in school don't connect. The school attitude – you just want to get a grade.

S5 – weekly discussion here - there is no room for mistakes, more cautions

S5 – interview here – more sterile than at school

S6 – weekly discussion here – more hands on research

S6 – interview here – getting data is different – in order to even start something you have to do background research – like medicine you have to do research on which one to order

S7 – interview We do fake science in school – helps you understand subject matter but doesn't serve a purpose.

S8 – weekly discussion here – more one on one

S9 – weekly discussion I used to protest dissecting as school [student goes on to say she now sees a purpose in testing animals – it helps find cures]

S9 – weekly discussion here – more one on one, not afraid to ask questions because no competition [with peers], school – didn't want to ask questions, too much competition

S10 – weekly discussion here - pay attention to sterile tech, don't reuse pipets here

<u>**How STARS changed or inspired career aspirations**</u>

S1- journal There are lots of career paths and fields opened most that had it not been for STARS I would have never known existed. I mean a whole lab concentrated on the study of how just one single protein interacts, lives and dies was something new to me. Teachers do try to encourage students, because lets face it, they are teachers its their job and passion, but I think it is also hard for them to get students really interested.

S1 – post test The bus that I ride in the morning to get to Southwestern facilitated many conversations with an electronic engineer... She and this environment made me realize many opportunities

S2 – interview Got to go with med student to see how researchers get patient's consent...Learning a lot of ways to get into med school.

S2 – interview I see I don't want to do research...I wanted to see doctors and nurses – if they are coming from where I'm coming form. Is their road similar?

S3 – post test I still plan to become a pediatric physician when I'm older, so STARS gave me one more reason why I should become a doctor...

S4 – interview This has heightened my interest in the medical field.

S5 – journal I also realized with medical school or graduate school, it's not as hard as everyone makes it out to be, but its no walk in the park. I know I'll be missing a lot of sleep, and I know that it will make me decide whether this is something I want to do.

S5 – interview I wanted to be a doctor and never thought about research

S7 – journal Then we ordered pizza as a unit. People from all the surrounding labs came and ate in Nancy's office – its quite a popular hangout. It was a lot of fun getting to eat with the group. Plus, most of them are fairly young like Judy… I also talked to Judy again about California and she was telling me about some other research opportunities.

S7 – interview Research seems more relaxed than the medical field…People underestimate research… they say, "I want to be a doctor." Why can't it be a PhD, not a medical doctor?

S7 – post test STARS has really opened my eyes up to pursuing a career in research.
This program has reiterated to me the importance that science has (subject was working to find a cure for MS). I will most definitely be pursuing a career in the sciences, this program has solidified that thought.

S9 – interview For the longest time I wanted to be a pediatrician, but from working here I want to be an OBGYN.

S9 – post test Before starting this program, I wanted to be a pediatrician, working with teens in low income neighborhoods. After working in an OB/GYN lab, I have realized that I can accomplish my dream of reaching young ladies better by becoming an OB/GYN. This summer was very encouraging.

S10 – journal On the whole this summer was a great experience for exposure to the medical field and to the process of being a doctor. I hope to do something similar next year.

S10 – interview Wants to apply to a medical school (maybe UT), talks to med. students in his lab.

S10 – final presentation S10 expressed how he got exposure to the medical field and research. It reconfirmed his desire to be a medical doctor.

On how STARS helped to develop interpersonal skills

S1 – journal I was thinking what I could do to strike up a conversation that didn't have the rat or the cells I am working with mainly as a topic. Most of the conversation ranges from "Where is so and so?" or "May I attend this?" But then I realized that I myself also make things harder in the sense that, I hate to admit this, but I prefer working alone rather than being strongly supervised.

S4 – journal I really agree with what [the STARS coordinator] said at the last meeting about asking questions. At the beginning I had absolutely no questions, everything was new. But now, I actually have a feel for what's going on and ask hopefully intelligent questions.

S6 – interview Now in school I will question or do something my own way.

On gaining confidence about doing science

S5 – post test I loved the lab experience. Hopefully, I'll get to do labs at school now. I'm more excited about my science class this year.

S7 – journal I felt like I was in on a big secret – like only we know about this process and how we were searching for such an awesome goal – discovering why MS occurs and how.

S7 – journal It is fun to be accepted by all these doctors and students (grad, med.).

S7 – journal It is kind of heat knowing you can do stuff better than college kids…I also showed Eddy (a new lab assistant) how to locate the CRB regions (the site where the antigen attaches). It is a neat experience showing older people how to do stuff when you are only in high school.

S9 – post test I now see myself as a scientist as well as a student because this experience has made me begin to think about many different things like how diseases can be prevented or cured or how something can be improved or what can be invented to help this out.

S9 – post test I am definitely more confident in doing science. I really have struggled with science in the past and I thought it was interesting but I was never successful. My interest in science has now grown because I have personally seen all of the cool things science can do.

S9 – journal I am really excited about learning science now. Before it was a bit of a chore, something I had to do to pass. Being here in this program has shown me to "real world" of science and how very crucial scientific learning and understanding is.

On how a student may NOT have gained an accurate portrayal of science

S5 – post test Science is simply progressed by trial and error. Science does not require as much knowledge about electronics or the world around you. Anyone can more so learn a protocol and perform an experiment. Everyone can't build and make a computer.

C2. Teacher Quotes

<u>On teachers being surprised at the cost of doing research</u>
T4 – journal The most amazing thing about watching these experiments is the cost of all of the equipment, chemicals, disposable materials. A sterile environment must be maintained at all times. This necessitates the use of a great deal of disposable pipet tips, plastic well plates, test tubes, vials, centrifuge tubes. The cost of the chemicals was staggering. FuGene costs almost $300 for a vial 1 ml in size. The cost to run each test of a given experiment is exceptional.

T4 – weekly discussion the money that is spent ($280 for 10 ml of substance), the waste generated, the error that takes place, the competition within the department (rush to beat people to publish paper)

T7 – weekly discussion the cost of the equipment

T9 – weekly discussion the total cost of the grant was a surprise

<u>On teachers being surprised at the time line of doing research</u>
T3 – interview I thought things progressed a lot more smoothly and quicker – not the case in science.

T8 – journal I suppose one thing that surprised me was the length of time experiments take. 5 blood samples might take a tech all day to process. There are no fast or pad answers in science – it's a process.

T9 – interview I learned the time factor is totally different. I didn't know science was that way.

<u>On learning scientific acronyms</u>
T2 – weekly discussion Last year I needed time to learn acronyms.

T6 – weekly discussion many acronyms

<u>On how problem solving occurs in the lab</u>
T2 – weekly discussion these people sit around and figure out the next step – amazing

T4 – journal The "journal club," as our weekly meeting has now been nicknamed, is an open discussion of techniques, errors, and problem solving performed by other labs. This generates discussions concerning lab techniques performed in lab as well as forces researchers to keep and open mind about hypothesis and conclusions.

T4 – journal The most amazing thing to witness is a philosophical scientific argument. There are many different hypothesis that can be presented for a single problem and well as many techniques used to prove or disprove a hypothesis.

T4 – post test [on analyzing data] In a new field and new techniques it is difficult. Normally it is based upon negative controls. New techniques, however, present internal control issues often skewing results.

