Interactive Qualifying Project

Effective Communication of Science and Engineering Breakthroughs to the Public: A Tool for Science and Engineering Professionals

An Interactive Qualifying Project Report submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Abstract:

The goal of our research was to gain an understanding of the problems of misinformation, linguistic misinterpretation, public comprehension, scientific justification, and audience gauging in presentation of research to the public. Surveys and Interviews were our primary means of gathering data. Language was one of the largest factors in misinterpretation. There is much discrepancy between what people think is a valid source and what the scientific community recognizes as a valid source. Ways of presenting data that scientists find easy to understand may be easily misunderstood by members of the public. These problems can often be avoided by properly tailoring one's presentation to one's audience.

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1. Introduction:

Despite the fact that the world is surrounded by science it still remains easily misinterpreted. There are many problem areas that professional scientists and engineers encounter when trying to convey their work to the public. The layperson tends to perceive words or subjects differently than a scientist. Science can be a completely different language than one's natural dialect in and of itself. The problem does not rise just from the public's interpretation. Many scientists and scientific writers fail to convey their work correctly, or carry out their experiments in a proper manner. Aside from correctly conveying work to the public, some scientists do not gauge their audience correctly. On February 28, 1998, Andrew Wakefield, a British Gastroenterologist and his colleagues published a paper describing 8 children who showed symptoms of Autism one month after receiving the MMR vaccine (measles, mumps, and rubella). Wakefield hypothesized that the MMR vaccine affected brain development. Many problems arose from this publication. Firstly, there were no control subjects in his study. Secondly, that year, about 50,000 British children per month received the MMR vaccine between the ages of 1 and 2 years, the time when Autism typically presents itself. It was inevitable that coincidental associations would be observed, especially considering how common autism was in England in 1998. By chance alone, about 25 children per month would receive diagnosis of Autism after receiving the MMR vaccine.[i] When looking at this problem from a scientific perspective, it can be dangerous to publish inconclusive or even ambiguous information that could alarm the general public.

Since 2001, the number of papers published in research journals has risen by 44%, but the number of retracted journals has also risen more than 15 fold. There were 22 retractions in 2001, but 339 in 2010.[ii] Science is based on trust, and most researchers accept findings published in peer-reviewed journals to be true. These scientific findings inspire other researchers to begin similar experiments or use the previously accepted studies within their own research. If one paper was found to be incorrect, then an entire field of work would come into doubt. Millions of dollars of private and government funding would go to waste, and, in the case of medicine, patients would be put at serious risk.[iii]

The problems in the scientific world lie in the ability of the scientists to correctly and impartially assemble and convey their scientific findings to the public in a comprehensive way. Through extensive research this Interactive Qualifying Project group has narrowed down this dilemma and identified five problem areas. The group has worked to offer solutions in these five topics.

The first of these five problem areas is linguistic or speech misinterpretation. This deals with English speech and the ambiguous terminology used in scientific presentations that cause confusion and misunderstanding amongst the public audience.

The problem of misinformation manifests itself in two ways. First is that the research and presentation could contain biased, improperly cited, or nonfactual information. Secondly, the public is not always presented with reliable and easily accessible sources regarding the topic of the presented research. Data gathered directly from the public then allows for comparison of these standards of information quality with the standards by which the public currently receives information.

The third problem area is scientific justification. As research is being presented, topics that always appear are the purpose and the justifications for the research that is being conducted. Scientific justification is concerned with the purpose of the research done by the professional scientists and engineers and its importance, relevance, and effect on the public. As the misinterpretation of scientific terminology is being explored, the public interpretation of the justifications of the scientists' research should also be explored. As with further exploring how the public interprets the scientific justifications, this can also be applied to scientists who strive to receive funding for future research. There is a limited amount of federal money budgeted to scientific research. Due to this fact, scientists should be aware of how to present their research proposals in a way that grant makers will be more likely to provide them with funding.

The fourth problem is public comprehension of science. For the purposes of this project, this area deals with the public's ability to understand and analyze data that are presented to them. If a scientist unknowingly presents his or her data in a format that members of the public are unable to understand, the public may become confused or mislead. This is a problem even if the scientist is able to adequately explain his or her results and conclusions, as members of the public will often receive news about scientific research second-hand from a news service rather than reading the original published research or going to a researcher's presentation. In this case, the member of the public may be seeing the researcher's charts and graphs out of context and with little or no explanation. Therefore, it is important that scientists are made aware of the public's ability to analyze data presented in a variety of fashions.

