IMPACT OF AUTHENTIC ASTRONOMICAL RESEARCH
ON ASTRONOMY CLUB STUDENTS

by

Lynn Louise Powers

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Lynn Louise Powers

July 2014
ACKNOWLEDGEMENTS AND DEDICATION

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My family and friends who supported me during the long hours throughout these past two years, I want to say thank you and I love you all. Your support and encouragement has meant a lot to me.
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ABSTRACT

The Bozeman High School Astronomy Club was used to look at the impacts of conducting authentic astronomical research through participation in several research projects. Students were given opportunities to learn real world science and develop new skills. Students worked with scientists and principal investigators from different NASA missions through different Citizen Science research projects using varied methods. The results indicated that student interest and participation in the astronomy club greatly increased. The students exhibited positive changes in attitudes and motivation towards how science is done both within and outside of the classroom. They also showed an improvements in skills used during the program.
INTRODUCTION AND BACKGROUND

Bozeman is located in southwest Montana, high in the Rockies. According to the 2010 census, Bozeman has a population of 37,280, consisting of 53% males and 47% females, with 91.8% white ethnicity, (retrieved from www.city-data.com/city/Bozeman-Montana.html). Bozeman High School has a student body of 1,910 with 49% male and 51% female, (retrieved from bsd7.org/superintendent). I am the Bozeman High School Astronomy Club advisor. The club is open to all high school students and has a core group of nine students, four male and five female. Three freshmen, two sophomores, three juniors and one senior met weekly during their lunch period. Newly formed during the 2012-2013 school year, meetings began with guest speakers, planning solar and night sky observations, and electing a student board of directors for the club.

As an informal educator and astronomy hobbyist, I have some astronomy background. I have been a member of the Southwest Montana Astronomical Society for twelve years and president for the past four, a National Aeronautics and Space Administration (NASA)/Jet Propulsion Laboratory (JPL) Solar System Ambassador, a member of the Heliophysics Community of Practice through the Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission, Van Allen Storm Probes Ambassador and a Mars Atmosphere Volatile EvolutioN (MAVEN) Educator Ambassador. My goal was to give the students a broad range of experiences in astronomy, I applied to three astronomy research programs. The club was accepted into the Mars Exploration Student Data Teams (MESDT), NASA/Infrared Processing and Analysis Center (IPAC) Teacher Archive Research Program (NITARP), and the International Astronomical Search Collaboration (IASC). All are authentic astronomy
research programs where the outcomes are unknown and students use current or archived data while working with scientists in real world situations. The Van Allen Probes is another project that was looked at by club members. We started working with the scientists on the mission to see if the students could help align some solar events with the data from the probes.

The first of the three projects, MESDT, was a seven month program in which students learned about Mars using data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). MESDT had online modules to train students to use CRISM and a diagnostic software program called JAVA CRISM Analysis Tool (JCAT). Students learned about Mars’ geological features and infrared imaging. MESDT allowed the students to pick their own research topic and area of Mars to study. The students looked at a region called Nili Fossae, analyzing spectral data from CRISM. They worked on the research, created an abstract of their work, submitted it for review to the scientists, and completed a presentation detailing their research findings they presented to scientists with the MESDT program via video conferencing. Most of the research with MESDT was student-generated.

As an informal educator and first year participant of MESDT in 2013, I was asked by coordinators at Johns Hopkins University Applied Physics Lab to test the program to see if it could be successful for non-educators in a club or small group setting. Other teams were high school or junior college groups of students where work was done within a classroom setting. Through MESDT, teams have the opportunity to compete with other teams by giving presentations of their research projects. Selected teams can earn a trip to Washington, D.C. to present their findings at the Planetary Geology Division annual
meetings. The astronomy club students were one of five teams who competed for that honor in 2013 and one of four teams in 2014. Although the students did not win the competitions, the feedback from the CRISM Principal Investigator was very encouraging. The evaluations gave several strengths from the students data analysis and comments for their continuing work with MESDT.

The second project, NITARP, was an intense one year project that pairs teachers with practicing astrophysicists within an interactive professional learning community. These teams work collectively using archived data from space based telescopes in a model to train the teachers in astronomical research. Each of the four teachers within each NITARP team has a group of students they work with at their respective schools. Teachers train for six months prior to bringing their students into the research project. We had weekly teleconferences with our scientist who gave us instruction and assignments to train us on the science behind our chosen research project. Additionally, teachers and students went through another six month process to learn the whole progression of astronomical research: picking a research topic, learning the science behind it, writing a proposal, conducting the research and data analysis, preparing and giving a presentation of their findings. In June 2013, NITARP sent the teachers and students to Caltech and JPL for a week of hands on training with the diagnostic computer programs. During the NITARP program, students examined protostars within a region of the constellation Cassiopeia. The region is known as the Pacman Nebula, or NGC281. In January 2014, two of the astronomy club students went to the American Astronomical Society 223rd convention to make a poster presentation from the results of the year-long
project. NASA funds NITARP for each selected teacher and two students to make the trips to Caltech and the American Astronomical Society convention.

The final authentic astronomy research project, IASC, was a short project spanning five weeks. Students analyzed data sets taken by CCD cameras at land based telescopes from various locations around the world. Students uploaded image sets daily to compile the pictures in a computer software program. Using IASC’s catalog of known objects, the software would tag moving objects and students would search for any moving object not tagged. Every year IASC has several campaigns to look for uncatalogued asteroids. Training for IASC involves a short online tutorial on how to use their software. Astronomy club students participated in this research project for approximately 15 minutes each day. Any new asteroid found during the research project could be named by the club. Students submitted one report of an unidentified moving light source; however we have yet to hear back from IASC on the determination of the source.

In the process of getting school board approval for travel with NITARP and MESDT, the Bozeman Daily Chronicle ran a story about the Bozeman High School Astronomy Club students (Appendix A). We were contacted by an author, Mr. John Barell, after he saw the article on the research the club was conducting. He asked if he could follow our progress with our research projects for inclusion in the follow-up to his books on Problem-Based 21st Century Learning. Mr. Barell applied for an IRB and was approved by the Bozeman School District #7 to conduct his research on the high school astronomy club students (Appendix B).
Each of the astronomy research programs the students participated in used authentic data and each gave them a rich and unique environment for learning. The astronomy club students learned different software programs for MESDT, NITARP and IASC. Each research program had a different time commitment and training process. These factors led to the creation of my focus statement: *What is the impact of authentic astronomical research on astronomy club students?* In addition, the following sub-questions were researched:

- Can students learn new techniques and methods used to gain knowledge in astronomy research?
- Can students develop analytical and problem solving skills by learning different types of astronomical research?
- Does conducting astronomy research in a club setting benefit the students academically?
- Which type of research is more beneficial? Short term or long term?
- Which method gives students a better chance to foster skills growth: a hands-on or a hands-off approach?

**CONCEPTUAL FRAMEWORK**

The Common Core State Standards define the knowledge and skills students should have when they graduate high school that aligns with college and work expectations (Common Core State Standards Initiative, 2013). There are many avenues schools can follow to give students opportunities for real life preparation. Clubs can provide students a more hands-on type of approach and a chance to research a topic further than can be done in a classroom (Shurluf, 2001). Participation in extra-curricular
activities and citizen science projects might offer students a glimpse into their future as schools prepare students for college and future careers.

When Shurluf (2001) looked at a wide range of Extra-Curricular Activities (ECA) students participate in, which include: sports, leadership, academic, performing and creative arts, and other community activities, he found positive results. In addition to higher GPA and test scores, he also found students were more engaged in school, had a better sense of self-worth, and had a better sense of their plans for the future. Through ECAs, students were able to spend more time in areas that interested them. This allows students an opportunity to explore the details in specific target areas. Students become more informed by testing the water prior to jumping into a field of study when they go to college. In turn, they found students were more engaged in higher education and more focused in the workplace when they were able to make better informed career decisions.

A study by Olszewski-Kubilius and Lee (2009) on the benefits of ECAs found out-of-school learning was pivotal in the growth of students’ talents. Students who meet peers, compete with them, and then compare themselves to other talented students have a more realistic view of themselves. The authors found the types of ECAs a student engages in, regarding the type of talent a student has, challenges these students, creating growth in their skills. In addition, participation in ECAs gives the student links to adults, either within the school or in the community, who share similar interests. They also found support from an adult has been shown to decrease antisocial and disruptive behaviors from participating students.