T4 – post test The scientific process is complex with lots of gray area…I thought data would point specifically to a yes or no answer but science doesn't seem to work that way.

T8 – interview I didn't realize the techs were people that do the procedures…the techs know every protocol but don't know the "whys" to the problem.

T9 – post test [surprised at] the way scientists do so much "thinking"! They do the experiments over and over again in their heads trouble shooting the experiment before they actually begin bench work.

<u>On the most important tools, skills, concepts, habits a scientist must have in order to do his/her job well. Question from Pre and Post Inquiry</u>

T1 – journal The broad picture that I am seeing is that knowledge; planning and determination are keys to success in what we do in life. Dr. X's weekly meeting discussed that as a surgeon that 50% of his surgery is completed when he washes his hands going into surgery. At first it did not seem correct. But as I ponder his words of advice I found that they were true…Hopefully I will be able to pass along the information that planning is key to success.

T1 – post test [what part of action plan was directly inspired by STARS?] other labs working together

T5 – weekly discussion Surprised at how much technical skill is required – homogenizing tissues!

T8 – post test Scientists had better be patient – big time. Sometimes, you might work on an experiment for days and use old primer and it wrecks your results.

<u>On learning about peer review, journal publication and obtaining grants by observing mentors at weekly meetings</u>

T1 – interview [surprised at] the number of meetings and the "hush-hush" attitude

T3 – post test I had 3 meetings a week.

T4 – journal Several things must happen to maintain a successful program. One, the PI must be able to write and receive research grants…The number of people with the disease or number of contributors plays an integral part in success at UT Southwestern. Second, the lab has to produce quantifiable results in a given time period. People in the US are into instant gratification and want science to move at light speed. However, cell research takes time and since this is where everything is taking place, it is often difficult for research groups to work.

T4 – weekly discussion Got to see major break through – see a paper being published.

T4 – weekly discussion writing up a conclusion, sit in meeting to publish a paper, send it to the Journal of Neuroscience, shoot it to editors, the data came back "skewed", how do you insert data in a paper discussion

T8 – post test You also better be ready for serious peer review – in the scientific community, peer review is tough stuff. You had better have concrete data and measurable results or you will <u>regret</u> it.

<u>On impressions pertaining to the personalities of scientists</u>
T3 – journal I had once thought that most researchers were quiet, "stuffy", sort of characters, but from a previous research experience I have found differently.

T4 – journal …the people do not seem too eager to bond, work between teams, and to share information, space and even their time…For instance the department seems to have a real rift between research labs. Space is at a premium and if you don't bring in the research grants (i.e. money) your space is taken.

<u>On mentors being too busy to help the teachers</u>
T2 – interview I feel like my mentor has projects going on and I don't want to interrupt them.

T5 – journal When I visited with the PI before the summer began. I thought he was going to be more hands on with me than he is. He was to leave (go out of town) a couple of days after I first began work and seemed very distracted and didn't have time to talk to me. He frankly seemed annoyed that I was there – one more thing to deal with.

T8 – journal My mentor is incredibly nice, but like most PI's, he's extremely busy.

T8 – post test My mentor was busy. I petty much had to take charge of my own learning.

On being able to work with grad students, medical students, etc.
T1 – interview is working with Ph.D. and M.D. so she gets two different perspectives…gets to be around techs, M.D. and Ph.D…

T2 – weekly discussion I am working with one med. student who came from a family of educators.

T6 – weekly discussion SURF student in there, observe, then let him do it, very comfortable

On being in a situation where inquiry is required to develop or rework a hypothesis
T1 – journal At this point in the lab – I expect from the articles that I am reading that my cells will convert to osteoblasts. I also expect that once they achieve that level then they will not stay osteoblasts long.

On being in a situation where inquiry is required to develop or rework a protocol / experimental design
T1 – journal My project was to start figuring out a protocol. My project does not have a set protocol, but instead a lot of theoretical knowledge but no previously documented cases. Thus, I was feeling frustrated. Then today the frustration gave way to understand and appreciating how and why cells grow. At this time in my life, I did not except to feel that way about a concept that I have understood for so long.

T1 – journal My cell flasks became majority contaminated. I thought that I was doing a sterile procedure currently but I'm not. I do not feel confident at all. My cell #'s are all over the place and do not correspond to the visual results – do not understand why…

T3 – journal Trial and error (or restart the design). I think the biggest part of the scientific method I have experienced has been the most important and most left out step, Retry! My apparatus has had difficulty and we keep making modifications.

T3 – final presentation was able to design procedure himself and problem solve conflictive constraints

T5 – journal 2 possibilities – 1) Treatments work but are quickly degraded so stored tissue treatments are no good 2) the treatment process itself isn't reliable...This shows an interesting principle in scientific research. Science research often proceeds 2 steps forward and 1 step back...(if we are lucky).

T6 – journal Southern blot results were poor using the SAC-1. Possible reasons 1. Improper temp during prep of membrane 68° instead of 42°...2. Radioactive marker did not appear to have been taken in by the membrane.

T7 – journal I have spent 3 weeks trying to get my restriction enzyme to cut the DNA bands. Every time I do a new test and a new PCR or gel I need to write down all the steps.

On being in a situation where inquiry is required to conclude that their data is right or wrong, accurate or not accurate, precise or not precise (on Pre and Post Inquiry)

T3 – journal I am not confident in my cell prep or the VSS [machine] to be confident in my data yet but we are improving all the time. Most of my error that would yield problems in my data comes form cell prep. My freshman attempts may be causing problems.

T4 – journal My data this week proved to be an error on my part. I was given a sample on Monday to restrict and examine. Either I picked up the wrong sample or it was handed to me. I assumed (along with my mentor) that the ligation had failed, so I reset the entire process and reran the ligation and transformation. This took three extra days to perform...As many samples and the level of organization present, I am sure this is a normal occurrence, and my mentor didn't seemed too upset.

T6 – journal [Identify the parts of the scientific method that you have participated in.] gather data, test, test, retest and test again, examine data (answers) and usually see where we went wrong

T6 – journal Ponder – (time) – why things do not go according to plan and where did I go wrong in the process and how can I correct it...when things work the data is probably accurate, when it doesn't something or someone (me) didn't do something right.

T6 – weekly discussion everything came back wrong, probes not reading, gathered RNA and it was degraded, had a week of failure, will re-grow culture now to increase the number of cells to use

T7 – weekly discussion Friday, accuracy in pipeting, mistake in pipeting 0.1 ul instead of 1 ul, be patient

T8 – post test Yesterday we were reviewing some data on some double blind dissections and cultures, but there was a big problem. Our data consistently was the opposite of our hypothesis. If the data is consistently wrong, it might mean that a previous research study was wrong. That means starting over again.

On experiencing a mistake, road block or constraint in the research

T1 – post test [What were the most profound things you learned?] patience, failure is a guarantee…my failures to gain results is amazing

T2 – weekly discussion Failure surprises me. I go home and feel bad. Things don't always go cookbook.

T4 – journal So much was made of mistakes we will make. I witnessed professionals make an error. Of course it wasn't their fault, but an error interjected somewhere in the protocol. The technician was having to return the set again to find out what gave her the false positive in her control in the banding.

T4 – post test most of ours [experiments] failed

T6 – final presentation Failure is abundant…failure can lead to something else.

