# The Elements Unearthed: Prototype Development Project Description

### *Project Overview*

*The Elements Unearthed: Prototype Development* is a **Pathways Project** to document the history, uses, sources, mining, refining, and hazards of the chemical elements and industrial materials through student-created podcasts. For this project, selected teams of students in high schools near mining, refining, or chemical manufacturing sites meet twice per week in an after-school program to plan and carry out the project. Each team partners with subject experts: a historian from a local museum, a scientist or engineer from the site, or others to research its history, science, and technology and write their results on a wiki website. Once the research is completed, they are trained to use digital video equipment to film interviews of the subject experts and also tour, videotape, and photograph the site. They capture the footage, write complete transcripts, and combine them with their research to create a final script. They then use digital software to edit the footage and photos into a series of video segments which are shown to the public at a premiere night at the local museum. Finally, the videos are uploaded to the Apple iTunes site and to YouTube where they can be accessed freely by the general public.

In addition to creating a resource of useful videos on the elements, this project assesses how involving students in telling the history of science in their communities improves their knowledge and engagement in science, technology, engineering, and mathematics (STEM) careers.

This proposal is a re-submission from a previous ISE proposal (# 0917628). The review panel for that previous submission felt that the project has strong intellectual merit and broad impact, but that improvements are needed to expand the management team, build partnerships with relevant organizations, and develop a more thorough evaluation plan. Those issues are addressed in this extensive revision; improvements have also been made in the strategic impact of this project on the ISE field as a whole.

### *Project History: Phase I*

This project is the second phase of a project that began in the fall of 2007. This first phase was a feasibility study or proof-of-concept. Students in the Media Design Technology program at Mountainland Applied Technology College (MATC) in Orem, Utah were divided into teams of four to five students and asked to choose from a list of possible nearby sites. Over the two years of Phase I, these teams developed and tested the process outlined above. Feedback from the first year was used to make improvements for the second year, such as adding subject experts from the sites and using a wiki website to collaborate on research and scripting. Because this was a program specifically for digital media students, team members were able to edit and clean up photos taken at the site, along with historical photos provided by the subject expert using skills they had already acquired. They created digital illustrations, diagrams, captions, credits, and 2D and 3D animations to complement the video clips. When the rough cuts were complete, they were alpha tested by showing them to the other students in the Media Design classes who provided detailed feedback and suggestions. The teams then revised their projects. They were evaluated again through a beta test by inviting students from other classes at MATC to review the videos.

The Utah sites selected by the teams for this first phase included the Ash Grove Cement Plant near Leamington, the Brush Engineered Resources beryllium refinery near Delta, the Tintic Mining District and museum around Eureka, the blown glass and stained glass workshops at Thanksgiving Point, and synthetic diamond manufacturing at Novatek in Provo. Participants of the beta tests suggested shortening the length the videos (they were about 20 minutes each) down to less then 15 minutes including credits. Because the end of the school year arrived before this final edit could be made by the student teams, the Principle Investigator is making these changes now and preparing the videos for uploading, with the first few episodes to be ready by Jan. 1, 2010.

During the summer of 2009, the Principle Investigator, David V. Black, was selected as the 2008-09 Research Fellow of the Société de Chimie Industrielle (American Section) at the Chemical Heritage Foundation (CHF) in Philadelphia, PA. For the three-month duration of the fellowship, he utilized the extensive collection of chemistry journals, archives, artifacts, paintings, and rare books at CHF to research and collect photos on several topics to use for future episodes. These topics include the origins of matter theories in ancient Greece; how these theories developed during the Middle Ages; how alchemy, metallurgy, glass making, and other crafts led to modern chemistry; the equipment, technology, and laboratory apparatus of the Middle Ages and Early Modern period; and the development of modern atomic theory and the periodic table. He was able to photograph many rare and seminal books in CHF's collection, including a first edition of Robert Boyle's *The Skeptical Chymist*; handwritten manuscripts of Isaac Newton's alchemical experiments; first edition works by Lavoisier, Dalton, Avogadro, Berzelius, and others; and selected works attributed to all the noted alchemists of the Middle Ages including Zosimos, Ramon Lull, Arnold of Villanova, Nicholas Flamel, Basil Valentine, and many more. He also took advantage of being in Philadelphia and traveled to nearby related sites, including the DuPont gunpowder works and Hagley Museum in Willmington, DE; the Sterling Hill Zinc Mine in Ogdensburg, NJ; the Lackawanna anthracite coal mine near Scranton, PA; the former site of Centralia, PA; and the Smithsonian Museum of Natural History's mineral and gem collection in Washington, D.C.. On his way home from Philadelphia, he stopped at more sites, including the Drake Oil Well in Titusville, PA; the Bonne Terre Lead Mine and Missouri Lead Mine Historical Site; the Kansas State Oil Museum in El Dorado, KS; and the underground salt mine in Hutchinson, KS. He also took the opportunity to interview Dr. Eric Scerri, author of *The Periodic Table: Its History and Its Significance*, who was at CHF for a conference. On his way through Illinois, he interviewed Theo Gray, who writes a column on the chemical elements for *Popular Science* magazine called *Gray Matters* and is an avid collector of the elements. All of this material, including over 10,000 photos and many hours of videotape, are being edited into final videos during the 2009-2010 school year to create additional podcast episodes. By the end of May, 2010, over 25 episodes will be available on our iTunes site (see Table 2).

In addition, during this school year, three additional projects will be completed using students from schools outside of MATC. These projects will test the feasibility of generalizing this project to other schools and of building coalitions with local museums to enhance the museum's collections and capacities. Once the decision is made to fund this proposal by summer, 2010, we will be fully ready to begin Phase II: Prototype Development, which will expand the project to 20 teams in three Western states.

The main purpose of the initial proof-of-concept project (Phase I) was to see if student teams, consisting mostly of high school students from surrounding school districts, could plan and execute a video on a technical topic to a professional level of quality. Although the final revisions are still being made, the alpha and beta tests indicate that we achieved our objectives of subject depth and accuracy as well as video quality. Samples of some of these podcasts are posted to our blog site and have been shown at conferences and presentations with favorable responses. In Phase II, which is this prototype proposal, as we move to other locations in Utah, Nevada, and Colorado we will implement a thorough evaluation plan (see below) which will provide evidence on how well this process works. With modifications learned through this effort, we will be ready to begin a full-scale project (Phase III) that allows student teams from around the country to document their local science history.

### *Project Audiences, Activities. Goals, and Operational Objectives*

We have identified three audiences for this project. Our primary audience consists of the student teams that participate in the activities of the project, as described below. Our top priority is to work directly with these groups, mostly in an after-school setting, to develop their technology skills and provide exposure to STEM careers. Our secondary audience includes the members of the general public who view the final videos, including members of the community who attend the premiere night and people such as chemistry students and teachers who download and watch the completed episodes on their own. Our tertiary audience consists of professionals in the informal science education field who attend our presentations at conferences or read articles that we write in professional journals.