Another study by Denault, Poulin and Pedersen (2008) found adults who interact with students in an ECA have an important role that can have a positive impact on the
students. The authors found adults are a key mechanism to integrating real world experiences in student’s ECAs. This interaction can increase the likelihood of students pursuing college. They also found that students will engage in an ECA for a variety of reasons, including wanting to learn about a new activity or to learn more about an activity in which they are currently interested. Teachers do not have time to gain sufficient subject knowledge to cover all topics in depth. Bringing in members of the community can be important to enhance ECAs.

Stanger (2009) found exposure to community members in a professional capacity promotes students to pursue careers in the community members’ fields. He also found students will find more relevance if the presenter can make it personal for the students. In a study by Gibbs and Berendsen (2007) using amateur astronomers who engaged in education and public outreach, it was shown they were more effective in influencing attitudes about astronomy in teenage students. Amateur astronomers were as effective as professional astronomers in their abilities to inspire young students, and correct misconceptions. Amateur astronomers tend to use language and examples that are easier for students to understand.

Considerations for the amount of time allotted to activities and socializing added to the effectiveness and longevity of a club. Middle school and high school students have an average of six and a half to eight hours of free time each day outside of school. During these middle and high school years, according to Makel, Li, Putallaz, & Wai (2011), students must choose how they will spend this free time. This is not a trivial choice for students. The authors found participation in ECAs has a significant relationship with development and academic achievement. Students who participate in
academic activities appear to be extremely well rounded and choose activities that will benefit them through sports or academics.

According to Bybee and Morrow (1998), bringing in a professional scientist as a collaborator gives exciting connections to real world exploration and discovery. Their time, talents and interests are resources that are vital to education. They also bring a deep knowledge of science and the scientific process motivating students to learn science, both within and outside of school.

A study by Hoffstein and Rosenfeld (1996) found in skills tests students who enrolled in ECAs out performed students who did not enroll in ECAs. The study showed student attitudes towards school science were significantly less positive than student attitudes towards real world science. ECAs provide an important addition to scientific literacy for students who are interested in a science environment beyond school science. These students are more inquiry-oriented, and they prefer activities that are more student centered.

Not only do students benefit from ECAs, but teachers do as well. Through a large sample of teachers and students, Silverstein, Dubner, Miller, Glied and Loike (2009) found New York State science teachers who participated in science research with their students during the summer had increases in student achievement in the science classroom. The study reported these students’ state test scores increased by 10% during the 4 years following their study. The authors also found the teachers who participated showed an increase in job satisfaction, took time to educate themselves, increased activities in their classrooms, and assumed leadership roles within the school district.
A Citizen Science project involves the general public in scientific investigations as data collectors or analysts. According to Raddick et al. (2010), in astronomy these types of projects have evolved out of the clear need to assist professional astronomers and scientists in the management of the “data deluge” which has become a critical problem. While improvements in astronomical detection and technology increase each year, the number of professional scientists who can analyze the data grows more slowly. Their research found Citizen Science can provide fun and a sense of community, can be done quickly and easily, and allows citizens to contribute to science.

Borne (2010) found the current data avalanche can provide a pathway to diverse careers in astronomical research and it was imperative to equip the scientific workforce to know how to access, retrieve, interpret, assess, organize, analyze, mine, and integrate complex data from different sources. He also found these data oriented approaches to astronomy do more, and enable collaborative research. Teachers who engage their students in research models help students to develop a sense of the methods scientists employ as they learn to “do science.”

According to Fields (2009), student involvement in ECAs provides the ‘little bit extra’ that can be the all-important difference between going on with science or not. In a long-term research project, students learn the process of science, can grow peer relationships, learn from others, and develop confidence. Her study also found students gained a perspective of how scientists work and a new understanding of the concepts of science.

According to Rosenthal, Sakimoto, Pertzborn and Cooper (2002), NASA’s Agency Core Mission Statement has expressed a need to inspire the next generation of
explorers. Their paper shows the need at the pre-college level to make scientific and technological literacy, and research an integral component to this policy. Further they outlined some basic operational principals the agency needed to implement in order to engage the public, such as to emphasize active and experiential involvement in NASA research programs and missions for both teachers and students. Another was to work on collaborations and provide meaningful opportunities to help scientists become more involved in education and outreach.

METHODOLOGY

The Bozeman High School Astronomy Club was examined to see if using astronomical research could impact students’ skills and knowledge for college and career readiness. I looked at the benefits of conducting authentic astronomical research in the club setting through participation in several research projects, and how to best train the students for future research programs. Students were given opportunities to learn real world science through several astronomy research projects, including a five-week project, a seven-month project, and a yearlong project. Two astronomy research projects, Mars Exploration Student Data Teams (MESDT) and International Asteroid Search Campaign (IASC), were module driven, while NASA/IPAC Teacher Archive Research Project (NITARP) had intensive hands-on training for the astronomy club students and me. Students were able to compare and contrast their experiences from the different astronomy research projects, which the club has participated in during a two year period. The research projects with MESDT and IASC were used to give students an introduction into astronomical research projects. NITARP was used to take the students to the next level. NITARP funded several travel opportunities through a grant from NASA.
The research methodology for this project received an exemption by Montana State University’s Institutional Review Board and compliance for working with human subjects was maintained (Appendix C). An approval for this study was required by Bozeman School District #7, an application was submitted and approval was received (Appendix D).

The Bozeman High School Astronomy Club Research Matrix gives an overview of the research projects the club participated in during the study (Table 1).

<table>
<thead>
<tr>
<th>Name of research project</th>
<th>Type of student training</th>
<th>Length of project</th>
<th>Computer programs used by students</th>
<th>Final Project</th>
<th>Participation dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESDT</td>
<td>hands off, internet module driven</td>
<td>7 months</td>
<td>JCAT, CRISM, PowerPoint</td>
<td>Yes, PowerPoint presentation</td>
<td>October - April, 2013 and 2014</td>
</tr>
<tr>
<td>IASC</td>
<td>hands on, module driven</td>
<td>5 weeks</td>
<td>Astrometrica</td>
<td>No, daily reports on findings</td>
<td>May 2013</td>
</tr>
<tr>
<td>NITARP</td>
<td>hands on, live and internet training</td>
<td>13 months</td>
<td>DS9, APT, Excel, PowerPoint, python</td>
<td>Yes, Poster presentation</td>
<td>January 2013 - January 2014</td>
</tr>
</tbody>
</table>

During the 2012-2013 school year, the club participated in MESDT and ISAC, the club participated in a second cycle of MESDT during the 2013-2014 school year. Through MESDT’s seven-month program, students competed against several other groups of high school and junior college students from around the country as they looked at and analyzed data from Mars. Students began by learning about Mars and the analysis
tools, CRISIM and JCAT, through the programs online tutorials. The students then went on to select an area which could be used as a possible future mission landing site. Their final presentation was to show the scientists why their selected site would be suitable for a mission. A sample slide from the students MESDT presentation shows their analysis, using CRISM, of the Nili Fossae region of Mars soil composition (Figure 1).

Figure 1. Student Generated Slide from MESDT Presentation.

ISAC was a five-week project where students learned a new computer program to search for asteroids. In the weeks prior to the beginning of the campaign, sample sets of pictures were given to the students to learn the computer program and see how to spot possible sources. During the campaign we received several data sets weekly and students examined them to look for moving objects that could have been main belt asteroids. Data
sets were stacked in the IASC computer program and cross referenced with a catalog of known objects. Students would flip through the sets and look for movement between the pictures. Any moving light source, not marked from the IASC catalog, needed to have a report compiled and emailed to IASC coordinators. Students did report one such source and we are still waiting on the determination as to whether it is a new source or not.

Following MESDT and IASC, the students started participating in NITARP and several Bozeman High School Astronomy Club students went to Caltech mid-June, 2013. They met with other NITARP team members and scientists and completed their first training with the scientists. Astronomy club students undertook an intensive hands-on training for the new research. They learned the entire research process, from proposal to presentation. Through NITARP, I worked with the astronomy club students in a more active role than I had with the other two programs. I participated in weekly video conferences with the other team teachers and our Caltech scientist. During our meetings we would go over work completed and obtain new assignments for the following week. Through this process, I was working and learning simultaneously with the students, providing students live training of new concepts for more interaction. We continued our work with MESDT and NITARP during the 2013-2014 school year.

Several methods were used in order to help determine the effectiveness of the treatment. As the astronomy club students started the NITARP program, the Student Pre- and Post-Assessment: Interests, knowledge, skills and abilities for Bozeman High School Astronomy Club was administered (Appendix E). This instrument was administered again at the conclusion of the research in January, 2014. The assessment consisted of 15
Yes or No type questions as well as four open-ended questions. The questions assessed how student interests, knowledge, skills and abilities changed over the research project.