The last of these five problem areas is audience gauging. This area refers to knowing an audience's knowledge level of the subject matter and interest in the topic, in order to present scientific work in the most understandable and engaging way possible. Audience gauging encompasses the other four problem areas. For the purpose of this Interactive Qualifying Project, five groups have been chosen as "target audiences" that professionals, scientists, researchers, and engineers are most likely to present their information to. Basic demographics were taken into account when deciding upon the target audiences; the biggest factor being highest level of education. The five target audiences include: elementary school education level, high school education level and below, college student, graduate student, and individuals with professional or doctorate degrees.

Scientific writings and lectures continue to be inadequate. That being said, many of the topics written about in science are complex. It is still essential to relay the important information in an understandable manner. Furthermore, many scientists do not work towards gauging their audience correctly. A speaker or a writer must be able to adapt to their audience and portray their information in different ways to fit to the people sitting in the crowd, or reading their papers. Along with comprehending scientific means of communication comes the understanding of the numerous aspects of the grant and peer review processes, which are not known to the layperson. There have been many standards set by science foundations, such as the NSF, directing scientists and scientific writers on standards for publications. The layperson would not be aware of this. Within this project, information will be addressed to help set forth solutions to these five problem areas.

Goal of IQP

The goal of this IQP was to develop a “tool” in which scientists and the general public alike could utilize to better understand science, and the communication of it from one party to another. This project was started with the intent of taking these five specific objectives that were just mentioned, and making a website where we engaged each of these subjects in depth. Then they would be linked together to create a credible source of information to the public and scientists. The goals of each individual objective are listed below:

- Misinterpreted speech:
  - Create a list of a few select words and phrases to avoid using when conveying scientific information to the public.
  - Create a list of “key tips” to follow when preparing to share scientific information to the public.
  - Provide a bridge between scientific writing and language interpretation.
- Misinformation:
  - Establish a guide in presenting trustworthy resources that the general public can be referred to for additional information on the presented topic.
  - Give scientists information about what people know about available sources and their trustworthiness to help them in prompting proper resources to the public.
- Scientific justification:
  - Determine the reasoning behind the research done in academia and industry, and how it affects the public.
  - Determine how researchers receive grants.

- Public comprehension:
  - Determine how well the public can understand scientific data presented to them in a variety of forms.
- Audience gauging:
  - Determine five different audiences that the general public falls into.
  - Create a guide that will allow scientists and engineers to target one of the desired audiences and gauge their audience's interest in, and understanding of the subject matter based on research into the other four sections.

Project Overview

The project group decided to design an interactive website that scientists and engineers could use as a guide to prepare for presenting in front of different audiences. Creation of the website required extensive research into each of the five sections. Each group member was assigned one of the five areas to research, and to then develop that section of the website. Knowledge and insight was gained on the individual sections through researching preexisting databases, studies, and articles that provided background information on our sections. In order to have specific questions answered and gain more insight on the sections, structured interviews were conducted. A set of questions was asked to professional scientists. Our questions were chosen carefully so that they may not leading or create biases. Interviews were conducted in person and recorded, with permission, by various means such as Smart Pen, cellular phone, and cassette tape recorder. These interviews were conducted with doctors of biology and chemistry from University of Massachusetts Medical School, and the Massachusetts Institute of Technology, along with educators from the Museum of Science, Boston. Aside from interviews, surveys were also used. Using the new qualitative and quantitative data along with previous research the project was completed with the idea of presenting a website for general consumption.

From our research we have seen that nobody has comprised all of our five topics into one tool that can aid in communication and education of science. We will extend some of the research that has already been done, but in a more "science specific" manner. All of the sources we have identified in our project are very informative but have not set a standard as to what needs to be done for the problem at hand. We want to make a website that is readily accessible and, hopefully, at some point in time, necessary for all scientists to use so that they may be able to see what the general public actually understands and can consume. Along with Scientists using this website we want the public to be able to access this tool and gain scientific knowledge on correct sourcing and scientific linguistics. This website will include sections that show credible sources for the public to use when researching science. It will also include a section on general writing techniques that will help to reduce ambiguity in scientific writing, and a list of words in the English language that cause misinterpretation. Another section will be on audience gauging and how to speak to what audiences, then lastly a section that shows scientific words that the layman does not understand and needs to be further explained. We want this to make an impact on scientific writing and reduce the ambiguity and misinterpretation that comes with many scientists' writings.

1.3 Literature Review/ Background

In the following background section the group will reiterate the five problem areas and include background research within those areas.

1.3.1 Language Comprehension and Models of Sentence Processing

The first of the problem areas is linguistic misinterpretation. A large amount of research has been done on speech misinterpretation and how the general public perceives words and sentences that could be ambiguous. From there, research was done on how the human mind sees, and then translates sentences. In the next few pages critical research in language misinterpretation and understanding, along with hermeneutic and science education will be briefly shown and discussed.