T6 – weekly discussion the amount of failure you go through…

T7 – final presentation Failure became a good friend of mine. I became frustrated but will take away do much

T7 – weekly discussion I didn't think that making a mistake would upset me as much.

T8 – post test Science doesn't care how smart you are, if you can't "stay in the moment" and keep a clean technique, you won't get consistent results.

T8 – post test If your project lasts 8 years, you might work a month with non-stop failure because someone made the TBE [buffer] incorrectly. Or the research to date may be wrong. If your failure is constant, you might have to rethink your hypothesis.

T9 – weekly discussion Meeting with my PI, he said more scientists have failure because they didn't have the dexterity to do it.

T9 – pre test My PI told me that 60% of what you do in the lab is just preparation to what your intended experiment is, then that over half of what you complete doesn't work, so you have to trouble shoot. But this is how more is learned so it might not be true failure.

<u>On what parts of the scientific method the teacher participated in</u>

T1 – journal So far in my own personal research at UT Southwestern, I feel that I have looked at the problem. Lists of factors and key concepts that will apply to my problem have been listed as well as the justification of how and why there are controls. At this point, I am examining which enzymes, markers, etc. to be used in my project. I have also experienced some problem solving with techniques that will be used in the project.

T1 – interview the thought process to come up with the protocol...she is going through the experience of developing the protocol and can now explain this "fork in the road" to students

T2 – journal I feel like I have been able to use most of the scientific method steps during my lab experience. I have been given a project that includes an overall question to be answered through research, and gathering data. I have had to follow a certain protocol or procedure step-by-step for each test run. I have used both positive and negative controls in my tests and have learned the value of having both in the test design. I have had to research to find out more information on my topic to help me better understand the research problem and the hypothesis developed by the researcher. I have had to gather certain materials and use specific equipment in performing the tests. I have collected data in the form of both qualitative and quantitative data. I have had to analyze the data to determine the next step in the testing. I have had t retest when the negative control had a positive reaction. I have had to problem solve in a systematic way to find out why the negative control showed a positive result. I have spent the majority of my time researching, collecting data and analyzing the results.

T2 – post test After initial discussion [with PI], I had more of the responsibility for my project...

T2 – post test The positive/negative controls helped me look at / analyze my data more accurately.

T3 – journal What are the effects of variable wavelength and intensities of light on epidermal cells? This is my mentor's question that I have adopted... The development of a good procedure will soon come into play. I am learning how to set up my samples and test them properly...At first my parameters were set by Joe. As time has past and after a few runs I have been making changes. Good or Bad?

T4 – journal Most of the hypothesis was developed before I arrived and I have just been participating in the conducting of the experiment. In fact, I do not believe I will even finish the experiment by the end of the summer. The process is quite tedious and time consuming. On the other hand, I have participated in evaluations of others' research including contemplating hypothesis, experimental design, error evaluation, and examining conclusions.

T4 – final presentation Went to clinicals, experienced patients with ALS, learned how important the research was [because of visiting with these patients]

T5 – journal Tuesday – poured gradient gel for CDK5 assay…It seems that the plan is for me to learn techniques so I can help others some what like a tech… it might be possible to set up a project for me later but we have to wait on that for a while…The lab tech left me a large portion of the analysis on my own…I spent most of the morning going over film and the article, trying to make connections, draw conclusions, etc…It was rewarding to take part in this planning process and to understand what was happening…followed standard lab protocol for all blots…followed standard protocol to avoid cross contamination of samples (hopefully)....followed protocol for Trizol isolation of RNA, used RNeasy to clean…

T5 – interview is coming up with his own protocol and has found it frustrating

T7 – journal Began making gel, mixed DNA samples with dye, used gel electrophoresis…ran PCR results from previous gel…

T7 – final presentation T7 learned to accurately pipet, did PCR, did DNA sequencing, had a picture of expected results and compared it to those observed results (they did not show a correlation), did the statistics to back up conclusions
T8 – journal I have found that writing every detail of the procedure down is important…I made solutions for the lab and did PCR. They also realized that I am the pipet queen…By Friday, I was doing a Parent of Origin DNA extraction by myself…

T8 – journal The problem I'm facing is that I'm not proficient enough to formulate conclusions…On a lighter note, I do know the problem, materials, procedure and observation. I'll probably get Dr. X to help me interpret the results of the genotyping before I formulate my conclusion. I've been doing all the DNA and buccal smear extraction for our lab. I've been doing half of the PCR prep work – making gels, loading dye. I've also been running the bio-imaging machine…I do blood extractions, take care of the mice, make gels – general "lab rat" tasks.

T8 – interview Interpreting results is what I need help with …she is on the procedure part and some of the observations

T9 – journal PI wants me to go to another lab, be trained on INSITU and then come back and train his lab personnel. He also would like me to produce a 60-90 min CDRom on how to use the cryo.

T9 – post test My mentor didn't tell me very much about what to do. This year was a little too free.

<u>On learning about a new discipline that is not a subject the teacher teaches</u>
T3 – journal We are going to meet some day next week with [another doctor] to discuss the cell lines and proteins. (subject is a physics teacher)

T8 – post test Reading and writing are crucial for science. Publish or perish is no joke. Scientists have to read – a <u>lot</u>! Every time a new article is published, scientists have an obligation to review it.

<u>On teaching science before STARS – how students do not participate in inquiry involving developing hypotheses</u>
T1 – journal My students probably do not ask this question [What explanation do you expect to develop form your data?]. It probably does not occur to them to ask or come up with the question. If they think of the question – they probably push it aside to finish the lab's lab write up.

T3 – journal [On if students think about what explanations they expect to develop from their data] Do my student have time? Rarely, but hopefully I can work on more Pre lab and Post lab with them.

T6 – journal Students – usually have trouble formulating the hypothesis, they enjoy the experiment part the most.

<u>On teaching science before STARS – how students do not participate in inquiry involving developing experimental design</u>
T1 – journal I felt that my students participate in actually doing for the experiment. The theoretically / logically system in which a scientist goes through finding the answer i.e. To set up the experiment is lost on my students. I feel that they just see the results instead of the whys (why did you pick this chemical instead of that chemical) and how (why did you run a spec 20 instead of calorimeter) you did the actually set up of the system to carry out your experiment. Thus, this could answer the question: why

students do not understand what they did in lab even though they performed the experiment.

T4 – journal It is almost impossible to get ahead and understand the direction of such complex problems and applications. I wonder if my students feel this same way. I have always assumed that we are building upon previous knowledge and we limit the complexities of the problems, that they do have time to develop ideas before data presentation. Of course, I know this is not always the case and some students struggle with the purpose of any lab.

T8 – journal I suppose my students participate in the procedure portion more than the other steps. Let's face it – it's easier.

<u>On teaching science before STARS – how students do not participate in inquiry involving data analysis</u>

T3 – journal Most analysis is left out or done independently.

T6 – weekly discussion graphing is bad

T8 – weekly discussion Students expect me to tell them how to do it, kids don't know the difference between independent and dependent variables, graphing, I had kids that ended up with square root problems, identify what variables to graph, bad at

<u>On teaching science before STARS – how students mostly participate in data collection / cookbook labs</u>

T3 – journal Students are usually involved in data collection the most.