Students were given the NITARP Student Survey at various times throughout the project to gauge their understanding of the project (Appendix F). Firm deadlines were given for each section of the research project from the scientists at Caltech. Students worked with other team members from across the country and collaborated on creating new computer programs to help analyze their data. The eight questions on the survey were used to help look at a broader picture and see what the students were gaining from the research process besides new skills, knowledge and making a connection to the science.

Interviews with the students were done jointly by myself and author John Barell via Skype using the Student Interview Questions (Appendix G). Mr. Barell received IRB approval from Bozeman School District #7 to follow Bozeman High School Astronomy Club students MESDT and NITARP experiences (Appendix B). Students were asked to compare how they did science in the classroom versus the astronomy club and how they were able to apply the new skills. Notes were taken to see the progress of the students through the different projects in which the club participated.

We followed the American Astronomical Society, NITARP and MESDT program specifications for the two final projects (Appendix H). For NITARP, the students worked with all team members to contribute to the final science poster displayed at the American Astronomical Society 223rd annual meeting in Washington, DC, in January 2014 (Appendix I). Students manned the science poster during the poster session. Interacting with fellow students and scientists, explaining what they had done over the course of the
research project (Figure 2). For MESDT, the students worked with team members from the astronomy club to make a presentation. A video conference with other teams and scientists was conducted in April 2013 and 2014, in order for students to present their research findings in a final project for evaluation from the MESDT program coordinators.

![Students at American Astronomical Society Meeting in Front of Science Poster.](image)

*Figure 2.* Students at American Astronomical Society Meeting in Front of Science Poster.

Students were encouraged to write in their journals about their experiences using the Student Journal Prompts (Appendix J). This was an ongoing activity for the students, using 10 open-ended questions to help students synthesize all that was happening during our different projects. Their journal entries were used both as a conversation starters with Mr. Barell in our Skype meetings and to watch for trends in their engagement in the research projects.
Throughout the fast-paced research projects student knowledge of terminology was assessed and use of the new skills with the Pre- and Post-Performance Assessment (Appendix K). Students were asked 18 questions that required them to either provide an answer, or show a skill within one of the different computer programs we used during the research projects. I kept track of their progress on their individual sheets. The changes for each item were analyzed for trends of growth.

I also used a Muddiest Points (Angelo & Cross, 1993) assessment combined with a Crystal Points Assessment to evaluate student understanding of content throughout the project (Appendix L). Through the Muddiest and Crystal Points, I encouraged students during most meetings to be sure they were clear on what we were doing prior to the next step. A simple two-question assessment, it showed me what the students were gaining or missing from our different research projects. When I first implemented this assessment students were given note cards to write down their comments. As they became more familiar with the process it became more of an open dialog. Data from this assessment was utilized to clear up misconceptions and review material prior to moving on.

All the students in the astronomy club also belonged to other clubs or participated in other Extra-Curricular Activities (ECA). Students were interviewed using the Bozeman High School Astronomy Club Student Interview Questions to gain further insight into how they processed the different projects the club had conducted (Appendix M). The purpose of these interviews was to see how students use ECAs, and to see if the astronomy club provided insight towards college majors or career choices. A series of 10 open-ended questions were used to analyze the effectiveness of the research projects. One question asked students to rate how likely it was for them to go into an astronomy
research field for college or a career. This question was scored using a Likert Scale of
not likely (1), unsure (2), probably will (3), definitely will (4). Results for these questions
were analyzed to look for trends and links between the types of research the club was
conducting and student attitudes towards the research projects.

The Data Triangulation Matrix gives an overview of the data sources that were
used for this study (Table 2).

Table 2
Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Focus Questions</th>
<th>Data Source 1</th>
<th>Data Source 2</th>
<th>Data Source 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Question:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. What is the impact of authentic astronomical research on astronomy club students?</td>
<td>Student survey</td>
<td>Student interview</td>
<td>Journal</td>
</tr>
<tr>
<td><strong>Secondary Questions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Can students learn new techniques and methods used to gain knowledge in astronomy research?</td>
<td>Pre- and post-skill assessment</td>
<td>Student survey and interview</td>
<td>Final Project</td>
</tr>
<tr>
<td>3. Can students develop analytical and problem solving skills by learning different types of astronomy research?</td>
<td>Pre- and post-skill assessment</td>
<td>Student survey and interview</td>
<td>Final Project</td>
</tr>
<tr>
<td>4. Does conducting astronomy research in a club setting benefit the students academically</td>
<td>Student survey and interview</td>
<td>Pre- and post-performance assessments</td>
<td>Journal</td>
</tr>
<tr>
<td>5. Which type of research is more beneficial? Short term or long term?</td>
<td>Student survey and interview</td>
<td>Pre- and post-performance assessments</td>
<td>Journal</td>
</tr>
<tr>
<td>6. Which method gives students a better chance to foster skills growth: a hands-on or a hands-off approach?</td>
<td>Student survey and interview</td>
<td>Pre- and post-performance assessments</td>
<td>Muddiest/Crystal Points</td>
</tr>
</tbody>
</table>
DATA AND ANALYSIS

The results of the Bozeman High School Astronomy Club Interview indicated 100% of the students joined the club because they were interested in astronomy, and 50% of the students were using the club as a stepping stone for a college major or career choice (Appendix M) \(N = 8\). One student, who was undecided about going into astronomy research prior to joining the club said, “I like the research and I’m learning. I joined the club thinking that it would help me get ahead of my science class.”

While most of the Extra-Curricular Activities (ECA) the students participated in were chosen by them, during the interview they each admitted to joining at least one club because a friend encouraged them to join. One student said, “One of my friends made me join another club to be with them, but I didn’t like it and stopped going.”

When asked why the students joined ECA’s, six of the eight students said they joined clubs because it was something they enjoyed. One student said, “I join clubs to learn something new.” Another student said, “By joining clubs I get to have fun and learning something new is a bonus, and being in clubs helps to make new friends.” The students reported they had different experiences from each ECA, but 25% of the students said they now know from participating in the astronomy club research projects they are not likely to go into a research field when they go on to college (Figure 3).
Finally, when asked what they think about astronomy research as the club finished up one of its research projects, 88% had a positive response. They were glad to be in the club, and they had fun learning about the different types of research. One student said, “I wasn’t sure if I’d like it. You talked about the travel and I wanted to try because of that. I think that what we do is really, really, cool, but I still don’t want to go to college and do this.” The students were surprised to see, as a whole, how broad the field of research is and yet how narrow each part can be, one student said, “When you said research, I thought it would be like in my English class. But these different things we did are all so different. I didn’t know there was so many types of research.” Another student said, “I have always loved astronomy, and just science in general, but what this experience has done is emphasize just how exciting and important this field is to me. I have a new appreciation for all the hard work that goes into every single project out there and I have a new fascination with just how vast this field is.”

The results of the Student Pre- and Post-Assessment: Interests, knowledge, skills and abilities for Bozeman High School Astronomy Club indicated 100% of the students...
maintained their like for astronomy and spending time on the computer, and pre-assessment showed 92% did not know about photometry, while the post-assessment showed 100% had worked with one or both of the computer photometry programs (Appendix E)(N=9). The 33% who did not like to speak in front of others maintained their dislike of speaking in front of others throughout the study.

There was an increase from 64% to 92% of students who felt comfortable in the use of Excel while maintaining and analyzing data sets from the research projects. One student wrote on the post-assessment, “A lot of scientific work is done merely sitting in front of a computer going through data tables, making various calculations and graphs, and developing a conclusion based on those results. No matter how precise you are, there will always be something you did wrong that you will have to return to and redo, because being close isn’t good enough. Being wrong in your calculations, collection of data, analysis of data, or whatever does not simply mean you get a point off on your lab, it means you have to go back and restart from the point at which things went wrong and fix it, so that you actually make progressive scientific discoveries.”

The results of the Pre- and Post-Performance Assessment showed a greater gain in skills from the regular club attendees of the astronomy club when compared to students who did not participate regularly in the club activities and research projects (Appendix K). With an average of 89% correct responses in the post assessment for students who attended and participated regularly in club meetings and research projects, and only 56% average for those who did not attend regularly or participate in the research projects (Figure 4). One student said, “I know what you are talking about, I just can’t explain it.”
Membership to the astronomy club is open to any student and attendance has fluctuated over the two years of the project. There has been a core group of nine students who regularly attend club meetings. Of the three students who have participated in all three research projects, two students remain active in the club. The Bozeman High School Astronomy Club Participation Matrix gives an overview of range of participation during the research projects (Table 3).