Language can be looked at as different words that can trigger different interpretations. For a language to ultimately function as an effective medium of communication it must be finitely learnable. So therefore an assumption can be made that language is finitely learnable without teaching.[iv] Children are brought into a home that speaks a language of some sort. Due to the child hearing the language and becoming accustomed to the dialect around them, they eventually start to speak it. Over the past 3 decades many theories of language comprehension have been created to try to determine how people compose the meanings of sentences from individual words. Two different models of sentence processing were developed: 1) Garden Path Model (Ferreira & Clifton, 1986) and 2) Constraint Satisfaction Model (MacDonald, Pearlmutter, & Seidenberg). In the Garden Path Model the language processor initially computes a single syntactic analysis without consideration of context or plausibility. The Constraint Satisfaction theorists, in contrast, assume all syntactic analyses at once on the basis of all relevant sources of information. This raises the question of whether the meaning of a sentence is always the sum of its parts. "People have been observed to unconsciously normalize strange sentences to make them sensible" (Fillenbaum, 1974).[v] The Moses Illusion (Erickson & Mattison, 1981) depicts this concept well:

How many animals of each sort did Moses put on the Ark?

When people look at this sentence they tend to respond, "Two" instead of thinking about the presupposition behind the question (it was Noah who put two animals of each on the ark, not Moses). People also tend to overlook the anomaly in a sentence:

The authorities had to decide where to bury the survivors.

Another study was also conducted to examine whether sentence meaning can activate individual words so they are easier to understand:

> "*Language processing is not always compositional and the semantic representations that get computed are shallow and incomplete (rather than computing the structure to the fullest degree possible, the comprehension system just does enough to contend with the overall task at hand)"* (Duffy, Henderson, & Morris, 1989)

Participants in this study were asked to say aloud the last words in various sentences after completing each sentence.

1) *The boy watched the bartender serve the cocktails.*
2) *The boy saw the person liked the cocktails.*
3) *The boy who watched the bartender served the cocktails.*

On average the participants of the study took less time to say the last word in BIASED sentences like number 1 than they did in sentences like number 2. This showed that the word cocktails had been activated earlier in the sentences. Unexpectedly the times were as fast for sentences like 3 as they were for 1 even though the word bartender has no linguistic meaning or logic towards the word "cocktails."[vi]

Ferreira and Stacey have studied Misinterpretation of passive sentences closely A question that came from their research was: Are people tricked by simple but implausible passive sentences? (Ferreira and Stacey, 2000). Below is a list of sentences. Some are plausible and some are implausible.

1) *The man bit the dog.*
2) *The man was bitten by the dog.*
3) *The dog bit the man.*
4) *The dog was bitten by the man*.

Participants read sentences 1-4 and were asked to indicate whether the event described in each sentence was plausible. This seemed like a simple task, however the participants called passive sentences like sentence 4 plausible more than 25% of the time.

Along with some of the research that has been conducted in linguistics there has been a large amount of research done on scientific writing. There are words, terms, and phrases that have been identified by many institutions and scientists as either useless, or harmful to final scientific writings. The following information has been selectively chosen from the University of Arizona Biochemistry and Biophysics Department and Professor Mark E. Tischler's writings:

1.3.2 Word Usage in Scientific Writing

It is beneficial to use precise words when doing scientific writing. Simpler words are preferred by the layperson over complex words, just like simpler sentences are preferred over complex sentences. And when using examples it is also more interesting and believable to the public if **concrete** examples are used. Always aim for precision. The following sentences depict precise scientific writing. "*Because instead of ~~based on the fact that~~. For or to instead of ~~for the~~*

~~purpose of.~~ There were ~~several subjects~~ who ~~completed. It is suggested that~~ a relationship may exist. ~~A total of~~ n subjects. Four ~~different~~ groups. ~~Absolutely~~ essential. ~~Small~~ in size. In ~~close~~ proximity. ~~Very~~ close to zero. ~~Much~~ better. ~~Period~~ of time. Summarize ~~briefly.~~ The reason is ~~because. Also~~ included. Except ~~for.~~"

Aside from precision in scientific writing there are some examples below that can help make writing more beneficial.