To clarify the processes and goals of this project, we have developed a logic model or process flow chart as shown in Figure 1. For our primary audience of the student teams and coalition members, the inputs are the funds provided by NSF and other sources; the knowledge and experience of the Principle Investigator and mentor teachers; the video production equipment and software that is used; the lessons we learned from the feasibility study; the expertise of our Advisory Committee; the partnerships we develop with museums, chemical manufacturing plants, the mining industry, professional organizations, and distributing channels such as the Utah Education Network (UEN); and the guidelines, standards, and systems we put in place.

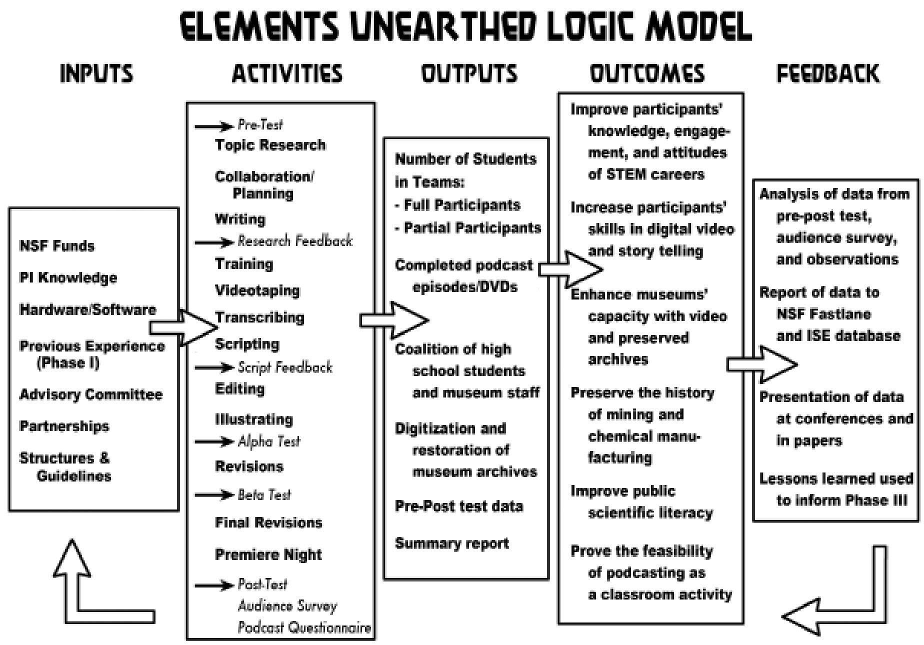


***Figure 1: Logic Model and Process Flow Chart***

The activities of the project teams include researching their topic; collaborating with the subject experts; writing up the finished research and sources in a Wiki site; planning the video shoot; training on digital video equipment and software; conducting and filming the interviews and site tours; capturing the footage and writing transcripts; combining the transcripts and research into a final script; editing the footage according to the script; creating illustrations, diagrams, titles, captions, and animations; revising the film; and presenting the final version to the public at a premiere night at the sponsoring museum. The achievement of our operational objectives will be determined through a thorough evaluation program (see below) including pre-post testing and formative and remedial assessments, indicated by the arrows in the Activities section of Figure 1. Audience members at the premiere night and people who have downloaded the podcast episodes will also be given surveys to evaluate what they have learned.

The outputs or products and deliverables of the project include the number of students participating in Phase II. Approximately 100-120 will be full participants and receive training; other students at each school will be partially involved as they help with research, writing, creating illustrations, and beta testing the videos, perhaps as many as 400-500 additional students. Other outputs include the completion of the podcast episodes themselves. With twenty teams, each team creating one to two video episodes of about 15 minutes each, we anticipate about 30 episodes will be finished by the student teams by May, 2011 in addition to episodes already done by then (an additional 30). These videos will be deployed to iTunes and YouTube as well as other podcast hosting and aggregate sites (Ourmedia, Libsyn, PodcastAlley, PodcastPickle, etc.) and the videos will also be converted to DVD format which can be used by the local museums for presentations, exhibits, marketing, and fundraising. Another output will be the coalition we will build between the high school student teams, their mentor teachers, the local museums, and the chemical sites. As the teams work with the museums, they will use their training in media design to scan and digitize the collections and exhibits and restore any damaged or faded photos. Other outputs include the assessment data and final project reports, which will be used to write professional papers and make presentations at conferences to improve the knowledge of the informal science education field.

The Outcomes or changes we hope to see as a result of this project form our project goals. We have six broad goals: (1) improve participants' knowledge of, interest in, and attitudes towards STEM careers;

(2) increase participants' skills in digital video production and story telling; (3) enhance local museums' capacity through producing useful videos and digitizing their archives; (4) preserve the history of mining and chemical manufacturing in local communities; (5) improve the scientific literacy of the general public through our podcasts/videos; and (6) demonstrate the feasibility of student-created podcasts as a useful educational activity. The operational measurements for each goal are summarized in Table 1 below.

| ***Broad Goal*** | ***Operational Measurements*** |
|---|---|
| 1 - Improve partici-paticipants' knowledge of, interest in, and attitudes towards STEM careers. | A - Through a pre-post test of particpating students compared with non-participants. |
| | B - Observations and self-reported anecdotes of PI, mentor teachers, and participants. |
| 2 - Increase participants' skills in digital video production and story telling. | A - Successful completion of podcast episodes as determined by project guidelines. |
| | B - Self-reported by students in post-test. |
| 3 - Enhance local museums' capacity through producing useful videos and digitizing archives. | A - Successful usage of completed videos by the museums as an exhibit, presentation, sales item, or on website. |
| | B - Successful completion of archive digitization and enhancement. |
| | C - Increase in community awareness of and interest in local museums as reported on premiere night audience survey. |
| 4 - Preserve the history of mining and chemical manufacturing in local communities. | A - Inclusion of first-person interviews, archival photos, or artifacts in final videos. |
| | B - Through questions on premiere night audience survey. |
| 5 - Improve the scientific literacy of the general public through our podcasts/videos. | A - Through podcast episode download statistics and blog traffic. |
| | B - Through questionnaire results returned by end users. |
| 6 - Demonstrate the feasibility of student-created podcasts as a useful educational activity. | A - Observations reported by mentor teachers, student comments on post-test, and PI observations regarding problems, successes, and results. |
| | B - Statistical results of pre-post test correlating level of involvement with attitude and knowledge changes regarding STEM careers. |

***Table 1: Broad Goals and Operational Measurements***

The logic model shown in Figure 1 includes the step of feedback. The pre-post tests given, the audience surveys at the premiere night, and feedback questionnaires returned to us as well as observations by the mentor teachers and PI will be compiled, analyzed, and used to create a final report for NSF. Data from the surveys and evaluations will be added to the ISE database.

The results for our primary and secondary audiences become the inputs for the professional (tertiary) audience portion of our project. The results will be written up in professional magazines and other publications and will be presented at several regional and national conferences to members of the informal science education profession. Data will be collected after these presentations to evaluate the strategic impact this project has on the field as a whole. The outputs for this portion of the project include the number of articles written and the number of professionals who attend the presentations and complete the surveys. The outcomes include one goal: to encourage and increase the number of museums and science classrooms that use podcasting. As additional schools and museums become interested in this project, we will be ready to move into Phase III: Full-Scale Development on a national level.