Table 3
Bozeman High School Astronomy Club Participation Matrix

<table>
<thead>
<tr>
<th>Research Project Name</th>
<th># of Student participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESDT</td>
<td>8</td>
</tr>
<tr>
<td>IASC</td>
<td>15</td>
</tr>
<tr>
<td>NITARP</td>
<td>5</td>
</tr>
<tr>
<td>Participated in one project</td>
<td>20</td>
</tr>
<tr>
<td>Participated in two projects</td>
<td>5</td>
</tr>
<tr>
<td>Participated in three projects</td>
<td>3</td>
</tr>
</tbody>
</table>
Responses from the Student Interview Questions with author John Barell and Journal Prompts showed growth between our 2013 MESDT project and our 2014 MESDT project (Appendix G, Appendix J) \((n=2)\). A second year MESDT participant was asked to show the club’s 2013 final presentation to the 2014 first time MESDT participants. After reviewing the presentation she said, “Oh wow! This looks so elementary, after what we did with NITARP this is going to be easy this year.” This type of response was observed several times as we closed out the projects. Another student said, “This experience has continued to push my intellect to new limits, expanding my abilities to approach problems and understand everything at hand.” She went on to say, “The best thing has been the personal sense of achievement I feel now after having completed so much work that has contributed to a revolutionary set of research and the ability to transfer that work capability to continuing this project and performing research projects in the future.”

The students felt a deep sense of belonging to a scientific community, one student said, “I didn’t expect so many astronomers to be so excited and interested in the research we had performed and our involvement in the sciences at a high school age. It was so exhilarating and inspiring to receive such a positive response, as well as advice, from people at the heart of the field.” When asked to reflect on her experiences at the AAS meeting she went on to say, “The most important thing I learned was how close knit and accepting the astronomical society truly is. I think, often the sciences are made out to be highly exclusive, in that you must be a genius in order to make any meaningful discoveries, and that there is a lot of deeply entrenched competition between scientists. But, experiencing the AAS conference has shown me that not only do people from
around the country collaborate with one another to perform research, they also have a wonderful alacrity to explain their findings to everyone, no matter their intelligence level within a particular subject because the understand that humans in general don’t understand much about the universe.” The theme of acceptance into the scientific community continued, with another student’s reflection of, “I was definitely not expecting such a high level of appreciation for everything us high school students were able to do. I really enjoyed talking to everyone at the AAS and having this common interest in astronomy. The coolest part of this was the fact that no matter how young or inexperienced you are, you are still treated with so much respect and enthusiasm, because everyone knows how much work goes into these projects. It was amazing to experience this side of science.”

Another reoccurring theme was learning it is okay to make mistakes in research, as long as you correct it. One student said, “A lot of scientific work is done merely sitting in front of a computer going through data tables, making various calculations and graphs, and developing a conclusion based on those results. No matter how precise you are, there will always be something you did wrong that you will have to return to and redo, because being close isn’t good enough. Being wrong in your calculations, collection of data, analysis of data, or whatever does not simply mean you get a point off on your lab, it means you have to go back and restart from the point at which things went wrong and fix it, so that you actually make progressive scientific discoveries.”

When asked what advice she would give to others who join our club and do research with us, one student said, “I think the most important thing to remember about this project is that you are allowed to fail. People will come up to you and tell you things
they may think are wrong with your research or things they see differently. The beauty of this is that no one is right or wrong, and as an entire community of astronomers, we’re all still trying to figure everything out. This project will teach you a number of things you will not learn in school, but in my mind the biggest one is that failure is okay and necessary.”

INTERPRETATION AND CONCLUSION

The purpose of this project was to determine if conducting authentic astronomical research in the Bozeman High School Astronomy Club could help students to gain new knowledge and skills and how this would benefit them. The data shows each of the focus questions were answered and the students were impacted by the work they did. When considering what component of the project might have given the greatest impact on the students, my findings seem to show the interactions and connections between the students and the various adults with whom we interacted, to be foremost to effect the positive changes I observed. Denault, Poulin and Pedersen (2008) had found there was a correlation between bringing in adults to an extra-curricular activity and student success. This key mechanism, of the interaction between students and adults who share a common interest, was also shown to increase the likelihood of students pursuing college.

The club participated in more than just the research projects with IASC, MESDT and NITARP. Other opportunities for learning about astronomy, that had a bearing on the students outcomes, included; club night sky viewings, guest speakers, and helping with public outreach for Astronomy Day, solar observing events, Science Olympiad night at the museum, Scout Day, and Yellowstone National Park.
Our research projects had their ups and downs. IASC was interesting to learn and students enjoyed the computer program they used. However, we utilized the data sets from the training module more than the data sets from IASC’s telescopes. We ran into a long stretch of bad weather and not many clear nights where pictures could have been taken by the organization. This was a learning experience for the students. They would come in and want to jump right into the work but we would not have any new pictures to work with. I needed to point out when either working with ground based telescopes or when collaborating with others the importance of having everything ready when promised. This served as a reminder as we worked through the other projects where other people were depending on our section of work.

Through our research project using MESDT we had some technical difficulties the first year when we were using the school computers. However, there was a group of students who were using the club to gain research skills and they took ownership of the project and found ways to work outside of our club meetings to complete the project. This showed me they were able to not only analyze the data, but also the situation and trouble shoot ways to get around the obstacles.

It was during our work with NITARP I started seeing the students making the connections between some of the guest speakers and what we doing. It was going beyond learning another computer program and type of research. Learning a base knowledge of the different computer programs and technology was beneficial, as was seeing the different types of research that are out there for students to do either with a Citizen Science project or at college. However, they were learning other skills, such as:
team work and collaboration, flexibility, adaptability, critical thinking and problem solving, self-confidence, presentation skills, and networking.

Going forward I hope to continue with MESDT if the program gets funded next year, and I have discussed with the students about starting a new project for the Van Allen Probes mission with lessons learned from our work with NITARP. We were lucky this year to have NASA funding through NITARP for the trips to Caltech and the AAS meeting. I will keep an eye out for other opportunities for the club members to interact with scientists and other students. The larger collaborative projects are great if I can keep a core group of students coming to the meetings and if they take ownership of the project. The smaller projects work well for students who have a busy schedule and can not make all of the club meetings.

VALUE

I was happy to see the students understood this past year was not about the individual research projects, but their growth from doing the different projects. Students found they gained more than learning a few new computer programs and saw it is not just one thing, but a combination of all the parts of the club activities and how far these new skills reach, beyond the club and the classroom. Club and student collaborations, between peers and other groups outside of our school, give a richness and dimension to the health and productivity of the astronomy club. In an interview one student said, “Astronomical research is a giant collaboration of people around the nation, sometimes even around the world, looking at the same bit of data, and working together to come up with a reasonable conclusion. Now my thoughts focus upon achieving the most accurate scientific conclusions, accepting my mistakes as they arrive throughout the research
process, taking the time to revise my work and not accepting ‘close enough’ as an answer.”

Personally, the greatest impact was how the research projects have changed me over the past year. Going into the project, I thought I was only going to impact the students by giving them different opportunities. What I learned from using the Muddiest Points and Crystal Points is how important it is to have the students self-reflect and analyze, then articulate how they are doing when we are working with the very technical parts of the research. A key factor is making sure I am checking in regularly with the students, and make it clear they understand where we are and clearing up any misconceptions before we move on to the next part. As a result of what I learned in this study, I was able to re-evaluate how I interacted with the students which I feel lead to a richer experience for them. It goes beyond me training them and speaking to them, the bigger step is to sit back and to listen to them.

My observations during this project agree with the findings from the study by Fields (2009), the astronomy club students, through their involvement in the research projects, were able to learn the process of science, grow peer relationships, learn from others, develop confidence, gain a perspective of how scientists work and a new understanding of the concepts of science. Finally, I will continue to look for guest speakers and new projects for the club to keep up the level of interactions and collaborations into the world of science. I was happy to share my hobby and love for astronomy with the club students. I am proud of the quality work the students produced as they represented Bozeman High School in the research projects with MESDT and NITARP.
REFERENCES CITED


Bozeman High School enrollment data. Retrieved from bsd7.org/superintendent


APPENDICES
APPENDIX A

BOZEMAN DAILY CHRONICLE NEWSPAPER ARTICLE FROM MARCH 2013
NASA lets Bozeman High students reach for the stars

GAIL SCHONTZLER, Chronicle Staff Writer
Posted: Saturday, March 30, 2013 12:15 am

Hannah Cebulla and Madie Kelly may be only teenagers, but they and other students in Bozeman High School’s Astronomy Club have the chance to do original research on Mars and the stars, thanks to NASA.