Using generalizations in writing can make the reader lose interest. For example avoid saying SOME if you know exactly how many, or if it was one instance. Likewise do not say SUBJECT if you know what the subject is. Lastly avoid changing directions more than twice in a paragraph. For example using HOWEVER more than twice could annoy the reader or confuse them.[vii]

1.3.3 Hermeneutics in Science

> *"Scientific knowledge, like all knowledge, involves a disclosure (saying) of something to somebody. It deals with meanings that are social entities, embodied in language, altered or fulfilled in experience…"* (Crease, Robert; Hermeneutics in natural sciences: Introduction)

Hermeneutics is the study of interpretations of text. When looking at hermeneutics, most do not relate science with interpretation of text but recently there have been important publications of the two areas combined together. "We will see that there is a basis for a dialogue between hermeneutics and our current understanding of the natural and social sciences."[viii] Looking at information by Martin Eger in his paper titled: *Hermeneutics and Science Education: An Intro* we can form a good bridge between, language, and science.

> *"What if we focus our attention not on science as research but on science as a knowledge, as it faces us all as we first encounter it? Suppose we consider not the relation of humans to nature but relation to a particular science. In that case surely what they encounter is a language already in being—the language of that science. And this language before it is mastered is for everyone as remote as any the anthropologists have studied, since it too partitions "reality" in a way different from the language of the "life-world." …"*

Many educators today have realized that understanding science by its definitions is not enough. It must be understood as a separate language. Real world experiences are now being taught in classrooms and some teachers are even doing away with lectures.[ix]

Along with hermeneutics and science there has been research done on meaning realism. This states that if a project of any sort is completed and presented competently then the meaning should be retained properly and realistically. One author goes on to say that "Qualitative researchers have generally rejected the doctrine of meaning realism" (Quine 1980, Roth 1987). Meaning realism is a part of any project and the negligence of it by researchers is an "affirmation of the subjective stance of qualitative research."[x]

1.3.4 Source Evaluation

The second problem area is misinformation. In developing a tool to aid professional scientists and engineers in the presentation of their work to the public, it is necessary to ensure that the public does not receive faulty information both from the presentation and from other outlets regarding the topic. It is thus essential that the tool begins with a discussion of the validity of information. In addition to the researcher presenting the public with good additional resources it is crucial that the public is aware of what makes resources trustworthy and is able to find such sources. Research among existing literature will aid in discovering what types of resources are reliable.

The first question to be answered in establishing guidelines for the trustworthiness of any presented research is "what makes information valid?" The obvious and immediate answer most researchers would offer is that it is based on fact, which in science is determined through empirical analysis of data gathered through observation and experimentation. This definition however may not be so obviously sufficient to those who are not familiar with scientific research. Because everyone cannot directly explore this process and determine whether or not it is sufficient evidence for fact, standards for quality are developed through deliberation amongst those who can examine the research process and agree on its validity.

1.3.5 Peer Review Argument

The problem with this process is that much of the public does not know about the academic judgment procedures used in the publication and funding of research. Inquiries into the peer review process indicate that the standards to which research is held vary across disciplines. Analysis of methods used by review panels across various disciplines indicates that the dynamics of evaluative cultures is only partially understood by most of academia and minimally understood by the public.[xi] The confidential nature of the peer review process is considered to be a large factor to the public's lack of awareness of quality verification systems and some editorial staffs have experimented with public review systems.[xii] [xiii] Some of these experiments have offered new practices that may be useful in displaying the validity of a paper to its readers, such as *Biology Direct*'s policy of allowing an author to publish signed editorial comments along with the paper.[xiv]

There is however, a stronger tendency to keep editorial review processes the way they are. One of the largest surveys of authors and reviewers on the topic of peer review conducted by the organization “Sense About Science” entitled *Peer Review Survey 2009* found that 69% of researchers are satisfied with the current system, 30% of researchers believe the public understands the term ‘peer review’, and “58% percent of reviewers would be less likely to review if their signed report was published”.[xv] These figures indicate that the established standards for quality are sufficient to ensure quality among the academic community, yet this does not carry over to the public and it is unlikely that reviewers will support open peer review will bridge the gap.

Furthermore, experiments in open peer review have shown that there is not enough interest by both authors and reviewers to improve the effectiveness of the process.[xvi] There are however some alternative methods of quality check that have gained popularity for online publications. One method that has become most prominent in the field of computer science is for authors to display their work on their own websites before publication. Though readers have to gauge the quality of the paper themselves, there is information available on the site that signals credibility of the work such as the author’s résumé, previous published work, and lists of affiliations and grants.[xvii] There are also websites such as D-Lib Magazine that publish papers in this fashion that are not peer reviewed that have gained trust by support of established authors and expert who value the site’s timely manuscript reviews and open access to readers.[xviii]

1.3.6 Inaccurate Presentation

After research has been established as trustworthy, there are still obstacles in presenting it accurately to the public. One well researched phenomenon that contributes to the misinformation of the public is media logic, which is a term explaining editorial choices of production.[xix] In a society so heavily dependent on media, there is constant competition among journalists for public attention. This is detrimental to the presentation of research because the journalists and producers who work with the researcher control the production and aim it at attracting viewers.