### *Project Structure and Timeline*

Phase I of The Elements Unearthed Project was a feasibility study which started during the 2007-08 school year as described above and continued through the next year, with seven video segments finished by student teams by the end of May, 2009. At that time, the Media Design Technology program at Mountainland Applied Technology College was eliminated due to budget cuts. Before leaving MATC, the Principle Investigator backed up all the data from Phase I and used personal funds to acquire the computers, software, cameras, lights, and microphones needed to continue the project. Upon leaving MATC, he spent three months completing the Research Fellowship at the Chemical Heritage Foundation in Philadelphia as described previously.

The PI is continuing the project on his own during the 2009-10 school year as an independent researcher. In addition to completing the student video segments from the previous two years and preparing them for upload to the Internet, he is also capturing, transcribing, and editing the footage and photos he shot over the summer. As of this writing (November, 2009) he has the materials such as photos, video clips, and background research to create approximately 30 podcast episodes. The first nine episodes will be completed by Jan. 1, 2010 and uploaded to iTunes and YouTube as shown in Table 2. Before January, several samples will be posted We have already posted a preliminary version of the Project Rationale to our blog site and to YouTube, as well as short samples of the Blown Glass and Synthetic Diamonds episodes. Other samples will include parts of an interview of Dr. Eric Scerri on the history of the periodic table that includes photos from the notes of Edward Mazurs (which are archived at CHF). The full episode should be complete by the end of January, as shown in Table 2.

| ***Name of Episode*** | ***Target Completion Date*** | ***Episode Number*** |
|---|---|---|
| Project Rationale | Jan. 1, 2010 | G-PO-V01 |
| Blown Glass A: History and Process | Jan. 1, 2010 | M-HU-V01 |
| Blown Glass B: Art and Science | Feb. 1, 2010 | M-CP-V01 |
| Synthetic Diamonds A: Discovery and History | Jan. 1, 2010 | E-06H-V01 |
| Synthetic Diamonds B: Process and Uses | Feb. 1, 2010 | E-06C-V01 |
| Greek Matter Theories A: The Pre-Socratics | Jan. 1, 2010 | H-AT-V01 |
| Greek Matter Theories B: Atoms vs. Elements | Jan. 1, 2010 | H-AT-V02 |
| Tintic Mining District A: History and Challenges | Jan. 1, 2010 | H-MD-V01 |
| Tintic Mining District B: Life in a Mining Town | Feb. 1, 2010 | H-MD-V02 |
| Stained Glass A: History and Processes | Jan. 1, 2010 | M-HU-V02 |
| Stained Glass B: Art and Science | Feb. 1, 2010 | M-CP-V02 |
| Making Cement: History and Processes | Jan. 1, 2010 | M-CP-V03 |
| Beryllium A: History, Sources, and Mining | March 1, 2010 | E-04C-V02 |
| Beryllium B: Concentration | Jan. 1, 2010 | E-04C-V03 |
| The Periodic Table: History and Development | Feb. 1, 2010 | H-ST-V03 |
| Elemental Properties: The Periodic Law | March 1, 2010 | G-PL-V01 |
| The Early Alchemists to 1000 AD | March 1, 2010 | H-ST-V01 |
| Alchemy and Matter Theories in the Middle Ages | March 1, 2010 | H-ST-V02 |
| Craftsmanship and Technology in the Middle Ages | April 1, 2010 | H-AP-V01 |
| The Rise of Chymistry (1450 to 1830 AD) | April 1, 2010 | H-AT-V03 |
| Anthracite Coal Mining in Pennsylvania | March 1, 2010 | H-MD-V03 |
| Zinc Mining in New Jersey | April 1, 2010 | E-30H-V02 |
| History of Petroleum: The Drake Oil Well | April 1, 2010 | M-EP-V01 |
| History of Petroleum: El Dorado, Kansas | April 1, 2010 | M-EP-V02 |
| Missouri Lead Mining History | May 1, 2010 | E-82H-V03 |
| Salt Mining in Kansas | May 1, 2010 | M-HU-V03 |
| Gunpowder: History and Processes | May 1, 2010 | M-HU-V04 |
| Minerals and the Elements: Overview | May 1, 2010 | G-ML-V01 |
| Minerals of Utah | May 1, 2010 | G-ML-V02 |
| Minerals of Missouri | May 1, 2010 | G-ML-V03 |

***Table 2: Titles and Completion Dates of Podcast Episodes***

In addition to completing episodes for which we already have materials, we will continue the project at new sites in order to gather preliminary data on the process of generalizing this project to other schools. The PI presented at the Utah Museums Association annual conference in October, 2009. He described how this project could aid local museums by archiving their photograph collections and producing video segments that can be posted on their websites, used for exhibits, and for other purposes. Several representatives from museums around Utah approached the PI after his presentation, and negotiations are underway to build three projects for this year. These include video episodes on the history and legacy of the uranium boom in eastern Utah during the 1950s and 60s; the phosphate mining or gilsonite mining operations near Vernal, Utah; and one other project, possibly the history of coal mining near Price, Utah or the Intermountain Power Project or Continental Lime plant near Delta, Utah. In all three cases, a small, underfunded local museum has some exhibits on local mining as well as archival photos, but they do not have the resources to produce their own historical videos. This project will provide the means and expertise for producing the videos and the museum staff will provide the historical knowledge, archival photos, and a central location for our efforts in each community. We are now contacting teachers in the local high schools at each site to set up dates for initial planning and team formation. We anticipate doing the student training and filming in early December before bad weather makes filming and travel difficult. These episodes will be edited at least to a rough draft stage by the local student teams by the end of April, 2010 and completed for upload by the end of June. Our observations and the results of a preliminary survey given to the participants this year will be used to plan the pre-post test and make adjustments to our approach as we begin Phase II: Prototype Development which will be funded by this grant.

Phase II will begin officially in July, 2010 with initial visits to the selected sites to begin planning with the teams, their mentor teachers, and the local museum expert and to administer the pre-test evaluation. Unofficially we will begin Phase II earlier in the spring (Feb., 2010) as a solicitation is sent out to prospective high school teachers and museums at appropriate sites in Utah. By the end of April, between five and seven sites will be selected and informed in early May. These schools will be selected on the basis of the thoroughness of their proposal and the inclusion on the teams of students from underrepresented populations. Most of the sites selected will be in rural areas that are economically disadvantaged or that experienced the bad effects of the mining boom and bust cycle. Priority will also be given to teams that have balanced genders and that include students from diverse groups such as Native Americans from nearby reservations or Hispanic students.