The students are doing such a good job, two or three will get to travel in June to Caltech and the Jet Propulsion Lab to learn more about star formation and how to conduct astronomical research.

“I’m so excited,” said Cebulla, a sophomore, adding that the Jet Propulsion Lab is where she’d like to work someday.

“It’s incredible,” said Kelly, a junior who wants to become an astrophysicist.

Bozeman High’s club is also one of five student teams remaining in the Mars Exploration Student Data Teams competition.

They’ve been working with NASA and Arizona State University scientists to do research on Mars, using images taken by an instrument called CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) aboard NASA’s Mars Renaissance orbiter.

One image from CRISM of a region called Nili Fossae makes the red planet look as colorful as tie-dyed shirts. The colors actually help scientists determine what kind of rocks are on Mars. The students are analyzing the region to see if it would make a good landing site for a future Mars Rover, and if the geology suggests there once was water flowing on the planet and possibly the right conditions to support life.

The Astronomy Club adviser is Lynn Powers, Bozeman High library secretary, a passionate amateur astronomer who is president of the Southwest Montana Astronomical Society and a NASA-JPL “solar system ambassador.”

Powers said for the Mars competition, students are preparing an online PowerPoint presentation that will be judged in April by scientists at Arizona State. The winners will get a free trip to Washington, D.C., in June to present their research at the Smithsonian Air and Space Museum.
The Bozeman High club members are so dedicated, they even gave up part of spring break to work on their project, she said.

“They’re doing phenomenally well,” Powers said. “It’s amazing.”

As soon as the Mars project is finished, the students will jump into a new research challenge. Using images from space collected by the Herschel Space Observatory, the students will analyze an area of cold, dense gas in the constellation Cassiopeia where stars are being born.

“It will be like pulling the blanket off a baby in a bassinette,” Powers said. “We’re going into the nursery.”

The Herschel telescope has gathered thousands of hours of data that have been archived because NASA doesn’t have enough man-hours to look at everything, Powers said. So the space agency has created opportunities for citizen-scientists.

Powers has been working with scientists from Harvard and Caltech and teachers from Illinois, Connecticut and Virginia to gear up for the stars project.

Astronomy Club members said they got hooked on the stars in different ways. Brittany Suisse, a sophomore, said she has always liked watching astronomy documentaries with her dad. Brandon Kelly, a freshman, said he loves watching “The Universe” in high-definition on the Science channel. Cebulla said when she was younger, she read a book on astronaut Sally Ride and “she became my idol.”

“I’ve always been a fan of science fiction,” said Matthew McWhorter, a sophomore. “The one thing cooler than science fiction, is science fact.”
APPENDIX B

BOZEMAN SCHOOL DISTRICT #7 IRB FOR MR. BARELL
April 30, 2013

John Barell, Ed.D.
444 E. 82 St. Apt. 10A
New York, NY 10028

Dear John,

Thank you for your interest in conducting research in the Bozeman Public Schools. Your research study, entitled, "Assessment of 21st Century Skills," is approved, provided that:

1. You work with Lynn Powers directly and have her distribute all permission forms and reflection journals.
2. You deliver to us a copy of your final study and a PowerPoint summary within four months of completing this study.

If you have any questions, please do not hesitate to contact either Lynn Powers or me. Best of luck with your research.

Sincerely,

Marilyn H. King, Ed.D.
Deputy Superintendent Instruction

Cc: Ken Gibson, Bozeman High School
    Lynn Powers, Bozeman High School
APPENDIX C

MONTANA STATE IRB APPROVAL FOR MS. POWERS
MEMORANDUM

TO: Lynn Powers and John Graves

FROM: Mark Quinn, Chair

DATE: December 2, 2013


The above research, described in your submission of December 2, 2013, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

[ ] (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

[ ] (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects’ responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects’ financial standing, employability, or reputation.

[ ] (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

[ ] (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

[ ] (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

[ ] (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.
APPENDIX D

BOZEMAN SCHOOL DISTRICT #7 IRB FOR MS. POWERS
December 2, 2013

Lynn Powers  
P.O. Box 3287  
Bozeman, MT 59712

Dear Lynn,

Thank you for your interest in conducting research in the Bozeman Public Schools. Your research study, *Impact of Authentic Astronomical Research on Astronomy Club Students*, is approved, provided that a copy of your final study and a PowerPoint summary is delivered to me within four months of completing this study.

We look forward to learning the results of your research. Best of luck on this project!

Sincerely,

Marilyn H. King, Ed.D.  
Deputy Superintendent Instruction

Cc: John Graves, Ed.D., Faculty Lead Instructor, MSSE Program, MSU  
Mr. Kevin Conwell, Bozeman High School
APPENDIX E

STUDENT PRE- AND POST ASSESSMENT: INTERESTS, KNOWLEDGE, SKILLS
AND ABILITIES FOR THE BOZEMAN HS ASTRONOMY CLUB
Student Pre- and Post-Assessment: Interests, knowledge, skills and abilities for Bozeman High School Astronomy Club

Participation is voluntary, and you can choose to not answer any questions that you do not want to answer, you can stop at any time. Your participation or non-participation will not affect your grade or class standing.

I like spending time on the computer Y  N
I like astronomy Y  N
I know how to use spreadsheets/excel Y  N
I know how to use presentation software/PowerPoint Y  N
I know about computer programming Y  N
I like to work with others on a team Y  N
I like to work solo Y  N
I like to speak in front of others Y  N
I know about the Mars Curiosity mission Y  N
I know about Mars Y  N
I know about star formation Y  N
I know about Photometry Y  N
I know how to do research Y  N
I’m hoping to learn about research Y  N
I would like to have labs during astronomy club to learn more about astronomy Y  N

Things I like
________________________________________________________________________
________________________________________________________________________

Things I think you should know about me
________________________________________________________________________
________________________________________________________________________

Skills that I have that will help with the astronomy research.
________________________________________________________________________
________________________________________________________________________

Things I think I might need to know/learn to be a better team member
APENDIX F

NITARP STUDENT SURVEY
NITARP Student Survey

Please use as much space as you need. NOTE THAT you should not try and fit your answers into the incredibly tiny space I have left for you here. Please use as much space as you need to convey your thoughts.

1. What was the most important or interesting thing (or few things) you did/saw/learned?

2. What was the most surprising thing you did/saw/learned? Did anything happen that you did not anticipate?

3. What was the least surprising thing you did/saw/learned?

4. What, in broad terms, did you do with the data associated with our project this past week?

5. What, in broad terms, do you plan to do with the data over the next week?

6. Did this experience (so far) change the way you thought about astronomy or astronomers?

7. What is “real astronomy”? Did you do anything on this visit that you expected would be part of scientific research? Or anything that you did not think would be part of scientific research? Why or why not?

8. Is there anything else you want me to know?
APPENDIX G

STUDENT INTERVIEW QUESTIONS WITH JOHN BARELL
This research project focuses upon assessment of 21st century skills of inquiry, problem solving, critical/creative/reflective thought, collaboration, and uses of technology. It is based upon the already completed study published in 2012 by Corwin Press, *How Do We Know They’re Getting Better? Assessment of 21st Century Minds, K-8*. (See author website, [www.morecuriousminds.com](http://www.morecuriousminds.com))

Both studies seek to determine how we can observe, monitor and draw reasonable conclusions about students’ growth in the afore-mentioned and all important 21st century skills.

These skills are a subtext of virtually every school mission statement: to educate all students to become responsible citizens who can think, work collaboratively and reflect.

Because there is such a press today from various quarters to evaluate teachers using standardized tests, it seems reasonable to ask how we can observe such growth by using those means already being employed by excellent educators in our schools systems.

The results of the 2012 study of K-8 schools indicated that excellent teachers have ways of showing how students, for example, become better inquirers, critical and creative thinkers over the course of a year without using standardized tests.

The current study is focusing upon high school educators and, currently, we have participants in physics, biomedical, biology, mathematics, language arts, social studies and civics. We are especially interested in those processes whereby students are given authentic, unstructured and complex situations about which to pose their own questions, conduct research/experiments, exercise choice and draw their own reasonable conclusions.

We are currently in the first full year of the research and plan on continuing during the academic year 2013-2014.