This leads to researchers whose personality or research fits the productions media logic will get more media coverage and also that the journalist will use experts to legitimize their angle.[xx]

The researcher is then not able to present their findings straightforwardly, but must answer the questions asked by the journalist. This also can lead to faulty presentation of the information in that the journalist may put more focus on parts of the presentation that make for good media, and details important to the quality of the presentation such as background information or research methods may be omitted or overlooked. Media logic also governs the amount of time that a researcher has to present information during an audio or audiovisual production. The negative effect on information can be observed by a journalist's quote from an interview media logic researcher Ursula Plesner.[xxi]

> "You know, [the researcher] sighed when I posed stupid questions. He wanted to include ALL the details, and I said you cannot include all details, you have 20 minutes to explain these five things. But he could not live with this kind of science communication"

The producer and journalist pace the production based on getting good media material, whereas the researcher often needs to present a specific amount of information in a specific order.

Because of the brevity of scientific presentations in the media, they often inspire more than educate. The majority of the American public uses the internet at their primary source of scientific information.[xxii] When inspired public are looking for more information on the topic of a presentation and do not have the correct resources, there will still be misinformed on that topic. A research presentation aimed at preventing misinformation would be most effective by including references to good sources for the public to acquire further information on the topic. In recent years there has been significant increase in research of online source evaluation with an accompanying increase in reliable online sources of science.[xxiii] [xxiv]

1.3.7 Scientific Justifications: The Purpose of Scientific Research

The third problem area is scientific justification. When discussing scientific research and all the time and effort that scientists, engineers, and educators spend into their specific fields of research, it is easy for someone to begin to ask about the reasons that are backing the research in question. Why is it that NASA is spending billions of dollars to send the Curiosity rover to Mars? Why did we build the Large Hadron Collider, a facility that is seventeen miles in diameter that sits in between two bordering countries? There is always talk about the furthering of science and the breakthroughs that occur over time but there is always one big part of the conversation that is almost always discussed: The purpose and reasons for all the research.

It has been described that there are two possible theories on the reasons of scientific research. The first theory says that research is done just to satisfy the curiosity or not only the researcher but of those who finance the researcher. The second theory says that the research is both theoretical and practical. The theoretical part of the research arises from theoretical problems that stem from the practical problems that are being faced in the research in question.[xxv] With most of the scientific research today being a combination of both theories, both can be said to be described as hypothesis-driven research. This type of research involves the proposition of a hypothesis with only a limited amount of initial background evidence which leaves the research open to new discoveries.[xxvi] With the discovery end of the research open to multiple ends, it is possible to leave the research to either bring new information and understanding to the table but, it can also be designed to provide practical answers to problems have direct impact on human life.

In today's modern society, with the vast amount of various groups of scientists and engineers working around the clock in their specific fields of research, they all must have their justifications for the effort spent furthering their research.

1.3.8 Grants: The Funding that fuels Innovation

As scientists and engineers must all have some type of justification for the research they are conducting, there must also be a justification for the funding that is supplied to them in order for them to conduct such research. The most crucial part of a scientist's research is not even the research itself but ones acquisition of the funding necessary to begin. As there is not only a need for the ability to easily and efficiently communicate your scientific justifications to the general public, one must also be prepared to communicate those justifications in great detail to grant makers that can provide the necessary resources in order to even begin the research. The expenses of scientific research are not only paramount to how well the research succeeds or progresses but, it's certainly an aspect that cannot be taken lightly. The expenses can include anything between the salaries of the personnel required to work on the research to equipment, maintenance of said equipment, and the supplies needed in order to conduct the research. So where does this kind of money come from?

In 1950, The United States established the National Science Foundation (NSF) when they enacted the National Science Foundation Act as a means to "advance the national health, prosperity, welfare, and the secure the national defense."[xxvii] As of 2012, The U.S. budget included $7.033 billion dollars to the NSF in order to provide funding to various types of research.[xxviii] The NSF not only funds 20% of the research done at numerous colleges and universities, they have also spent over $2 billion on 727 different contractors over the past decade.[xxix] To name just a few, some of the NSF's biggest contractors include Raytheon Company, Compuware Corporation, and Info USA, Inc. with Raytheon given a sum of $ 908.5

million just over this past decade.[xxx] The NSF is also in the process of receiving an additional $340 million for the 2013 Fiscal Year.[xxxi] This funding helps with not only with the research and development of various contractors but it is also used towards graduate fellowships, science and math education reforms, and the protection of the Nation's information infrastructure.[xxxii]

With all of this government funding, how one receives a piece of these funds is a question that is always on the minds of scientists with a brand new idea.