From July through mid-September, the teams will collaborate with their local experts (historians and scientists) to develop the wiki website that includes their research notes and sources. This will be gradually added to and improved until it is evaluated as complete by the PI and museum expert. In the meantime, the date for the site visit and interviews of the subject experts will be planned for a Tuesday or Wednesday in late September through early November. During the week of the planned site visit, the PI will travel to the site and provide training and oversight of the production process, familiarizing the student teams on how to use digital video equipment and practicing the shoot. This will be done through two after school sessions. On the day of the site visit, the mentor teacher will arrange for the participating students (five to six per team) to leave school as a field trip. They will travel to the site using school vehicles, set up the equipment, and interview the subject expert. If the site is an active mine, such as the phosphate mine near Vernal, they will interview a chemical engineer or site manager concerning the processes and science used. The expert will then act as a tour guide to show us around the mine site and will wear a wireless microphone system so that we can record the tour without the interference of other sounds. We will use at least two cameras and microphones for all parts of the shoot to ensure redundancy and allow us to use multiple camera angles in the final video edit. One of the students will also use an SLR digital camera to photograph the site and another will use a third video camera to record the students as they conduct the shoot for a "making of" presentation for the premiere night. Once the shoot is complete, we will meet again the next day for training on the capturing, transcribing, and script writing process. Finally, the students will be trained through two sessions (Friday and Saturday) how to edit the footage using digital video software (Apple Final Cut Pro or Adobe Premiere Pro) and how to edit and restore photos that are taken using Adobe Photoshop. Altogether, the PI will spend six days at each site.

Once the week of training and production is complete, each team will capture the footage taken, upload and clean up photos, and transcribe all the interviews. This is a lengthy process and could involve other students besides the initial team. Students with experience in drawing illustrations or other needed artwork could be recruited to help as well. English students can help write and evaluate the script based on the transcripts and original research notes. These partial participants will also receive the pre-post tests.

Once the final script is approved, the teams will begin editing the footage in the video software and adding titles, illustrations, photos, and other B-roll clips to produce a rough draft of the video. This stage, from capture through script to rough edit will take about three months, from December through February. The team will stay in contact with the PI as any technical questions arise. By the end of February the teams will post a compressed version of their video to their wiki site where it will be watched and commented on by the PI, museum expert, site expert, Advisory Committee, and students of other teams at other sites. These comments and recommendations will focus on technical aspects of the project: color consistency, audio mastering, transitions, and basic structure. This remedial evaluation will be used by the teams to revise and improve their videos. The teams will then conduct a beta test using a sample of their target audience: students from other classes in their own school. This can be done by asking students to stop in after school or during lunch over a week's time to watch the video and make comments on a form provided. These suggestions will address the content, interest, and story telling aspects of the films. Final corrections will be made by the end of April and a premiere night will be scheduled in late April or early May at each of the local museums. Involved students, classmates, family members, and the community at large will be invited to attend. If the museum does not have a space for such a gathering, it will be held in a local venue such as the high school auditorium (which will be rented for the purpose). The project team and museum expert will make short presentations on the purpose and process of the project and show the "making of" video and then the final video program will be presented. The audience will be given surveys to see the extent to which this video has increased their knowledge of local history and affected their attitudes toward their local museum.

Once the videos have been presented, all the digital files (which are stored on a hard drive purchased specifically for this project) will be handed over to the Principle Investigator for storage and archiving. The final videos will be compressed, metadata will be added including search tags, and the videos will be uploaded to the Internet.

While these projects are underway, the podcast episodes that have been completed through Phase I will be on our website, on the iTunes site, on YouTube, and available through the Utah Education Network (UEN) video repository/iTunesU site. Questionnaires in .pdf format will be posted with these videos and viewers will be encouraged to complete a questionnaire on how they found the videos, what they were used for, how useful they found them, and how they changed their knowledge and attitudes about STEM careers and chemistry history. These surveys will be returned to the PI and analyzed.

During the summer of 2011, the results of the pre-post tests, audience surveys, podcast questionnaires, and observations by the PI and mentor teachers of the process will be analyzed and the results used to improve the process and delivery of training for the second year of Phase II. During the 2011-12 school year, an additional five teams will be chosen from Utah and the project will be expanded into Colorado and Nevada as four-five teams from each of those states are chosen. Again, likely sites will be identified and recruited by contacting local museums and high school science or technology teachers in early spring, 2011 and final choices made by late April. During the second year, the PI will not make training visits for six days to each site (this would not be feasible for 13-15 sites). He will make an initial visit during the summer/early fall, 2011, and in some cases visit for two days during the actual filming or the premiere night, but will only visit twice per team. The teams will instead receive training through on-line video tutorials produced by the PI based on the visits of the previous year and posted to the project website and blog. By moving the training online and collecting data on its effectiveness, we will be able to move into Phase III where teams from across the country can be involved in this project without having the PI present at all; any communication and coordination will occur online.

By the end of May, 2012, a total of 20 teams will have participated and approximately 30 additional episodes will be produced. It is anticipated that some topics will require two episodes to fully cover, such as the uranium boom in eastern Utah. One episode will be needed to tell the history and geology of the uranium discoveries; the second will show the legacy of the boom years, including the radioactive tailings piles, abandoned mines full of radon gas, and the cancer clusters that have occurred in these towns. Two years worth of data from the student teams and their classmates as well as audience feedback from the premiere nights and online usage will be analyzed and added to the ISE database and a final report written during the summer of 2012.

During both years of the project and the year following the submission of the final report, the PI and mentor teachers will travel to professional conferences for science educators and museum associations. They will present the findings and results of the project, encouraging professional attendees to consider participating in Phase III of the project, when it will be scaled up to a national level. Articles will also be written for professional magazines, and the project blog and website will continue to discuss the results and future of the project. Further funds will be requested from NSF and other sources in the fall of 2012 with anticipation of Phase III beginning in late summer, 2013. In the meantime, during the 2012-13 school year additional teams will be recruited using non-NSF funds so that momentum will continue.

### *Project Research Design and Evaluation Plan*

As shown in the logic model in Figure 1, each year of the Elements Unearthed Prototype Project will be assessed through summative, formative, and remedial evaluations as well as informal observations.

In order to determine if our operational objectives are met and that the project activities were the most likely cause of any changes, a pre-post test will be given to students who participate in the project either fully or partially (the experimental group) and to students in their same schools who do not participate but who are taking the same or similar classes (the control group). Because the students who participate do so voluntarily, it will not be possible to assign students to the control or experimental groups randomly. To mitigate this problem and allow for better comparisons, we will collect demographic information from both groups, then match individual responders from the experimental group with students in the control group using demographic information. For example, if a student in one of the project teams is a female Native American who has a 3.7 GPA and is taking Chemistry I and is familiar with computers, then we will match her up with similar students in the control group and compare their responses directly.

As we design the pre-post test instrument, we will make it as simple and unobtrusive as possible while collecting both numeric ratio data that will allow direct statistical analysis as well as asking for anecdotal data in the form of student comments. We will look specifically at the extent to which their knowledge of, interest in, and attitudes about STEM careers have changed over the course of the project as they have been exposed to scientists, engineers, historians, and other professionals and as they have conducted their research. Secondly, we will assess the skills they have attained while completing the video segments. This will partially come through observation – did they successfully finish the podcast episodes and fulfill all the standards outlined for them? It will also be assessed through self-reporting on the post-test survey.