The Bozeman Chronicle recently (3/30/13) published an article about Ms. Lynn Powers’ sponsorship of the Astronomy Club and their original work with NASA related to Mars--examining the area known as Nili Fossae for its suitability for another Mars landing.
This is the kind of student-driven learning experience that mirrors my own fascination as a youngster with Antarctic exploration (www.morecuriousminds.com/Quest for Antarctica). I would be most interested in learning from these students what their research has taught them about doing science. If granted permission my research would focus upon asking these students a series of reflection questions, for example:

“What interested you about this kind of study/research?

What have you learned during the process about doing science?

What are you learning about yourself? as a scientist, as an inquirer?

And How might you transfer these learnings into other areas of your life (academic/non-academic)?”

The data gathered from these interviews (researcher’s hand written notes during interviews) will be analyzed and used within a case study. This work will then be submitted directly to the faculty advisor and students for their approval and the making of modifications to said document. Within this document all students’ names can be changed if so desired. No information derived from students’ reflections will be included without students’, faculty and parents’ permission.

II. Benefits to the Bozeman educational community:

The benefits to the Bozeman community would include the following:
A. Developing students’ awareness of their strengths and ways of using this knowledge in all areas of their lives.
B. With enhanced awareness comes greater control of one’s learning approaches.
C. Benefits that accrue from sharing enriching learning experiences with the wider educational community through publication.
D. National and international recognition for excellence in educational programs, for the school, faculty and students (assuming, of course, suitable publication)

III

A. Number of students: the five students currently in the Astronomy Club and those who might join in the future.
B. Estimated time: If we were to conduct our reflections during the coming academic year, it might be appropriate for students to reflect in journals at least once a month--or more often if feasible. What would be desirable is to hold a reflective Skype conversation with the students in June, September (2013), January and June, 2014. A total of about eight-nine hours (@ 30 minutes per month for journaling and two/three hours in June, September, 2013, January and May or June, 2014).
C. One teacher required: Ms. Lynn Powers
D. No parents required, save for their permission to have students share their reflections with researcher. But parents’ observations about the process would be most valuable so would hope that each parent would want to share her/his observations and conclusions on two separate occasions: January, 2014 and June 2014.
E. Total time for each parent would be one to two hours, or more if desired.
F. No other BSD7 staff are required, although Superintendent’s staff, principal/assistant principals would be aware of this project and their observations and conclusions about students’ growth would be valuable as well.
G. Total time of other staff: one to two hours.
H. No material from students’ cumulative records is required.
I. This research is conducted independently of any university/school and is not part of any degree-granting process. I am currently Professor, Emeritus, Montclair State University, NJ.
J. No subjects are currently being (nor have any been) paid.
K. I expect this project to conclude by June, 2014.
L. No pilot is required. We have been conducting pilots this academic year.
M. I intend to submit to Corwin Press a formal proposal to publish the results of this research by September 2013. Final rough draft results should be available by July, 2014.
N. We can protect the anonymity of students participating by using pseudonyms, as was done in some cases in 2012, K-8 study. In this study it was the parents’ and teachers’ discretion to use real names or not, associated with written and pictorial work. No standardized tests results were nor would be used.
O. Parent and student permission will be obtained by following BSD7 guidelines in separate documents outlining research goals, procedures and time line.
P. Date of first contact: June/September 2013 (Preferably both, but minimum of one) Last contact: June 2014

Since my intention is to share findings of this BSD7 group and other educators participating in the study, I will want to publish findings following the model of the Corwin 2012 book. (See www.morecuriousminds.com for reference to this book, How Do We Know They’re Getting Better?

Principal Investigator:
John Barell, Ed.D.
Professor Emeritus, Montclair State University, Upper Montclair, NJ
444 E. 82 St. Apt. 10A
New York, NY, 10028
212-744-5892

www.morecuriousminds.com

http://www.morecuriousminds.blogspot.com
Recent Publications:


Author of Antarctic Stories: Surviving Erebus—An Antarctic Adventure onboard Her Majesty’s Ships Erebus and Terror (2008); Quest for Antarctica—A Journey of Wonder and Discovery (2011, ebook); “Twenty Below,” a story of Antarctic survival (Boys’ Life Short Story winner; Boys’ Life Anthology; translated in Norwegian and Braille).
APPENDIX H

FINAL PROJECT SPECIFICATIONS
Poster Presentation requirements from the American Astronomical Society

Posters allow far more time and flexibility and are the default presentation type. Posters are ideal for using charts, graphs or detailed visual aids. The poster area serves as the meeting’s social center.

- Your presentation should fit within the 44" x 44" area. Poster boards are slightly different at each meeting and may be as large as four feet square. Please bring your own thumbtacks.
- We will arrange poster sessions by topic.
- Approximately two hours each day will be set aside for the poster presentations when no other sessions are scheduled. The authors need not be present the entire time but should post the hours when they will be present at their poster.
- Posters may be set up after 8:00 am and must be removed by the end of the each evening. Posters left up after the Exhibit Hall Closes will be discarded.
- When preparing your poster, remember to use bold graphs, photographs, figures, and tables. Include a title and the names of authors in large type. Text should be large enough to be legible from a distance of three to four feet, ~ 20 point font. Keep the poster simple and easy to read.
- Consider posting a photo of yourself with your presentation.

MESDT Final Project specifications:

Rubric for MESDT Competition

1. Original Work, Significant Growth and Participation
   Original Work and Significant Growth:
   - Students presented research from this year only (it may have been built upon from previous years, but only original research from current year is presented.
   - If team is a returning team: Evidence of original research is presented and significant growth in understanding of MESDT key topics is demonstrated.
   - If team is new this year: Evidence of significant growth in understanding in basic knowledge of MESDT key topics such as: basic geology, mineralogy, Martian geology/topography, CRISM map, JCAT, research practices.

   Participation:
   - Evidence of Participation in Forums/ Telecons/Archives
   - Participation in prescribed protocols throughout year: (following directions, presentation follows research guide sheet, submitting data/ questions via prescribed protocols, etc.)

2. Abstract
   - Scientific content included
   - Presentation/writing: (description is clear and understandable, followed 1 -2 page guideline, checked for grammar, spelling, etc.)
   - Abstract submitted on time
3. Research and Presentation (Following the MESDT CRISM Map Research Guide Sheet):
☐ Introduction/Background: Examples might include: Area of study is clearly identified, background research was done on this area, why this area was chosen.
☐ Methods: Are methods sound according to what was taught this year? IE: Use of JCAT, Use of CRISM Map.
Are methods clearly described?
☐ Data/ Interpretation of data: Research includes use of CRISM data; Data is shown/discussed; Does the interpretation of data make sense in accordance to the students’ level of understanding?
☐ Conclusion: Students are able to summarize what they learned, any additional information they hope to convey and acknowledgements.
☐ Delivery/Layout/Visuals: Students were able to convey a clear message about their research through visual and oral presentation within the allotted time limit of 6-8 minutes.
☐ Questions/Discussion: When asked questions, students were able to demonstrate they have a clear understanding of the research they presented.
APPENDIX I

NITARP SCIENCE POSTER
Class 0/I Protostars & Triggered Star Formation in NGC281

Thesis:
Do differences in star formation triggers produce different protostars?

Motivation, Methodology:
A variety of trigger mechanisms are seen to cause the onset of star formation (SF) in the Galaxy. Larson, R.B. 2003, Rept. Prog. Phys. 66, 1681. NGC 281 is an unusual case in which two separate triggers appear to be responsible for SF in the same cloud.


We used Herschel to map NGC 281 in the far-IR (70, 100, 160 µm).

Herschel observations allow us to identify and measure brightnesses of the youngest protostars.

Star Formation:
The youngest protostars are most easily identified in the far-IR and submm because the bulk of their emission is in those wavelengths.

Results:
The East and West populations occupy the same region of the color-color plot. A lack of difference may signify lack of evolutionary differences in the accretion rates, or ages of the two groups.

NGC 281: A Tale of Two Populations


- 70 visual candidates
- 31 after further vetting

Final Results:
- 18 Yes candidates
- 23 Maybes

West: Star formation is triggered by lateral compression of gas.

- 118 visual candidates
- 58 after further vetting

Final Results:
- ? Yes sources
- 51 Maybes

Photometry Details:
We were limited to aperture photometry only. We used the Aperture Photometry Tool:

http://www.astronomicaltechnology.org

We cannot reliably determine backgrounds for 160 µm channel with aperture photometry. Consequently, 160 µm photometry was dropped from further analysis.

Conclusions:
East and West side comparison:
- We did not find any systematic differences in protostellar populations between the East and West groups.
- However, our experiment is sensitive only to the high-luminosity protostars. Differences may yet exist in the low luminosity protostars.