1.3.9 Grant Writing: The First Step in Research

The process of obtaining funding for research can certainly be challenge as it is approximated that about 15% of the proposals, in the realm of engineering alone, that were considered "actionable" in the eyes of the NSF in the 2011 fiscal year were funded.[xxxiii] With this in mind, one must be certain of the process required by the NSF to even be considered for funding. The National Science Foundation (NSF) provides funding and grants for many research projects at colleges and universities. Some of its main goals are to increase the scientific literacy of U.S. citizens, invest in advanced facilities and instrumentation to expand the nation's research capability, support STEM (science, technology, engineering, and mathematics) research, and act as a main source of federal backing in fields like computer science, social sciences, and mathematics. In the 2010 fiscal year, the NSF had an annual budget of approximately $6.9 billion and funded nearly 20 percent of all federally supported basic research conducted at the nation's postsecondary educational institutes. [xxxiv]. The NSF gives a detailed approach of their proposal submission within their Grant Proposal Guide. They begin with descriptions of submission of letter of intent, a preliminary proposal, and then finally a full proposal. Focusing on the full proposal, they go into describing their requirements of their own formatting rubrics, cover sheets, a page including the qualifications of all parties involved with the grant writer, the budget proposal including a breakdown of the funding, and last but not least the actual objectives or the scientific research in question as well as its significance.[xxxv] This can be looked at as writing a paper that has to be fit to publish.

The question that comes to mind is with over 40,000 proposals being submitted to the NSF each year, how does that 75% get rejected and what mistakes should be avoided? Common mistakes that have occurred in the grant writing have come from a lack of clarity of the purpose of the research as well as the inability of showing why there is a reason of presenting existing literature and the reasons why the research should be further explored.[xxxvi] Where these mistakes involve some of the more vital aspects of the proposal itself, other mistakes occur elsewhere in the grant writing process. There had been instances where grant writers have applied for grants from the wrong organization and figured that due to just their publications on how much grant money they have and are willing to distribute, they have the idea to apply to said organization even though that grant money may be allotted for a completely different field of study. Other errors have occurred even in the math done in the proposal's requesting budget. Grant writers have overlooked calculations in the amount of money they are asking for in terms of which items are appropriate and if those items reflect real world costs. The proposal budget also needs to be realistic for the kind of research being done.[xxxvii] A study was done by a Dr. Ernest M. Allen, Chief of the Division of Research Grants at the National Institutes of Health which was published in 1960 listing a breakdown of the most common writing mistakes that have been seen in proposals. The study was done using 605 proposals that were rejected by the National Institutes of Health. With these percentages not out 100 percent to account for the possibility of proposals having multiple mistakes, the largest mistakes include an issue with the objective not likely to produce any new or useful information (33.1%), the proposed methods, tests, or procedures are unsuited for the proposed objective (34.7%), the objective lacks enough clarity to allow for enough evaluation (28.8%), and the researcher does not have enough experience or training for the proposed research (32.6%). Previously mentioned, there are also about 10% of those proposals that have unrealistic requests for resources.[xxxviii] It can be already concluded that grant proposals require much more time and effort that one make have previously thought.

1.3.10 "Public Understanding of Science"

The fourth problem area is public comprehension. In conducting our research, we found it difficult to find any sort of data that show that the public has difficulty understanding science. Most of our attempted research in this field led to an emerging, multi-disciplinary known as "Public Understanding of Science," or PUS. Though we could not find hard data to back up the claim that the public has difficulty understanding scientific research, evidence in support of this unfortunately abounds. From the scares over Y2K and supposed links between the MMR vaccine and Autism, or cell phones and brain cancer, to the continued and widespread belief in astrology, mysticism, and other pseudosciences, it seems clear that the relationship between scientists and the public is a bit rocky. The question is not whether the public understands science, as it clearly does not, but what can be done to improve the public's understanding of science.

PUS, being a rather new field, is still in the process of figuring itself out, so the question of improving science-public relations is taking a back seat to questions about which fields are relevant in PUS, what sorts of research methods should be used, and what the words "public," "understanding," and "science" mean in the context of PUS.[xxxix] Though the information we found on PUS was not immediately and directly useful, it certainly shows that there is a need for a tool such as ours.