One question we hope to solve through the preliminary study and through the two years of this project is the optimum level of involvement for the student team members in order to achieve the maximum change in knowledge and attitudes regarding STEM careers. To achieve maximum skills in digital video production, the teams will need to complete their videos to a professional or excellent level; however, to reach the optimum change in attitudes and interest, it may be that they will only need to complete the videos to a good level (rough edit) and that insisting they revise the project further will lead to diminishing or even negative returns for additional involvement. Figure 2 shows the relationship between the level of quality of a work and the amount of time and effort it takes to reach that level. Most students are used to completing projects to a good level only, which is the level required to receive a desired grade.

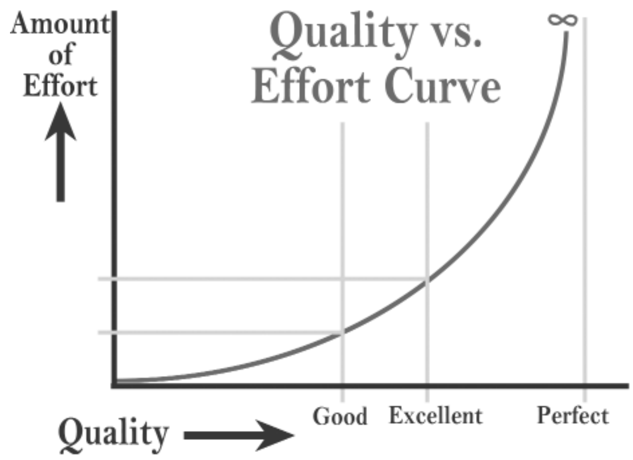


*Figure 2: Curve of Quality vs. Effort*

However, for a work to be acceptable to a public audience, it must be completed to a professional or excellent level. Most students and novice designers assume the relationship between quality and effort is linear; that is, if you double your effort you get twice the results. This isn't the case. Developing a project from good to excellent is only an incremental change in quality (excellent isn't twice as good as good), but it takes twice the effort because the curve is exponential. This is why most inexperienced project managers don't allow sufficient time to complete the finishing touches of a project. Some students and professionals make the opposite mistake and have difficulty ever finishing a project because they try to take it to perfect level of quality, without flaws. However, this is not necessary for any project for public audiences; any flaws the designer notices probably won't be visible to the average audience member and are probably not worth the effort to fix. Tweaking things forever to make them perfect is counter-productive; it takes infinite effort to reach perfection. Our goal for creating the design rubrics for this project will be to encourage students to take their projects to an excellent level but to then let them go at that point and consider them done.

In order to determine the relationships between hours of involvement and changes in attitudes toward STEM careers and skills in digital video, we will ask the students to keep track of the number of hours they spend working on this project through a type of timecard. Partially involved students may only work on this project for a few hours whereas the students who receive the initial training may be involved in filming, editing, scripting, researching, etc. for several hundred hours. From our preliminary study this year, we hope to at least determine if these relationships are linear or if there is an optimum level of involvement for maximum changes. This data will help determine the final structure of the pre-post test and the project itself for Phase II. As we collect and analyze this data from Phase II, it will prove to be of extreme interest to the informal science education field for those considering similar projects.

As this preliminary study data is completed, we will consult with a professional organization or individual with experience in instrument design and statistical analysis to ensure that the test items for Phase II are appropriate and unobtrusive. We do not want to have a study instrument that will take two hours to complete and will turn off any prospective student team members. Ideally, it should increase their interest and motivate them to participate in the project. This person will be a member of our Advisory Committee and will be paid a consulting fee to travel to the sites and administer the tests and to oversee the statistical analysis to prevent mistakes or bias and to guarantee the integrity of this study.

In addition to the formal pre-post test, we will use formative and remedial assessments to help keep the project teams on track. As shown in Figure 1, there will be checkpoints where the student teams must reach an acceptable level of accuracy, depth, and quality before proceeding to the next steps. These include feedback after they have completed their initial research and after they have completed their script. Alpha and beta testing will be used as remedial assessments so that any problems with quality, continuity, or content of the videos can be corrected. This process is identical to that used by professional productions; audience testing is used to make final edits in commercial movies and TV programs.

To determine if we have achieved our additional objectives of improving the STEM literacy of the general public and have enhanced the local museums' capacities, we will conduct audience surveys both at the premiere night and from the iTunes sites. Audience members at the premiere night will be asked if they are more likely after viewing the video to visit the local museum and contribute to its role to preserve local history, as well as whether or not they improved their knowledge and attitudes about mining, refining, and STEM careers. Those people who download our podcast episodes from iTunes and the Utah Educational Network iTunesU site will be asked to download a .pdf questionnaire and fill out how they heard about the podcast episodes, which ones they have viewed, how they have used them, what they have learned from them, and how to improve them. If asking this audience to voluntarily return the questionnaires doesn't seem to be working well, we will add a more formal test by asking chemistry teachers in Utah to download episodes and show them in their classes, then report on the results. This survey will be continued throughout the two years of the project and during the preliminary study this year and the cumulative results will determine how effective these podcast episodes have been at reaching our secondary audience of students and teachers in chemistry classes and the general public.

Finally, observations by the Principle Investigator of each team's effectiveness will be added to reflective observations of the mentor teachers, who will be asked to set up and write a weekly blog of the team's progress and accomplishments. Individual students may be asked to contribute to the blog entries, and their experiences will be added to the final report as anecdotal evidence.

### *Project Management, Partnerships, and Advisory Committee*

One of the concerns of the review board for our previous submission of this proposal was that this project relies too heavily on the experience and skills of the Principle Investigator, David V. Black. The management and oversight of this project need to be expanded in order to ensure its success even if the PI were incapacitated. To this end, strategic partnerships are being formed with regional and national organizations to help oversee and promote this project. Major support has already been provided by the Chemical Heritage Foundation in Philadelphia, PA and the American Section of the Société de Chimie Industrielle in the form of a paid Research Fellowship at CHF during the summer of 2009 as described above. In addition to the photos, images, research notes, and video acquired through the fellowship, staff at CHF also provided contacts and advice on marketing and promoting this project. They recommended contacts with several professional chemistry organizations, since they will be looking for education efforts to coincide with the International Year of Chemistry in 2011 and this project could be what they need.

Upon returning to Utah this fall, the PI began developing partnerships with other organizations. These relationships are still tentative and are pending financial support of this project by NSF or other organizations. We are forming a partnership with the Utah Education Network (UEN) to host the final video segments as part of their educational video repository and on their iTunesU site. UEN is an entity that was created by the Utah State Office of Education to promote the use of technology in Utah schools and to be the source of Utah's closed circuit educational network, a series of interactive courses offered to remote video conference sites at schools throughout Utah. UEN also provides the fiber optic trunk line for Utah schools' Internet access, and provides training to teachers on new and emerging technologies. They have recently been selected as an iTunesU site to develop podcast content and lessons that are distributed through iTunes and offered freely as open-source courses. UEN is just beginning this effort and is in need of excellent content; we are negotiating currently to provide UEN with the finished podcast episodes in exchange for their acting as a host and distributor for this project. We will also create a standard website to act as an additional home for this project or use a podcast hosting service; our blog site will not be sufficient to host all of the final podcast episodes. Other partnerships are also under development with organizations in Utah that represent the mining and chemical industries and that promote science education. They will provide sponsorship, promotion, marketing, and expertise.