Comparisons to models and Orion A&B:
- Protostars in NGC 281 appear to have low mass infall rates, and are bluer than protostars in Orion.
- We offer three scenarios to explain these results:
  - Protostars in NGC 281 are at a later evolutionary stage compared to those in Orion.
  - It is possible that only the lowest luminosity protostars (not detected here) are at an earlier evolutionary state compared to Orion and the models.
  - Protostellar evolution is faster in NGC 281 compared to Orion.
APPENDIX J

JOURNAL PROMPTS
JOURNAL PROMPTS

Please use your journal to record all that we as a group will be going through over the next few months. It will go fast and you need to keep track of what we’ve learned to see how far we’ve come. And as always, use this to discuss crystal points and muddiest, but be sure you hand those over to me.

Participation is voluntary, and you can choose to not answer any questions that you do not want to answer, you can stop at any time. Your participation or non-participation will not affect your grade or class standing.

What interested you about this kind of study/research?

What have you learned during the process about doing science?

What are you learning about yourself? As a scientist? As an inquirer?

How might you transfer this learning into other areas of your life (academic/non-academic)?

Also, reflect on how the current research project is different from the last project. Skills that you needed to learn and science that you needed to know.

How has this affected your thoughts on research?

Which research project have you liked the most, the least, why?

How has it been working in a group?

Which research projects do you think you’ve gained the most from? The least? Why?

Do you see a difference between the short term and the long term research projects?
APPENDIX K

PRE- AND POST- PERFORMANCE ASSESSMENT
PRE- AND POST PERFORMANCE ASSESSMENT

Participation is voluntary, and you can choose to not answer any questions that you do not want to answer, you can stop at any time. Your participation or non-participation will not affect your grade or class standing.

I’m going to ask you a series of questions. Some will require you to give me an answer; some will require that you complete a task. Are you ready?

Do you know what an ASCII file is?
How is it used and why do astronomers like to use it?
Do you know what a FITS file is?
Can you find a FITS file?
Can you upload a FITS file?
Can you open a FITS file in APT? In DS9?
Do you know how to do photometry on a point source?
What is FWHM? What does that tell us?
Can you create a regions file?
Can you open python?
Can write a simple program is python?
Can you run slope charts in excel?
Can you run a histogram in excel?
What is the CRISM tool?
Can you find it? What is it used for?
What is a magnetometer?
Can you find a graph on the RBSP website?
What do the colors mean?
APPENDIX L

MUDDIEST/CRYSTAL POINTS
Teacher Prompt:
(hand out 3x5 cards)

On this 3x5 card on one side I want you to write "muddiest point" on the other side write "crystal point".

Now please take the next three minutes and reflect on what we've done today.

On the side that is crystal, write down at least one point that was clear to you today.

On the side that is muddiest, write down at least one point that was not clear to you.

Remember that it's better to work out the misconceptions or misunderstandings and clear them up prior to us moving forward. Participation is voluntary, and you can choose to not answer any questions that you do not want to answer, you can stop at any time. Your participation or non-participation will not affect your grade or class standing.

Thanks.

Also, change up with Plus/Delta cards.
Instead of crystal, ask students to give one positive thing about the day – Plus.
And instead of muddiest, ask student to give one thing that has changed or needs to change – Delta.
APPENDIX M

BOZEMAN HIGH SCHOOL ASTRONOMY CLUB STUDENT INTERVIEW QUESTIONS
BOZEMAN HIGH SCHOOL ASTRONOMY CLUB STUDENT INTERVIEW QUESTIONS

1. What types of extra-curricular activities have you participated in?
2. Did you choose these? Or did you join to be with friends or a parent encouraged you?
3. Which is your favorite extra-curricular activity, and why do you like it?
4. Which is more important when it comes to choosing an extra-curricular activity: being with friends, learning something new, or doing something you enjoy?
5. What do you feel that you get out of your extra-curricular activities?
6. What experiences have you had during an extra-curricular activity that may influence your college major/career choice?
7. Prior to joining the astronomy club, did you want to do research in college or as a career?
8. From the research we've done in the club, what do you think of research so far?
9. Rate how likely you will go into a research field for college or a career.
   1- not likely, 2- unsure, 3- probably will, 4- definitely will.
10. Is there anything else you want me to know?
Bozeman High students present their research on baby stars

Bozeman High School students Madie Kelly, 17, left, and Hannah Cebulla, 17, both Astronomy Club members, recently returned from the 223rd Meeting of the American Astronomical Society in Washington, D.C., where they presented their study on protostars.

Posted: Sunday, January 12, 2014 12:15 am
GAIL SCHONTZLER, Chronicle Staff Writer

Somewhere in the Milky Way galaxy, far, far away, baby stars are being born, and two Bozeman High School students have spent months working to uncover some of their mysteries.

Hannah Cebulla and Maddie Kelly just returned from a trip funded by NASA to present their research at the American Astronomical Society’s January meeting in Washington, D.C.

More than 3,000 scientists, professors, graduate students and college undergraduates attended – along with a handful of high school students.

“It was fantastic,” said Kelly, 17, a senior. “They were really impressed with the work we were able to do at our age.”

“For me it was real cool to see everybody’s hard work,” said Cebulla, a junior. “Everybody is so excited to see everybody’s research.”

They were two of about a dozen high school students from Connecticut, Virginia, Chicago and Bozeman who collaborated in researching “Class O/I Protostars and Triggered Star Formation in NGC 281.”

Basically that means they studied baby stars, the different ways stars form and whether those differences create any differences once they’re “adult” stars, the two students said.

Lynn Powers, library secretary at Bozeman High’s Bridger Alternative Program and Astronomy Club adviser, said it’s exciting for students to be doing original research, “not
knowing what they’re going to find,” instead of repeating experiments others have already done and the outcome is known.

“It teaches students how to do science, do critical thinking, and take real live data and analyze it,” Powers said. “That’s amazing.”

Astronomy has changed from the days of looking through telescopes with the naked eye. Today astronomers look at computer screens and analyze data, said Powers, an avid amateur astronomer and Southwest Montana Astronomical Society president.

The Bozeman High students analyzed data from the Herschel telescope, named for the scientist who discovered invisible infrared radiation in 1800. The Herschel telescope has gathered thousands of hours of data that have been archived because NASA doesn’t have enough people to analyze everything. So the space agency has invited citizen-scientists to help out.

The students looked at stars forming in clouds of swirling gas and dust in an area near Cassiopeia called NGC 281. It’s nicknamed the Pac-Man Nebula because its shape resembles the video game character.

Last June the Bozeman students traveled to Caltech in California to learn how to do Python computer programming to analyze the Herschel data. They met the other high school students on their team, who continued to work together in the ensuing months using Skype and teleconferences.

Powers said she hopes the Astronomy Club can keep working on the project in the coming year. The club will probably have to do some fundraising, she said, because NASA’s education and outreach money has been “zeroed out” of the federal budget. Kelly said she has always loved science and participating in the research conference “really drives your passion.” She plans to attend Montana State University and study astrophysics.

Cebulla said she first became interested in astronomy on family camping trips, when she’d look up at the stars and think they were “the coolest thing ever.” She plans to attend college and study astrophysics or astrobiology.

Powers said she and the students enjoyed visiting the Smithsonian’s National Air and Space Museum, but the coolest moment of the trip for her was meeting Neil deGrasse Tyson of the Hayden Planetarium and a host of NOVA science shows. She got his autograph.
Tech Tools for Assessing the “Soft” Skills
By: Cathy Swan in Tech&Learning Magazine, March 2014

Search for “soft skills” in Google and you’ll find 45,800,000 results. The first screen includes business Web sites, Web sites listing job and interview skills, career developer Web sites, and an article from National Careers Service asking, “What are the ‘soft’ skills employers want?” The U.S. Department of Labor links to a curriculum focused on teaching workforce readiness skills to youth ages 14-21 called “Skills to Pay the Bills: Mastering Soft Skills for Workplace Success.” The course consists of six modules: communication, enthusiasm and attitude, teamwork, networking, problem-solving and critical thinking, and professionalism. The one link focusing on education is titled “Should schools teach soft skills?” Forty-five million sites think we should.

**Reflection and Goal Setting:** Google Docs and Spreadsheets
Hannah Magnan and Susan Steidl, New Canaan High School English teachers in Connecticut, formulated a plan to teach students to reflect more deeply and to appreciate reflecting as an essential life skill.