1.3.11 Standardized Testing & Designing Our Survey

In order to empirically assess the need for such a tool, the collection of data by the use of a survey may give us more insight as to how much the general public actually knows and comprehends about science. As part of designing our survey, we looked at three different standardized tests for high-schoolers, the Connecticut Academic Performance Test (CAPT),[xl] the Massachusetts Comprehensive Assessment System (MCAS),[xli] and the ACT[xlii]. Both the CAPT and MCAS are typically taken by public school students in the 10th grade, and predominantly test for memorization of various facts, laws, formulae, and techniques. The ACT, however, is generally taken in the 11th or 12th grade, and asks questions involving reading comprehension, analyzing graphical data, and other broadly useful skills that can be applied to many subjects. We expected that if we tested for specific facts in specific subjects, most members of the public would have forgotten, misremembered, or never learned whatever we tested for. We also felt that, in order to get good results this way, we'd need to have several questions in a broad range of science topics, which would make our survey large and intimidating, causing a large drop in response rate. Therefore we designed our questions with the ACT in mind, trying to analyze our participants' comprehensive and analytical toolboxes, rather than their ability to remember arbitrary facts for long periods of time.

1.3.12 Audience Gauging and Design

The last of the five problem areas is audience gauging. Audience gauging is perhaps one of the most important factors in presenting scientific work. Knowing your audience and how to engage them are key in effectively conveying the information you are trying to present. A presentation to a researcher in the given field would be much more thorough and in depth than a presentation on the same topic given to a high school graduate. A central aspect of audience gauging is audience design, which refers to how presenters assemble their speech in a way that is understood by a particular audience.[xliii] In order to successfully engage in audience design, you must satisfy Grice's (1975) Cooperative Principle, meaning you must construct your presentation material in a manner that is "relevant to the topic at hand, suitably informative, truthful, and clear." [xliv] Different audiences have different characteristics. The audience's needs, wants, and expectations of a scientific presentation will vary from audience to audience. The part of Grice's cooperative principle that most applies to audience design is the *maxim of quantity* which is stated below:

> *1. Make your contribution as informative as is required (for the current purposes of the exchange).*
>
> *2. Do not make your contribution more informative than is required.*[xlv]

The *maxim of quantity* and the cooperative principle apply to the scientific arena. Scientists need to adjust their presentations when speaking to certain audiences. As with most public audiences, the average audience member will be the layperson which we will assume has only a basal level of knowledge of the material at hand.

1.3.13 Experts versus Novices

A major theme that reveals itself from the main focus of this IQP is the line of communication from an "expert," those in the scientific community and the "novices," the people that make up the general public. A study on references between experts and novices was conducted in 1987 at Stanford University by Ellen A. Isaacs and Herbert H. Clark. The study was published in *The Journal of Experimental Psychology* and titled *References in Conversation Between Experts and Novices*.

In conversation amongst two people, it is given that one person will be more knowledgeable on the subject matter than the other. Isaacs and Clark provided a good example in the introduction of their report of a typical situation between doctors and patients. The example is shown below.

> *"Doctors, for example, ordinarily assume their patients know little anatomy, pathology, and pharmacology, so they believe they must use lay terminology, such as heart attack instead of myocardial infarction, and couch their explanations in a form that non-physicians can understand. Yet the moment they discover their patient is also a doctor, they realize they can adjust their terminology and explanations to fit the broader common ground. Even when discrepancies in expertise are not as great, people have to adjust."*[xlvi]

In order for the discussion to proceed, a common ground must be established where the participants assess each other's level of expertise, determine mutual knowledge and beliefs, and accommodate accordingly for the conversation to continue. Partners in a conversation, as proposed by the study conducted at Stanford University, assess, supply, and acquire expertise to make referring more efficient and to accommodate each other's differences.

In this study on references in conversation between experts and novices, 32 pairs of Stanford University students were given two identical sets of 16 postcards containing images of common New York sites and were asked to arrange them in the same order on a four-by-four grid by describing them. The pairs were separated by a screen so that neither student could see the other. One student, the *director*, had postcards prearranged on the grid. The other student, the *matcher*, had the postcards randomly placed beside the grid. The director had to describe each postcard to the matcher who in turn had to place them in the correct order on the grid to match the director's grid. They were allowed to speak freely, and encouraged to do so to aid them in completing the grid correctly. After each round, the director's postcards were switched in position, and the matcher's cleared off the grid. This procedure was repeated for a total of six rounds. The directors and matchers were either New Yorkers or non-New Yorkers – an expert or a novice. The pairs did not know each other before hand and were not aware of whether their partners were from New York or not. There were four sets of eight pairs – expert directing expert, expert directing novice, novice directing expert, and novice directing novice. Experts had lived in New York for ten years and within three years of the study. Novices had never been to New York.