Other partners are the local museums that we will involve in the planning and creation of these videos. They are full partners in that their expertise is fully integrated into all phases of the teams' efforts, and they are provided with the finished video episodes to use however they may need. We provide assistance to place these videos onto the museums' websites as streaming video to help promote interest in the museum for potential visitors. We gain access to the expertise and archives of the museums to further the goals of this project while providing much needed aid to the museums themselves. One museum we partnered with this year is the Tintic Mining Museum in Eureka, Utah. This museum is operated by June

McNulty and his wife and is only open by appointment. They have no other staff, no website, and no facilities for large tour groups. June has collected materials and memorabilia from the surrounding area and organized them into a series of rooms that take up the old railroad depot building and the upper floor of the old City Hall. In addition to photographs and an excellent mineral exhibit with samples of ore from the various local mines, he has a room that shows what a typical kitchen or living room or school room looked like when the town was in its heyday in the 1920s and 30s. One room is a cobbler's shop, another area a printer's shop with a recently discovered manual printing press from the 1870s. Another room is a general store. He also has placed artifacts from mining on display outside behind the depot building. In the case of this museum, any help we can give will be useful; everything from improving the labels on the displays (many are faded and hard to read) to promoting the museum in order to help raise funds to find a better location (the old City Hall building has a leaky roof that threatens the displays). We hope that the videos we produce will be used directly by the museum; so far June doesn't own a DVD player, so we may have to provide one if he is going to show the videos as part of the tour. We hope through this project to develop a coalition with students at Tintic High School that can work with the museum and also direct us to sites that we haven't documented yet, such as the towns of Mammoth and Silver City.

In addition to the Tintic Mining Museum, we have contacted or been contacted by the Hutchinson Museum in Lehi, Utah which has an excellent mineral collection; the Western Heritage Museum in Vernal, Utah with access to the phosphate, gilsonite, and oil shale deposits in that area; the Four Corners School of Outdoor Education in Monticello, Utah which is interested in telling the story of the uranium boom in that area; the Great Basin National Heritage Partnership which is developing promotional materials for Millard County, Utah and White Pine County, Nevada; and the Topaz Museum which will be part of the new Great Basin Museum in Delta, Utah which is a central location to cement manufacturing, beryllium refining, power generation (through the Intermountain Power Project), and lime mining and refining. We will develop three partnerships for the 2009-10 school year, and expand to 20 additional sites in Utah, Nevada, and Colorado during the two-year duration of this project.

To broaden the management and oversight of The Elements Unearthed project, we are instituting an Advisory Committee, which consists of representatives from chemistry education (both high school and college teachers), from the mining and chemical industry, and experts in research design, statistical analysis, video production, and marketing. This committee will be complete by the end of November; several people have already agreed to serve and others are being contacted. We will hold our first meeting in January, 2010. We will meet formally twice annually and the PI will present the current status and future plans of the project. Once Phase II is underway, the first meeting each year will occur in early September to introduce the teams/topics for the year. The second meeting will occur in May or June to present the final video segments and report on the results of the assessments and on expenditures to assure financial accountability. During the rest of the year, the Committee will stay abreast of the progress of the project through reading the wiki sites created by the student teams and reading the ongoing blog entries of the PI and the mentor teachers. They will be given access to the wiki sites to comment and make suggestions for the research notes and script and alpha test of the videos. The Advisory Committee will also be charged with determining the standards and guidelines to be followed for the final videos. Since both high school and college teachers will be on the Committee, they will be able to incorporate national science and technology education standards into these guidelines. Once the Committee has met two times during this current school year and its members are fully up to speed on the project, one of its members will be asked to serve as Deputy PI; this person will be designated to take over the project in case of illness or death of the PI. This person will also help make site visits once the project expands to Colorado and Nevada in the second year.

### *Project Rationale and Intellectual Merit*

Our broad goals and operational objectives outlined in Table 1 are based on a sound theoretical and practical rationale. As a high school teacher of chemistry and other physical sciences and computer technology for 20 years, the Principle Investigator has seen a number of trends in STEM education as well as increasing societal needs. These needs form the basis for this project and can be summarized into four broad areas: (1) to protect lives, (2) to preserve history, (3) to ensure the future, and (4) to improve the U.S. economy.

The general public in the United States is woefully ignorant about the processes or proper uses of everyday chemicals or of chemistry in general. In the case of household chemicals, ignorance isn't bliss and what you don't know can certainly hurt you. Environmental pollution and other hazards can affect people's health, and their awareness of these issues can help protect their lives.

To give several examples of the effects of chemicals on just one person's life, the PI, David V. Black, grew up in Deseret, a small town in western Utah. As a young child he was exposed to radioactive iodine from the nuclear weapons tests in Nevada which accumulated on the alfalfa eaten by the family cow and was then concentrated in the cow's milk. As a result, he has an increased likelihood of contracting thyroid cancer. In 1978, tests of the local water supply in Deseret (an underground aquifer) found it to be contaminated by arsenic salts at four times the allowable levels. Medical and longitudinal mortality tests of the effected populace found an increased incidence of certain diseases including prostate cancer (Lewis, et. al; 1998). The PI's grandfather, who lived in the town all his life, died of prostate cancer. During December, 1996, Utah was hit by three hazardous materials emergencies. The worst of these occurred on Interstate 15 a few miles north of Nephi when a semi-truck overturned in high winds and spilled its load of sodium azide pellets onto the highway. Drizzling rain reacted violently with the pellets, which burst into flames and sent a plume of toxic fumes toward the town of Mona. Public information on sodium azide was scarce and reporting by local news channels only helped to spread panic as Mona was evacuated. Some residents refused to leave, claiming that a little smoke couldn't hurt them. Fortunately the plume never reached the town and there were no injuries. The PI was living in Nephi at the time and was diverted off of I-15 onto an alternate route over 30 miles out of the way to get home. The next morning, another truck carrying sulfur dioxide spun out on slick roads on that alternate route, causing it to be closed as well. In order to get to his teaching job, the PI had to travel on yet another alternate route over 50 miles out of his way. These examples highlight how chemicals and materials can affect our lives. The more we know about them, the safer we will be. By producing these podcast episodes, we hope to contribute to the scientific literacy of the general populace by providing excellent, interesting, and accurate content on chemicals and chemistry in freely available locations using Web 2.0 technologies.

The history of mining, refining, and chemical manufacturing is in danger of being lost for several reasons. The first is that the buildings and structures of defunct mines are gradually falling apart; time and the elements are taking their toll. In Eureka, center of the Tintic Mining District, the area has been declared an EPA Superfund Site because of lead contamination of the soil. 18 inches of topsoil have been replaced and limestone rocks have been layered over the old tailings piles to help stabilize them. Open mine shafts and addits have been closed for safety reasons. However, these needed changes have come at a price. The vibration of the heavy machinery used for the clean-up efforts has caused many of the historic buildings and structures such as headframes to fall down. We hope to document and preserve what these towns look like before it is gone. A second reason that history is in danger of being lost is that the people who worked in the mines and lived in the towns when the mines were open are now elderly and beginning to pass away. We hope to interview as many of these people as we can and retain their first person accounts. The history of mining is a vital part of the our heritage, especially in western states.