T3 – pre test Most labs I have are cookbook.

T4 – pre test Some labs are cookbook labs. With class sizes of 30 it is hard to do labs that are inquiry based.

T5 – pre test Superficial data gathering, cookbook observation labs.

T6 – pre test [before STARS, T6's labs were] about ½ inquiry and ½ cookbook

T7 – weekly discussion Gave students directions, had students read directions…read protocols, gives students a list of directions

T7 – post test most are cookbook labs

<u>On teaching science before STARS – how students mostly participate in inquiry labs</u>

T1 – journal My students hit conflicting restraints quite often. They have physical restraints like limited lab space; limited shared equipment i.e. hot water baths, centrifuges, etc. On the mental end, they have some idea of mental errors in lab, but it needs to be developed more (I am working on that).

T2 – pre test At the beginning of the year I use more cookbook labs. This is when we are learning the scientific method and how to use the tools safely. We also focus on writing a hypothesis and drawing conclusions (specific skills). Then I expand to inquiry based labs. I use those to engage the students and to challenge their problem solving skills.

T2 – journal I think that the students in my class participated in different parts of the scientific method based on the type of lab that they are doing. At the beginning of the school year the students are given more of the lab steps in the form of the scientific method (cook book form to practice different skills). Then as the students become more skilled they are responsible for more of the lab write up (are given less of the lab paper). These labs are more inquiry based and help the student apply their science process skills and knowledge of the scientific method. My goal is going to be to have the students have a more authentic lab experience and make them more responsible at an earlier stage for using the scientific method / science process skills.

T4 – pre test However, we are moving in that direction [doing more inquiry based labs]. Our district has pushed for performance based grading of labs with free open procedures, setups, and conclusions.

T4 – journal The methodology in which to implement the action plan was the easiest part . We use Bloom's taxonomy starting with an introductory level and more to an evaluative level.

T7 – journal Most of my students at school participate in s Science Fair and I grade them according to the scientific method. I also teach this to all my students as they are expected to know the steps of the scientific method and we use this in most of our labs.

T8 – pre test I teach in a variety of ways. In the beginning (August) since most of my students have never before been exposed to science, I use some cookbook labs, but in conjunction with these, I begin to teach scientific methodology. As the year progresses, students begin constructing their own solutions to problems eg. – Catapults with a purpose, Junkbag Wars, etc. Student also begin Science Fair.

T8 – weekly discussion in April every group in all classes did a performance-based lab

On teaching science before STARS – what teachers would change about the way they teach laboratory investigations

T1 – pre test I would change the method I do inquiry based labs. I would build up to the big inquiry projects that we do by conducting smaller inquiry based labs to teach hands on techniques of the scientific method.

T3 – pre test I hope to change that [having mostly cookbook labs] soon. I want to have more inquiry based labs.

T5 – pre test Change to be open ended so kids have to draw their own conclusions.

T9 – pre test Most of my labs are inquiry based or their purpose is to review concepts. I only see a need for continued improvement in my labs, no drastic changes are needed.

On what teachers hope to gain from STARS

T1 – pre test T1 is hoping to gain keys to assist her students through their own projects and research.

T4 – pre test T4 wanted to develop new laboratory techniques, to practice complex problem solving, and T4 plans to develop curriculum for students to create long term science projects, science fair programs and to develop lab activities for large classes [to do inquiry].

T5 – pre test I hope to reconnect with "real world" science, so that I can better model my classroom to reflect the scientific paradigm, with great emphasis on inquiry based learning.

T6 – pre test My goal is to become familiar with the latest research techniques in the area of molecular biology.

T6 – pre test [T6 wants to] increase the number of inquiry based labs.

T7 – journal I know I would like to reach a point where my students are writing out the labs instead of these recipe labs.

T8 – pre test I am at UT to learn cutting edge techniques to take back to my classroom.

T8 – pre test I am firmly entrenched in scientific methodology. My weakness clearly lies in the use of scientific technology and up-to-date lab techniques.

T9 – pre test My goal is to learn more "real" science. I hope to incorporate what I learned into application examples and better inquiry science in my classroom.

On teaching differently after STARS – understanding true inquiry better

T2 – post test T2 learned of the need to focus more on the "questioning" aspect and problem solving skills – having students ask more questions / analyze their data…

T3 – weekly discussion What if I want to make it [the action plan] inquiry and make a planning lab? Do I skip the "data" sections? Can I just give general instructions?

T3 – post test I am going to make labs a little more open-ended and allow more time for reports.

T4 – interview It has changed my philosophy about how I'm going to do lab, spend more time on scientific method analyzing data, the thought process of how to write a good conclusion, evaluating other people's work, how do you know weather to through out data…

T5 – interview Get kids to ask more questions, their assignment would be to ask more questions

T7 – weekly discussion trying to get inquiry based labs

T8 – journal This experience has been illuminating. I see things now more clearly. I knew that inquiry – based learning was important – now I know why. It's real science.

T8 – post test I want to do research side by side with my students. I want them to know what interests me and how I plan to approach the problem and conduct the research.

T8 – post test We are also going to "overwhelm and devastate" at the science fair – I cannot wait.

T9 – journal But I keep thinking it would be great to reinforce scientific method and allow students to observe animal behavior and allow for open-ended inquiry all at the same time. What if I provided them with planaria, egg yolks, butteries, ice, heating pad, dilute lemon juice, dilute detergent, various colors of transparencies, black paper, flash light, thermometers, and various other things (glassware, scopes). Then I told them to set up an investigation, using the scopes. Then I told them to set up an investigation, using the steps of the scientific method and delve into a behavior of planaria? Have them take it from start to finish with a free write up on their methodology. Is that too much independence?

T9 – interview My students don't get answers to the questions. This experience has reinforced the need to not tell kids answers

T9 – post test I've become more convinced that my students need more independence in lab and more feed back on their "processing skills".

<u>On teaching differently after STARS – on having students experience conflictive constraints / failure</u>
T1 – weekly discussion Your students are set up to succeed, they don't except to fail

T1 – post test try to give the students some failure in lab, better picture of research

T2 – final presentation We always set students up to make them successful. I'm learning that's not the best way to go with my students. I've had to start over with 250 samples 3 times…I learned how to really sit down and analyze data.

T3 – weekly discussion Failure is summed up with "patience." You learn there are other factors here.

T4 – post test I plan on designing more open ended labs and labs that do not work for the purpose of increasing problem solving.

T4 – final presentation I will tell my students to be patient, expect failure.

T5 – weekly discussion I don't think I've given my students the chance to fumble. I will try to now.

T6 – interview [Any student misconceptions?] yes, students don't realize error and failure associated with science. Students don't know how to fix it if it doesn't go wrong. [T6 pondered how to change this – but didn't come up with answer during our interview]

T7 – weekly discussion If we can teach our kids to accept the failure and then go on…

T9 – weekly discussion We come from a situation were it takes an effort to fail

<u>On teaching differently after STARS – on timing in science</u>
T7 – journal They will learn Rome wasn't built in a day. Research takes time.

<u>On teaching differently after STARS – on giving students more "real world" situations</u>
T2 – interview Now I will ask, "What am I doing? Am I doing this to get them ready for the real world?"