They ask students to submit work on a Google doc, which receives written feedback in the form of inserted comments from their teacher and peers. Students document and track this feedback on their own spreadsheets in Google Drive. After gathering enough evidence, each student evaluates the feedback, searches for patterns used to develop specific writing goals, submits plans for achieving those goals, and writes reflections on each step of the implementation process. Since the entire process is done online, the individual student practices giving, receiving, and evaluating feedback from various sources on a
variety of posted assignments. At the end of the process, students reflect on their progress and decide whether they need more instruction, practice, or feedback on their current goal, or re-evaluate whether it is time to set a new goal. At the end of the course, student responses to the goal-setting process were overwhelmingly positive, specifically due to the high level of autonomy, differentiation, and accountability the method afforded.

**Collaboration, Discussion, and Metacognition:** Moodle
Right down the hall, Evan Remley and Bob Stevenson co-teach an American Studies class of 45 students where they use many of the interactive features built into Moodle to cultivate collaboration and facilitate meaningful discussion among students. These features include forums, peer revision tools, blogs, wikis, and the other functions of the read-and-write Web application. With continual use and timelined access to the feedback cycle, teachers and students can reflect thoughtfully on their progress and set meaningful goals around content and processes. Most powerfully, Moodle’s 24/7 accessibility through email, apps, tablets, and smartphones helps students and their support networks take control of their own learning beyond the classroom. This powerful tool enables students to cultivate skills that, once mastered, they can use for a lifetime.

**Future Thinking, Risk-Taking, Coping with Failure and Collaboration with Experts:** Dropbox, CoolWiki, Online Databases, and Data from Expert Sites
In a Bozeman, Montana, high school Lynn Powers is creating future thinkers engaged in the real work of adding and creating new knowledge in astrophysics. Students use CoolWiki and Dropbox to share research, photos, and findings with professors and experts at CalTech and Harvard. They use archived data from two telescopes to determine if stars are being formed in NGC281, also known as the Pac-Man Nebula, and work with an expert at CalTech to learn to program in Python to analyze these data and draw conclusions. They presented their findings at the American Astronomical Society meeting in Washington D.C. in early January. John Barell, author and expert on inquiry and problem-based 21st century learning ([morecuriousminds.com](http://www.morecuriousminds.com)) said, “These students are on the frontiers of new knowledge…their work …contains elements that can be transferred to any classroom: reverence for and openness to making mistakes/‘failure’, which means we try and try, take some risks, fail sometimes, learn and improve.” These are soft skills that are crucial to any scientific endeavor.

**Global and Cultural Communication and Understanding:** Google Drive, Picasa, Voicethread, Skype, Facebook, and Twitter
The Center for Global Studies (CGS), a magnet school in Norwalk, Connecticut, under the directorship of Roz McCarthy, is focused on global understanding. Students at CGS are learning their second or third language and routinely communicate with their sister schools in Japan, China, and Arabic-speaking countries. They use Google Presentations to create projects, Picasa to share photos, Voicethread to allow a spoken exchange to be delivered in the target language, as well as Facebook and Twitter for social networking. Most projects are shared online with the sister schools and designed to demonstrate what it means to live in their respective countries. Some projects, like the Voicethreads, are
collaboratively created with partners in the target culture. Once online sharing has occurred, there is often a Skype session where students can talk about the work. Speaking and communicating with other cultures requires a different set of norms; therefore students have an opportunity to learn what topics should and should not be discussed.

**Critical Thinking, Organization, Time Management, and Independent Thinking:** Mentor Mob, Socrative, BlendSpace, Google Voice, Blogger, YouTube, and Teacher Tube

MentorMob is an online playlist tool that is useful for teaching time management, personal organization, and independent thinking because kids can be given step-by-step guidance that can be accessed chronologically or randomly depending on the student’s individual need. Students can also be asked to create a MentorMob file for their own work, breaking it down into manageable chunks and creating the steps needed to complete a project.

Michelle Luhtala, librarian at New Canaan High School in Connecticut, uses MentorMob to assess research skills as high school juniors begin work on a research paper. Luhtala measures research skills through a 20-question pre-assessment on Socrative.com that students take on mobile technology (their own or library-owned). Each class’s overall performance on each question is compiled and published in MentorMob, and posted to the library’s instructional blog on Blogger, sorting the questions from lowest number of correct responses to highest. Teachers are also given individual student performance results in ranked order so they can quickly determine who might need the most support. Individual students receive their overall scores as well as the ability to self-remediate using MentorMob’s playlist. Here they can access a “step” for each pre-assessment question that links to a mini-instructional module explaining the correct response using Google Presentations, NCHS teacher-created YouTube videos, BlendSpace (another online playlist tool), Prezi (a presentation tool), and in one case, a simple screenshot. Students are also invited to text the library with their questions in Google Voice, which provides teachers with additional data to inform future instruction.

**Personal Goal-Setting:** Naviance

In Bridgeport, Connecticut, Diane Tung, Director of Instructional Technology and Student Assessment for the Diocese of Bridgeport, reports that Naviance is being piloted at the middle school level for student surveys and to help students write SMART goals. Naviance offers tools like the Gallup StrengthsExplorer that let students identify their strengths and talents, such as achieving, caring, competing, confidence, and relating, among others. Naviance helps match those students with college and career options, and it also offers strategies for applying them not only to school, but also to a future career and life.
Personal Archiving, Prioritizing, and Filtering: e-Portfolios in Google Sites and Digication

Deborah Olsen-MacDonald of Nathan Hale High School in Moodus, CT, works with a student on an e-portfolio created in Google Sites.

A crucial aspect of student success planning is teaching students to archive their work electronically so it can follow them as they move from school to school or change districts. At Nathan Hale High School in Moodus, Connecticut, Deborah Olsen-MacDonald, business education and finance technology teacher, teaches a class called Information Technology, primarily for freshmen. Our BIG P.A. is a project they created using Google Sites where each student creates a personal Web site to be used for collecting schoolwork, listing personal interests and hobbies, showing extracurricular activities, and reflecting on their growth over time and their work to fulfill the district’s learning expectations. Students continually add to the portfolio over the course of their high school careers. Then, when they become seniors, they take a course called “Senior Project” in which they use their portfolios to demonstrate their readiness to earn a high school diploma by showing their learning and growth over time.

Accountability and Self-Monitoring: RubiStar and iRubrics

Today’s students expect a rubric for each assignment and they know how to use them. A skill that doesn’t appear on a given rubric is, by default, not a skill worth worrying about. As such, teachers should focus on creating rubrics that assess not only content, grammar, usage, and mechanics, but will also explicitly assess soft skills. You can write your own or go to Web sites like RubiStar or iRubric (accessible through Google Apps for Education) to see how others assess these skills. Rubrics on these sites can be used as is or modified to suit your needs. You can also create and add your own rubrics to the shared database.

Across our nation, state departments of education are creating new policies that recognize the importance of soft skills. In Connecticut, for example, students in grades 6-12 are required to file a personal student success plan made up of goals in social, emotional, physical, and academic growth.

Online article: http://www.techlearning.com/features/0039/tech-tools-for-assessing-the-%E2%80%9Csoft-skills/54730
APPENDIX P

NITARP EDUCATION POSTER
Charming the Snake
Using Python Programming in High School Astronomy Research Programs

M. Booker, Evanston Township High School, Evanston, IL; Citron, W. C. Towns, Farming High School, Medfield, MA; M. Myers, Lincoln Way High School (Elk Grove Village), Chicago, IL; L. Niver, Boeing High School, Renton, WA; B. All, Chicago, Evanston, IL.

Getting Started
- Visit the NASA/IPAC website.
- Download the repository "Python Programming in High School Astronomy Research Programs." [Link to repository]
- Explore the tutorials and course materials available.
- Watch videos and live sessions to enhance your understanding.
- Practice coding exercises and submit your solutions.

Tutorial Topics
- Introduction to Python Programming
- Data Analysis with Python
- Machine Learning with Python
- Web Scraping and Web Development
- Advanced Topics: Databases, Network Programming

How was Python Used During Research?
- Data manipulation and analysis using NumPy and Pandas
- Visualization using Matplotlib and Seaborn
- Machine learning models for predictive analysis
- Web scraping techniques for data collection
- Development of interactive web applications

Student Responses to Learning Python
- "I really enjoyed the hands-on approach to learning Python. The guided tutorials helped me understand the concepts better."
- "I was initially intimidated by the syntax, but the examples provided helped me overcome that."
- "Python is a very powerful tool for data science and I'm looking forward to using it more in my future projects."

Thoughts for Future Implementation
- Enhance the interactive components of the course to engage students more effectively.
- Incorporate more real-world projects to make the learning experience more practical.
- Provide additional resources and support for students who may struggle with the material.

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