To ensure the future, any democracy depends on a well-educated public so that proper decisions can be made and leaders chosen. Most of our political leaders were educated in the social sciences, humanities, or history (Wilson, 1998). It is rare to find a politician who is educated in the physical sciences. As a result, since just about every major issue has social and physical scientific components (from global warming to chronic poverty to unemployment), these leaders must rely on experts and lobbyists who don't always provide balanced information. Previous administrations have passed the buck and kicked the can to future generations because they are not aware enough or committed enough to make the necessary changes; they can pretend the dangers aren't real because they simply don't know better. The only way proper choices can be made is to make scientific literacy and science education priorities. Our project can't do all of this, but it can help by providing a source of unbiased, balanced information on the chemical elements and materials that will help future leaders and the public make informed decisions.

Finally, many studies are showing that we are at a crisis in the availability of STEM graduates for our science and technology businesses. In the late 1970s, science and engineering graduates increased rapidly only to stall out and even decline in the 1980s and 90s (National Science Foundation, 2007). Because of recent efforts to change this trend, we are seeing a slight increase in STEM graduates since 2000, but it is still not enough. The general competitiveness of the U.S. in science and math is also declining. The Program for International Student Assessment (PISA) tested 15 year olds in 59 countries worldwide in 2006. Results showed that U.S. students are below average on science and math knowledge (Institute of Educational Sciences, 2007). This doesn't bode very well for the future of the United States as the leader in science and technology. As the world becomes flatter economically, we are finding it increasingly hard to compete with developing nations that are turning out well-trained scientists and engineers who stay in their home countries and work for much less than if they were to live here (Friedman, 2005). American businesses find they can save a great deal of money by outsourcing their science and engineering tasks to firms in such countries as China and India, especially since American graduates are hard to find. By encouraging high school students to become more aware of careers in STEM fields and by exposing them to scientists and engineers in local companies, we hope to excite the students to choose these careers.

We have chosen podcasting as the vehicle for our project for several reasons. First, it allows us to provide multimedia content to the public without worrying about the competition of broadcast media channels, which have limited airtime and must appeal to a mass audience (Anderson, 2006). We can create excellent content on a fairly narrow and specific topic, post it to the Internet where there is unlimited shelf-space, and distribute it for free on-demand to our secondary audience (the public). Second, it will allow us to test the hypothesis that students learn a subject more thoroughly through creating their own content that is used by their peers and the public. Since their efforts have more meaning and will be useful for others, student are more motivated to dig deeper, work longer, and subsequently learn more than their peers who don't participate. In science education, current practice is that science classes should be constructive and discovery-based, with scientific inquiry as the central goal of student activities. These hands-on processes have been shown to increase student motivation and engagement with science, but not to help necessarily with increasing their knowledge of science facts. We propose that science classrooms should go beyond hands-on to incorporate activities that encourage

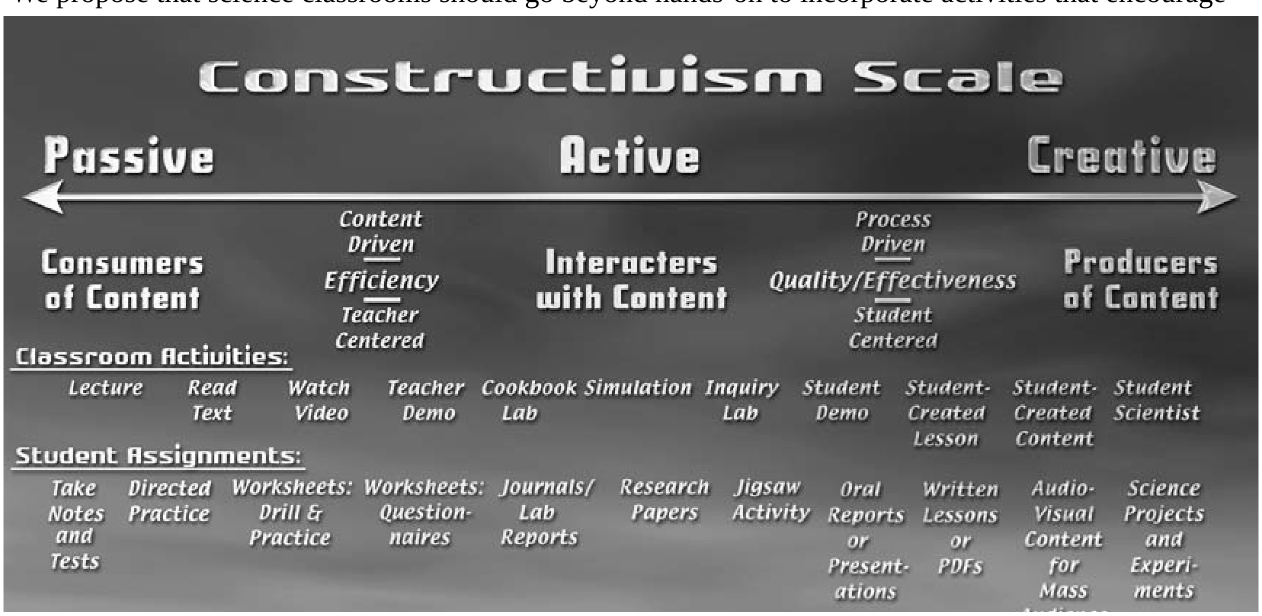


*Figure 3: Constructivism Scale*

students to create their own content and become citizen scientists or historians. Figure 3 on Page 13 shows the constructivism scale we propose to test through this project. If we can show that students who create their own podcasts for public distribution have better attitudes towards STEM careers and develop new skills, we will have made a major contribution to the fields of formal and informal science education.

Podcasting has also been chosen because it is an emerging technology that will have lasting impacts on both formal and informal science education. It has the potential of greatly increasing the participation of non-professionals in the creation of science content. Just as the citizen-science movement is involving amateur scientists in the collection and analysis of scientific data, the podcasting/internet video movement is turning anyone who chooses into a published video creator. Before the Internet, the business model of broadcast TV or theatrical movies was based on scarcity; limited airtime meant only a few programs were approved for production and only if they appealed to a mass audience (where high ratings could bring customers to advertisers). The breadth of available subjects was limited, even on PBS stations. Someone wanting to learn about the history of mining or the uses of a particular chemical element would have to wait a long time to see any related programming. With the Internet's almost infinite storage capacity, there are no limits on the types of programs that can be posted, even for small potential audiences.