T5 – interview I want to frame problems with more practical applications in science, seek more real life applications

<u>On teaching differently after STARS – safety in the lab</u>
T8 – journal Another application that I'll do this weekend is to make digital-picture posters (a lab safety poster, a lab equipment poster, a proper lab protocol poster).

<u>On teaching differently after STARS – the need to read journal articles</u>
T1 – post test How to read and understand science journal articles

T8 – journal Each time I read a technical article, I understand a bit more. Even if the article is fraught with DNA vocabulary, I can still learn from it. I'm going to have my students read more scientific journals when they are in my class. Just like me, the more they read, the more they understand.

T8 – weekly discussion will have students keep up with a science journal (even if you don't understand it, write it down anyway),

T8 – post test I am going to subscribe to *Nature*. It is the "bible" of scientific journals.

<u>On teaching differently after STARS – changing the use of notebooks</u>
T2 – journal ...why it is important to document each step of the testing process (including both qualitative observations and quantitative data).

T4 – journal The amount of notes taken concerning their experiments is overwhelming. Volumes upon volumes of research studies fill the book shelves. This is one area that I plan to impress upon my students in the future.

T4 – journal The number one item to change this fall is a notebook. Research is predicted on knowing what, when, where, how, and why an experiment was performed. I currently use a notebook for labs but do not place much emphasis on its use. Next year I plan on doing a better job of managing its uses.

T8 – weekly discussion have students rewrite protocols

T8 – post test I'm going to make my students keep lab notebooks like an actual lab does.

<u>On teaching differently after STARS – having students develop their own problem</u>
T8 – weekly discussion will help her students think of problems [to study]

<u>On teaching differently after STARS – having students develop their own procedures</u>
T3 – interview I'm going to develop a lab that makes students develop a procedure.

T7 – interview Wants to get to the point where students will not be graded on the answer, but the process.

T9 – final presentation What I wanted was to assess them on the process not the results. Learning is not from results.

<u>On teaching differently after STARS – the use of controls in classroom</u>
T1 – post test more positive and negative controls

T2 – journal I have some good examples of what happens when your negative control turns out to be positive after the testing.

T2 – weekly discussion Negative controls are important.

T2 – journal I have also learned the importance of having both negative and positive controls in an experiment.

T5 – weekly discussion because my control didn't work on gel, can show this example to my students

T9 – journal Dr.[her mentor] has 3 lab rules: First - do it on a small scale first, second – don't trust anyone, even yourself (validate everything), and always run a positive and negative control. I intend to take positive and negative controls into my classroom.

T9 – weekly discussion will teach positive and negative controls in classroom

On teaching differently after STARS - the need for more accuracy
T2 – interview Learned why accuracy is important for students, if not, grant money is wasted.

T2 – journal ...how being accurate and patient are important skills of a research scientist.

T6 – journal The need for accuracy – even if the results are right or not we must be certain that each protocol was followed to the letter. Any mistake will always affect the outcome.

T8 – interview Needs to work on with students – the accuracy of techniques and precision

On teaching differently after STARS – preforming techniques
T1 – weekly discussion will take back [to classroom] contamination, sterile procedure

T2 – journal I can give examples in a lab situation of why it is important to read and follow directions (the protocol / procedure) when doing any type of lab / test...

T4 – weekly discussion [On what skills teachers should emphasize more in classroom] pipetting micoliters is hard

T8 – journal With the money that I receive from STARS, I'll set up a "bio-tech kids" corner in my room...For example, one box might contain various types of small-cheap pipets and four containers of colored water. Students could learn pipeting techniques by mixing the correct amounts to form colors eg. green, etc. Another box might contain a plastic graduated cylinder, some non-hazardous powders and instructions on making solutions.

On teaching differently after STARS – math problem solving
T2 – post test Will focus more on math, problem solving math, find the concentration, calculate metric conversions to the micro and nano level

On teaching differently after STARS – data analysis
T2 – interview Students need more emphasis on graphing, statistics, data analysis

T4 – interview being wrong doesn't make a difference...It's okay to be wrong as long as you can document

T8 – journal He [mentor] told me of a study conducted by a scientist in 1997 that had caused some problems in the field. The scientists had overstated his conclusions and leapt to unjustified conclusions. The lab is conducting research in a more methodical manner to test his conclusions…Secondly, the whole notion of holding faulty conclusions "to "he light" for inspection is such a valuable project for my students to see

On teaching differently after STARS – peer review
T4 – interview more constructive criticism on their papers, model with students a "paper shred", evaluate each others work paper, more peer editing

On teaching differently after STARS – exposing students to cutting edge science
T2 – journal I also feel I can expose the students to cutting edge science practices and more technology related to science research.

T8 – post test I'm not going to hesitate to use more advanced equipment

On teaching differently after STARS – having empathy for what students are going through
T2 – interview Is now putting herself in her student's shoes.

T3 – interview Learned how difficult the apparatus is…he is going through what students are going through…kids walk in and see Bunsen burners and don't know what that is…this experience is humbling

T4 – final presentation I know how my kids feel – the amount of information that's given to them.

T8 – weekly discussion feels like students feel – overwhelmed

T8 – weekly discussion frustration – I know how they feel, I am going through it

On teaching differently after STARS – on using resources found at UTSW during school year
T2 – post test T2 learned all of the resources available at STARS and UTSW, learned the types of research being done in the labs today.

T7 – weekly discussion I will take my students here to show them the research world.

T7 – interview He will bring his advanced students here [his UTSW lab] next.

T8 – post test I got a centrifuge from the warehouse today.

T8 – post test I will not hesitate to call for science fair info., judges, etc. I also plan on becoming a regular fixture at the warehouse [where teachers can get used supplies].

T9 – post test I intend to request the medical examiner and [her mentor] for presenters to my students during next year's field trip.

<u>On teaching differently after STARS – on having first hand examples to tell students</u>

T1 – post test T1 now has guest speakers for her class tours and will attend the STARS symposiums

T2 – journal Almost everything that I have learned this week can be used in one form or another in the classroom. On of the most important things I can bring the students is "real world" application of the scientific method and science process skills.

T5 – interview I find little examples of small things that fit into experiments

T7 – interview Has another experience [story] to talk about in school.

<u>On teachers discussing how many of their mentors have a problem with English as a second language</u>

T1 – weekly discussion English – we argue over what the doctor is trying to say

T2 – weekly discussion The language barrier creates problems. My mentor can't get past it. In journal clubs I cannot understand the talk – its not English.

T4 – post test [on qualities of good scientific notebook] in English for us Americans

T9 – weekly discussion There is a language barrier in my lab, the doctor cannot communicate in English for his papers

<u>On limitations of replicating STARS in the classroom</u>

T1 – weekly discussion difficult to take back to classroom

T2 – post test Inhibiting factors – time, curriculum constraints, money for needed equipment and supplies

T3 – interview The hindrance is time, because we have so many objectives to teach.

T4 – journal The most difficult aspect was cost effectiveness of the experiment. To be able to replicate or even simulate activities currently being used in my research lab is extremely expensive and very difficult in terms of expertise required. I had to spend a great deal of time researching a means of making a cost effective, low maintenance, and lower level technique.

T4 – pre test With class sizes of 30 it is hard to do labs that are inquiry based.