Using professional science as an example, if we plot the level of professional scientific training of the population on a horizontal axis with PhDs on the left and the untrained populace on the right and the number of scientific studies produced and published in professional journals on the vertical axis, as seen in Figure 4, we see a steeply sloped Pareto curve with a small number of studies by professional scientists receiving most of the publication. If the level of acceptability for science production could be broadened to include studies by citizen-scientists, high school students, and teachers, then the total amount of science created (the area under the curve) dramatically increases (Anderson, 2006). Because of the limited space in professional journals (economics of scarcity), these studies by amateurs would most likely find a home on the Internet where different rules apply. Even small-scale studies on specific topics can find a home because of the economics of abundance; the long tail of the curve. The same type of curve exists in educational materials production; most educational materials are produced by a small group of professional curriculum designers and teachers. Yet the potential exists for many more people to create useful materials using the same economics of abundance and target these materials to smaller niche audiences. With the Internet and such Web 2.0 technologies as podcasting, our student teams will become educational content producers instead of consumers and make valuable contributions to science education. These technologies can also foster new forms of collaboration such as the wiki research sites and mentor teacher blogs we will produce (National Science Board, 2007).

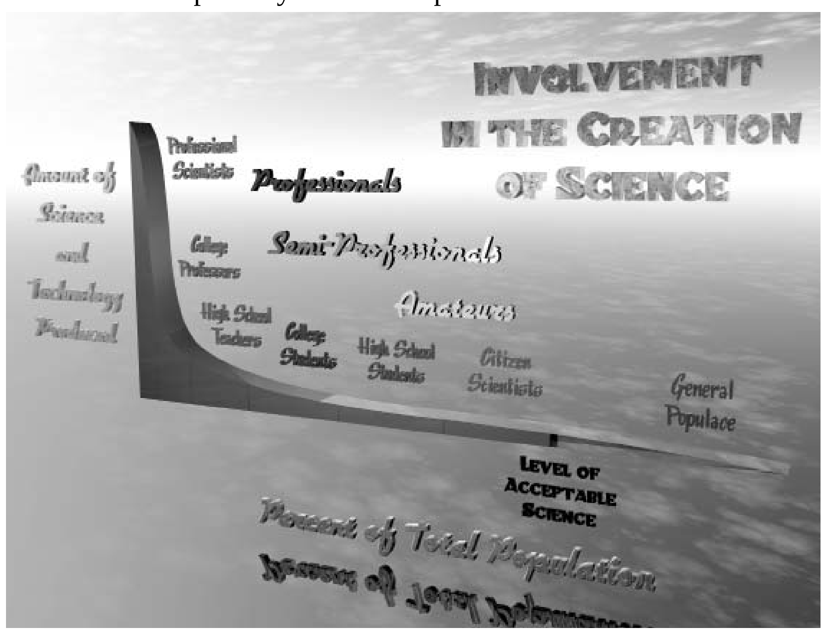


***Figure 4: Science Creation Curve***

The biggest concern for student-created content is the issue of quality. Previously, when professional curriculum designers or movie producers created programs or textbooks, they had to appeal to a broad audience of varying abilities, so textbooks were created for the lower common denominator. The quality was good, but not excellent and the breadth narrow. As shown in Figure 5, as we move to the creation of

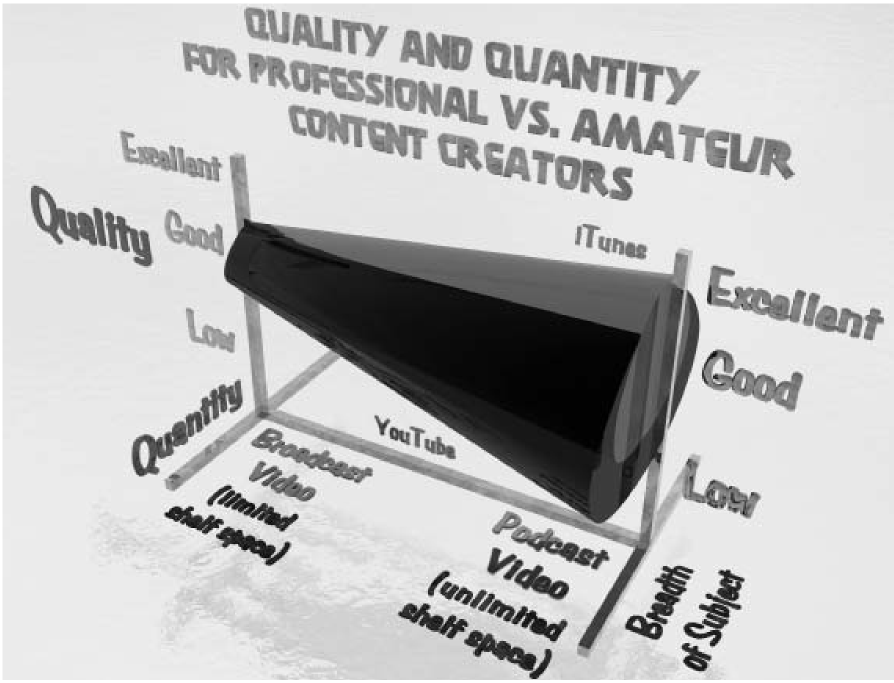


*Figure 5: Quality, Quantity, and Professional Creation*

content by amateurs, the breadth of programming available increases and the range of quality also expands. Most of this programming will be of poor to fair quality, but the potential exists to surpass the commercial broadcast media or professional curricula and achieve excellent quality. Our goal is to produce student-created podcast episodes of excellent quality by enforcing strict standards of excellence and through the frequent assessments described above.

### *The Broader Impacts of This Project*

This project will have both immediate and long-term benefits to the field of informal science education. First, our coalitions built with student teams from local schools collaborating with museum experts and local scientists and engineers will enhance the reputation of the local museums and provide them with video files they can use for many purposes. In the process of creating these videos, we will need to use many still photos and artifacts from the museum's collections as well as additional materials brought in by interviewees and the community. By scanning or digitally photographing these collections, they are preserved in a format that is useful for future museum exhibits. As the final videos are premiered at the museum, the community will see the museum as a center of learning instead of merely a repository of old stuff. The museum staff will actively work in the community to preserve its history. These benefits, although on a modest scale impacting only a few small towns, will still make a difference in those towns.

In the long term, this project has potential for results that will inform the ISE field as a whole. The data from our pre-post tests and audience surveys posted to the ISE database can be used by other prospective projects. We will demonstrate (or not) that podcasting is an effective classroom activity that motivates students and improves their interest in STEM careers. Our podcast episodes will also provide a useful resource for other teachers and students and a source for improving the scientific literacy of the general public. As we write articles for professional journals outlining our project, write blog entries, and present our results at professional conferences, we will encourage other museums and teachers to use these techniques and either join our project of produce podcasts of their own. We will encourage students and citizen-historians and scientists in the general public to create their own content and their own experiments. We hope, in a small way, to inform the public on chemical safety, to preserve the history of the chemical elements, to educate the public on chemical issues so that correct decisions can be made, and to promote STEM careers while enhancing the ability of museums to also achieve these ends. We hope to engage the public in a new perspective of science and how it affects our daily lives and our communities and enriches our culture (National Science Board, 2007).

Because of the potential positive impacts of this project to the participating students, to the communities whose history we tell, to the local museums that serve these communities, to the general public, and to the informal science education field, we submit this proposal for your consideration.