T4 – pre test Time is the biggest problem. When you have 160 students it is hard to find time to do anything but teach, grade papers and write lessons.

T7 – weekly discussion hard to find how what I'm doing fits into my classroom

T7 – weekly discussion What I'm finding is the stuff that I'm doing is so advanced, I don't know what I'm going to do. I will probable end up copying a DNA lab that others have done

T8 – weekly discussion safety is a constraint

T9 – weekly discussion all I can really take back to the classroom is concepts, can't take back his [Mentor's] research

T9 – interview Can't teach inquiry-based because there is no time...Has to be a balance because they have no idea of the concepts.

<u>**On how STARS has increased confidence**</u>
T1 – post test Yes – more exposure to science taught me that I can handle cutting edge research so I can handle explaining the harder concepts better t my students.

T3 – post test I feel more comfortable asking for any help from the lab.

T4 – post test I can honestly say that this experience has given me the desire and aptitude to be a great science teacher. I now understand (all too well) the process of scientific discovery and how to start teaching my students about the techniques.

T8 – post test I'm not scared of "smart" people anymore. Not that I know how they can help me, I will call and ask…I'm not afraid to try just about any procedure.

Thoughts from two teachers who are participating in STARS for the second summer

T2 – weekly discussion never used my action plan [from STARS program last year]

T2 – interview Gets in trouble with other teachers because she now has different ideas than them.

T2 – interview Last year, students respected her for being on her project last year.

T9 – pre test This is my second summer at UTSW. The previous experience enhanced my teaching methodologies, but didn't really change them.

T9 – pre test T9 went to STARS symposium and took a field trip to UTSW. I incorporated what I learned into my classroom activity labs.

T9 – interview I have always encouraged careers, but students didn't really believe her – now they know she has been through it and they are hooked.

APPENDIX D

UCRIHS and IRB Approvals

MICHIGAN STATE
UNIVERSITY

May 30, 2002

TO: Merle HEIDEMANN
118 North Kedzie Hall
MSU

RE: **IRB# 02-325** CATEGORY: EXEMPT 1-2
APPROVAL DATE: May 30, 2002

TITLE: THE SCIENCE TEACHER VERSUS THE SCIENTIST: WILL PARTICIPATING IN LABORATORY FIELD EXPERIENCE LEAD TO INCREASED PROCEDURAL UNDERSTANDING OF SCIENCE AND SCIENTIFIC PROBLEM SOLVING?

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the UCRIHS approved this project.

RENEWALS: UCRIHS approval is valid for one calendar year, beginning with the approval date shown above. Projects continuing beyond one year must be renewed with the green renewal form. A maximum of four such expedited renewals possible. Investigators wishing to continue a project beyond that time need to submit it again for a complete review.
REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please use the green renewal form. To revise an approved protocol at any other time during the year, send your written request to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.
PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at (517) 355-2180 or via email: UCRIHS@msu.edu. Please note that all UCRIHS forms are located on the web: http://www.msu.edu/user/ucrihs

Sincerely,

Ashir Kumar, M.D.
UCRIHS Chair

OFFICE OF
RESEARCH
ETHICS AND
STANDARDS

University Committee on
Research Involving
Human Subjects

Michigan State University
202 Olds Hall
East Lansing, MI
48824

517/355-2180
FAX: 517/432-4503
Web: www.msu.edu/user/ucrihs
E-Mail: ucrihs@msu.edu

AK: kj

cc: Angela Lynn Alexander
14501 Monfort Dr., #1327
Dallas, TX 75254

MICHIGAN STATE

UNIVERSITY

April 9, 2003

TO: Merle HEIDEMANN
118 North Kedzie Hall
MSU

RE: **IRB # 02-325** CATEGORY: 1-2 EXEMPT

RENEWAL APPROVAL DATE: April 8, 2003

EXPIRATION DATE: March 8, 2004

TITLE: THE SCIENCE TEACHER VERSUS THE SCIENTIST: WILL PARTICIPATING IN LABORATORY FIELD EXPERIENCE LEAD TO INCREASED PROCEDURAL UNDERSTANDING OF SCIENCE AND SCIENTIFIC PROBLEM SOLVING?

The University Committee on Research Involving Human Subjects' (UCRIHS) review of this project is complete and I am pleased to advise that the rights and welfare of the human subjects appear to be adequately protected and methods to obtain informed consent are appropriate. Therefore, the UCRIHS APPROVED THIS PROJECT'S RENEWAL.

This letter also notes approval for data analysis only and change in co-investigator's last name and contact information.

RENEWALS: UCRIHS approval is valid until the expiration date listed above. Projects continuing beyond this date must be renewed with the renewal form. A maximum of four such expedited renewals are possible. Investigators wishing to continue a project beyond that time need to submit a 5-year renewal application for complete review.

REVISIONS: UCRIHS must review any changes in procedures involving human subjects, prior to initiation of the change. If this is done at the time of renewal, please include a revision form with the renewal. To revise an approved protocol at any other time during the year, send your written request with an attached revision cover sheet to the UCRIHS Chair, requesting revised approval and referencing the project's IRB# and title. Include in your request a description of the change and any revised instruments, consent forms or advertisements that are applicable.

PROBLEMS/CHANGES: Should either of the following arise during the course of the work, notify UCRIHS promptly: 1) problems (unexpected side effects, complaints, etc.) involving human subjects or 2) changes in the research environment or new information indicating greater risk to the human subjects than existed when the protocol was previously reviewed and approved.

If we can be of further assistance, please contact us at 517 355-2180 or via email: UCRIHS@msu.edu.

Sincerely,

Ashir Kumar, M.D.
UCRIHS Chair

AK kb

cc: Angela Lynn Alexander-Forte
5510 Lafayette Dr.

OFFICE OF
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SOUTHWESTERN
THE UNIVERSITY OF TEXAS
SOUTHWESTERN MEDICAL CENTER
AT DALLAS

Institutional Review Board

TO: Angela Alexander
14501 Monfort Dr. #1327
Dallas, TX 75254

FROM: David Waller, MD
Institutional Review Board 1 Chairman
IRB - 9007

DATE: 17 April 2002

RE: **Expedited Approval of Protocol and Subject Consent Form**
IRB # 0402-223
The Science Teacher Vs. the Scientist: Will Participating in Laboratory Field Experience Lead to Increased Procedural Understanding of Science and Scientific Problem Solving

The Institutional Review Board determined that this research was eligible for expedited review in accordance with 45 CFR 46.110(a)-(b)(1), 63 FR 60364, and 63 FR 60353. The Board approved the protocol and informed consent document(s) dated 16 April 2002. IRB approval of this research lasts until 15 April 2003. If the research continues beyond twelve months, you must apply for updated approval of the protocol and informed consent document one month before the date of expiration noted above.

Please note that this protocol has been approved for 30 subjects.

Please note that the IRB will need to approve the translated consent form before enrolling non-English speaking subjects.

The IRB requires that you report to the Board any unexpected adverse events that occur during the study. In the future, if you require a modification to the protocol, obtain review and approval by the Board prior to implementing any changes except when prompt changes are necessary to eliminate apparent immediate hazards to a subject.

The IRB requires that all personnel who interact with research subjects or who have access to research data identified with the names of subjects receive a copy of the Multiple Project Assurance on file with the Department of Health and Human Services. Document their agreement to comply with the statements therein. Such documentation should be kept with other records of the research, which are subject to review by the IRB. Copies of the Multiple Project Assurance and the Federal regulations governing the participation of human subjects in research (45 CFR 46) are available on the IRB website (http://www2.swmed.edu/irb) or from Patrick Fisher at irb@utsouthwestern.edu.

Approval by the appropriate authority at a collaborating facility is required before subjects may be enrolled on this study.

Reminder: Please put the following information on the footer of every page of the consent form: 1) IRB file number, 2) consent form approval date (date of this memo) and consent form expiration date (see first paragraph).

If you have any questions related to this approval or the IRB, you may telephone Andrea Logue at 214.648.3691.

DW/al

5323 Harry Hines Boulevard, B8.406 / Dallas, Texas 75390-9007 / (214)648-3060

SOUTHWESTERN

THE UNIVERSITY OF TEXAS
SOUTHWESTERN MEDICAL CENTER
AT DALLAS

Institutional Review Board

TO: Angela Alexander-Forte
STARS Program
5510 Lafayette Dr.
Frisco, TX 75035

FROM: John Sadler, MD
Institutional Review Board 3 – Chairperson
IRB - 8843

DATE: 27 March 2003

SUBJECT: **Continuing IRB Review – Expedited Approval**
IRB File Number: 0402-223
Project Title: The Science Teacher vs. the Scientist: Will Participating in Laboratory Field Experience Lead to Increased Procedural Understanding of Science and Scientific Problem Solving?

The Institutional Review Board reviewed this research activity on an expedited basis. Your protocol was approved for continuation for the period beginning 16 April 2003 and expiring on 15 April 2004. The consent form was not considered for re-approval because enrollment is closed to new subjects.

Please report to the IRB any unexpected or serious adverse events that occur during the study. Any proposed changes in this research must be submitted to the IRB for review and approval prior to implementation, except for immediate changes necessary to assure research subject safety, which must be reported to the IRB within two days.

This study will require continuing review from the IRB and a reminder will be mailed to you 60 days prior to the **expiration date of 15 April 2004.**

Should you have any questions, please telephone Reda Hall in the IRB office at 214.648.3378.

JS/iw

5323 Harry Hines Boulevard, C1.206 / Dallas, Texas 75390-8843 / (214)648-3060 Fax (214)648-2171

APPENDIX E

UCRIHS and IRB Approved Consent Forms

Date: June 3rd, 2002
To: Participants in the STARS Research Program, Parents and Guardians
RE: Requesting permission to use participants' work in master's thesis paper.

Dear STARS Research Program Participants, Parents and Guardians:

Michigan State University has a masters degree program through the Division of Science and Mathematics Education that is available to high school teachers. As a student in this program, I will be writing a thesis pertaining to science education. The purpose of this letter is to seek your child's confidential responses in my study.

I have been a high school biology teacher for three years at Crestwood High School in Dearborn Heights, MI and a Research Assistant for almost two years in The Alliance for Cellular Signaling at UT Southwestern. I am interested in analyzing how field research (such as the STARS program) increases students' procedural understanding of science.

The collection of data will be brief and will not interfere with your child's work in the STARS program. I alone will analyze all data, and in full confidentiality. Your child's name will in no way be associated with their written or oral responses. Your child's privacy will be protected to the maximum extent allowable by law.

Applicable to high school student participants only ...
For participating in this study your child will receive a $10 gift certificate to *Barns and Noble* upon handing in this fully signed consent form to the STARS office (L4-140) on June 4th. If your child chooses to withdraw at any time throughout this study, his/her data will be destroyed and the $10 gift certificate may still be kept. Thank you for considering to be a participant in this study.

Sincerely,
Angela Alexander
Angela Alexander
Master's of Biological Sciences Student
Michigan State University

High school students who wish to participate in this study will receive a $10 gift certificate to *Barns and Noble* (curtsey of Angela Alexander) if their consent form is turned in fully signed to the STARS office (L4-140) on June 4th, 2002.

Page 1 of 5

IRB File: 0402-223 (UT)
Consent form approved (UT) MAY 29 2002
Consent form expires (UT) APR 15 2003

IRB File: 02-325 (MSU)
Consent form approved (MSU)
Consent form expires (MSU)

The University of Texas Southwestern Medical Center at Dallas
(in conjunction with Michigan State University)

CONSENT TO PARTICIPATE IN RESEARCH

Title of Research: The Science Teacher vs. the Scientist: Will participating in Laboratory Field Experience lead to Increased Procedural Understanding of Science and Scientific Problem Solving?

Sponsor: Dr. George Ordway (UT Southwestern) & Dr. Merle Heidemann (Michigan State University)

Investigator: Angela Alexander, Masters of Biological Science Student, Division on Science and Mathematics Education, Michigan State University	Telephone No.	Fax No.
	(972) 233-8761	(972) 233-3281

PURPOSE: The purpose of this research is to help high school students and science teachers gain an increased awareness of how to learn and teach the procedural understanding involved in 'the doing of science'.

This research is being done because previous research in the field of science education suggests that some high school students lack recognition of the procedural understanding involved in scientific experimentation and problem solving.

PROCEDURES: Your child will be asked to...

- Fill out a pre and post survey detailing their perceptions about science and the process of how science is done (30 minutes each).
- Volunteer to keep a journal about their learning experiences in the STARS program (variable time commitment).
- Volunteer to participate in a brief interview with the project's investigator detailing what they are learning in the STARS program (30 minutes).
- Agree to have their spoken words confidentially and anonymously quoted for this project's research paper (no extra time commitment).

POSSIBLE RISK(S): There are no risks involved in this study.

POSSIBLE BENEFITS: Participants will engage in a systematic inquiry into their own learning styles. The self-reflective surveys and interviews in this study are designed to have the subject analyze his/her learning experience in a real laboratory setting. Participants may gain insight into how one generates ideas, uses theoretical models, conducts experiments, evaluates data and comes to conclusions about science.

IRB File: 0402-223 (UT)
Consent form approved (UT) MAY 2 9 2002
Consent form expires (UT) APR 1 5 2003

IRB File: 02-325 (MSU)
Consent form approved (MSU)
Consent form expires (MSU)

Benefit to others: This study may help future high school students and teachers sharpen their scientific processing and problem solving skills.

ALTERNATIVES TO PARTICIPATION IN THIS RESEARCH: One alternative is not to participate in this study.

PAYMENT TO TAKE PART IN THIS RESEARCH: Your child (for high school student participants only) will be given a $10 *Barns and Noble* gift certificate for participating in this research. The gift is courtesy of, Angela Alexander, the investigator of this project. If your child does not complete all study procedures, he/she will still be able to keep the certificate.

COSTS TO YOU OR YOUR CHILD: None.

VOLUNTARY PARTICIPATION IN RESEARCH: You and your child have the right to agree or refuse to participate in this research. If you and your child decide to participate and later change your mind, your child is free to discontinue participation in the research at any time.

Refusal to participate will involve no penalty or loss of benefits to which you and your child are otherwise entitled. Refusal to participate will not affect you and your child's legal rights or the quality of health care that you receive at this center.

RECORDS OF YOUR PARTICIPATION IN THIS RESEARCH

Information kept at UT Southwestern: You and your child have the right to privacy. All information obtained from this research that can be identified with you or your child will remain confidential within the limits of the law.

Information available to other people: An Institutional Review Board (IRB) is a group of people who are responsible for assuring the community that the rights of participants in research are respected. Members and staff of the IRB at this medical center (and Michigan State University) may review the records of your participation in this research. A representative of the Board may contact you and your child for information about your child's experience with this research. If you wish, you and your child may refuse to answer any questions the representative of the Board may ask.

Publication of the results of the research: The results of this research may appear in scientific publications without identifying you and your child in any way.

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Consent form approved (UT) MAY 2 9 2002
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Consent form approved (MSU)
Consent form expires (MSU)

YOUR QUESTIONS: Angela Alexander is available to answer you or your child's questions about this research at 972-233-8761. The Chairman of the UT Southwestern IRB is available to answer questions about your child's rights as a participant in research. You may telephone the UT Southwestern Chairman of the IRB during regular office hours at 214-648-3060. You may also contact the Chairman of Michigan State University's IRB if you have any questions regarding your child's rights as a study participant, or are dissatisfied at any time with any aspect this study – anonymously, if you wish. His contact information is...

Ashir Kumar, M.D.
Chair of the University Committee on Research Involving Human Subjects (UCRIHS)
Michigan State University
Phone: (517) 355-2180 / Fax: (517) 432-4503 / e-mail: ucrihs@msu.edu
Mail: 202 Olds Hall, East Lansing, MI 48824

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YOU WILL HAVE A COPY OF THIS CONSENT FORM TO KEEP.

Your (and your child's) signature below certifies the following:

- **You and your child have read (or been read) the information provided above.**
- **You and your child have received answers to all of your questions.**
- **Your child has freely decided to participate in this research.**
- **You and your child understand that you are not giving up any of your legal rights.**

Participant's Name (printed)

Participant's Signature **Date**

Legally responsible representative's name (printed) (if applicable)

Legally responsible representative's Signature **Date**

Witness' name (printed)

Witness' signature **Date**

Name (printed) of person obtaining Consent

Signature of person obtaining consent **Date**

ASSENT OF A MINOR: (if applicable)

I have discussed my participation in this research with my mother or father or legal guardian, and I agree to participate in this research.

Signature (participants from 10 to 18 years old) **Date**

IRB File: 0402-223 (UT)
Consent form approved (UT) MAY 29 2002
Consent form expires (UT) APR 15 2003

UCRIHS APPROVAL FOR THIS project EXPIRES:

MAY 30 2003

SUBMIT RENEWAL APPLICATION ONE MONTH PRIOR TO ABOVE DATE TO CONTINUE

Date: June 3rd, 2002
To: Teacher and Mentor participants in the STARS Research Program
RE: Requesting permission to use participants' work in master's thesis paper.

Dear STARS Research Program Participants:

Michigan State University has a masters degree program through the Division of Science and Mathematics Education that is available to high school teachers. As a student in this program, I will be writing a thesis pertaining to science education. The purpose of this letter is to seek your confidential responses in my study.

I have been a high school biology teacher for three years at Crestwood High School in Dearborn Heights, MI and a Research Assistant for almost two years in The Alliance for Cellular Signaling at UT Southwestern. I am interested in analyzing how field research (such as the STARS program) increases students' procedural understanding of science.

The collection of data will be brief and will not interfere with your work in the STARS program. I alone will analyze all data, and in full confidentiality. Your name will in no way be associated with your written or oral responses. Your privacy will be protected to the maximum extent allowable by law.

Thank you for considering to be a participant in this study.

Sincerely,
Angela Alexander
Angela Alexander
Master's of Biological Sciences Student
Michigan State University

If you agree to participate in this research, please turn in your fully signed consent form to the STARS office (L4-140) on June 4th, 2002.

Page 1 of 5

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The University of Texas Southwestern Medical Center at Dallas
(in conjunction with Michigan State University)

CONSENT TO PARTICIPATE IN RESEARCH

Title of Research: The Science Teacher vs. the Scientist: Will participating in Laboratory Field Experience lead to Increased Procedural Understanding of Science and Scientific Problem Solving?

Sponsor: Dr. George Ordway (UT Southwestern) & Dr. Merle Heidemann (Michigan State University)

Investigator: Angela Alexander, Masters of Biological Science Student, Division on Science and Mathematics Education, Michigan State University	Telephone No.	Fax No.
	(972) 233-8761	(972) 233-3281

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POSSIBLE RISK(S): There are no risks involved in this study.

POSSIBLE BENEFITS: Participants will engage in a systematic inquiry into their own learning and/or teaching styles. The self-reflective surveys and interviews in this study are designed to have the subject analyze his/her learning experience in a real laboratory setting. Participants may gain insight into how one generates ideas, uses theoretical models, conducts experiments, evaluates data and comes to conclusions about science.

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Benefit to others: This study may help future high school students and teachers sharpen their scientific processing and problem solving skills.

ALTERNATIVES TO PARTICIPATION IN THIS RESEARCH: One alternative is not to participate in this study.

PAYMENT TO TAKE PART IN THIS RESEARCH: You (for high school student participants only) will be given a $10 *Barns and Noble* gift certificate for participating in this research. The gift is courtesy of, Angela Alexander, the investigator of this project. If you do not complete all study procedures, you will still be able to keep the certificate.

COSTS TO YOU: None.

VOLUNTARY PARTICIPATION IN RESEARCH: You have the right to agree or refuse to participate in this research. If you decide to participate and later change your mind, you are free to discontinue participation in the research at any time.

Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. Refusal to participate will not affect your legal rights or the quality of health care that you receive at this center.

RECORDS OF YOUR PARTICIPATION IN THIS RESEARCH

Information kept at UT Southwestern: You have the right to privacy. All information obtained from this research that can be identified with you will remain confidential within the limits of the law.

Information available to other people: An Institutional Review Board (IRB) is a group of people who are responsible for assuring the community that the rights of participants in research are respected. Members and staff of the IRB at this medical center (and Michigan State University) may review the records of your participation in this research. A representative of the Board may contact you for information about your experience with this research. If you wish, you may refuse to answer any questions the representative of the Board may ask.

Publication of the results of the research: The results of this research may appear in scientific publications without identifying you in any way.

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Ashir Kumar, M.D.
Chair of the University Committee on Research Involving Human Subjects (UCRIHS)
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Phone: (517) 355-2180 / Fax: (517) 432-4503 / e-mail: ucrihs@msu.edu
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- You have received answers to all of your questions.
- You have freely decided to participate in this research.
- You understand that you are not giving up any of your legal rights.

____
Participant's Name (printed)

________________________________ _______________
Participant's Signature Date

____
Legally responsible representative's name (printed) (if applicable)

________________________________ _______________
Legally responsible representative's Signature Date

____
Witness' name (printed)

________________________________ _______________
Witness' signature Date

____
Name (printed) of person obtaining Consent

________________________________ _______________
Signature of person obtaining consent Date

ASSENT OF A MINOR: (if applicable)

I have discussed my participation in this research with my mother or father or legal guardian, and I agree to participate in this research.

________________________________ _______________
Signature (participants from 10 to 18 years old) Date

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