Experts referring to the landmarks in the postcards were able to use the bare proper names for the scenes, such as Rockefeller Center. In using the proper names of the landmarks, by implication, experts know the place by sight and expect the matcher to know it as well. The director's expertise is assumed when he or she uses proper names and the matcher's expertise is confirmed by accepting the reference. Experts can immediately use proper names, whereas novices are limited to descriptions until they learn the names of the places. Experts are also more likely to use place perspective when describing (from any vantage point) as opposed to novices who stuck mostly to picture perspective (what could be seen on the postcards). Below are a few exchanges from the study of expert directing expert, expert directing novice, and novice directing expert:

Expert-Expert:

Director. What's this? This is probably South Street Seaport.

Matcher. Yeup.

Director. You got it?

Matcher. Fulton Fish Market. Yeah.

Director. Right. Okay.

Expert-Novice:

Director. Okay, next is a Central Park scene. It's a take. Uh, it's fairly dark with a couple of trees in the foreground. And some benches.

Matcher, And it's real clear? The lake is real/clear?

Director. Yeah.

Matcher. Okay

Novice-Expert:

Director. Seventh is looking oat across the square, it looks like the middle of town, with a bunch of flags, international flags.

Matcher. Fine, Rockefeller Center.[xlvii]

From these exchanges, we can see that participants in a conversation follow the collaborative theory of reference, meaning that they draw on mutual beliefs and assumptions and confirm each other's understanding before moving on with the discussion. In the scientific arena, in which we are focusing our IQP, we will assume that the presenting professional, scientist, or engineer is the expert and his or her audience is novice in comparison. However, if a scientist is presenting to fellow colleagues, minor or perhaps no adjustments will have to be made for the audience because a certain level of expertise will have been assumed. Therefore, scientists must constantly assess and adjust their presentations for their audience to understand.

1.3.14 National Center for Education Statistics

A good measure of the public's scientific knowledge can be determined by examining past standardized test scores which can be found on the National Center for Education Statistics' (NCES) website. The NCES website gives a great idea of student performance in all academic areas in grades four, eight, and twelve. It also has some statistics on postsecondary education. Although the target audiences for this project include education levels higher than high school level, this is still a good resource for professionals to use, if presenting to high school students and below, to get a general idea of the students' understanding of certain subjects. Standardized tests such as the MCAS (for Massachusetts) and the SATs and ACTs cover math, reading, writing, and science. Science is the main focus for this IQP project. The NCES website has a tool that scientists can use to filter test statistics based on many credentials such as race/ethnicity, state, neighborhood, student interest in material, teacher credentials, and much more.

Thomas D. Snyder of the National Center for Education Statistics and Sally A. Dillow of the Education Statistics Services Institute and the American Institutes for Research published *Digest of Education Statistics 2011* in June 2012. The digest contains statistics for 2011 and projected statistics for 2012. Statistics for the science abilities of fourth, eighth, and twelfth graders in public and private schools assessed by the National Assessment of Education Progress (NAEP) are shown below.

> *"The 2009 assessment scores were based on a scale that ranged from 0 to 300. In 2009, White 4th-graders had a higher average science score (163) than did Black (127), Hispanic (131), Asian/Pacific Islander (160), and American Indian/Alaska Native (135) students (table 150). The average science score was higher for male 4th-graders (151) than for female 4th-graders (149). The pattern of differences in average science scores by students' race/ethnicity at grade 8 was similar to the pattern at grade 4. The average science score also was higher for male 8th-graders (152) than for female 8th-graders (148). At grade 12, average scores for White (159) and Asian/Pacific Islander (164) students were higher than*

the scores for Black (125), Hispanic (134), and American Indian/Alaska Native (144) students. The average science score in 2009 for male 12th-graders (153) was higher than the score for female 12th-graders (147).'[xlviii]

In June 2012, the NCES published *The Nation's Report Card: Science in Action: Hands-on and Interactive Computer Tasks From the 2009 Science Assessment*. The "nation's report card" evaluates the performance of fourth, eighth, and twelfth grade students on a science assessment that tests their knowledge of the subject matter as well as their reasoning skills on complex problems and their ability to apply science to real-world situations. The students are tested on how they perform scientific investigations, if they can draw valid conclusions, and how well they explain their results of two types of tasks: hands-on and interactive computer tasks. Results from the assessment show that in all three grades, White and Asian/Pacific Islander students did equally as well the hands-on and interactive computer tasks; but on the main science assessment, White students in grades four and eight scored higher. Also at grades four and eight, there was an achievement gap between higher and lower income families in both the interactive computer and hands-on tasks. It was also reported that students who did more hands-on activities in the classroom and whose teachers had higher credentials performed better on the assessment. These and other results show that demographics do play a role in the public's level of scientific knowledge.[xlix]

From the evaluation, the NCES made three key observations:

1. Students had a higher success rate with investigations containing limited sets data and with making direct observations of those data sets.

2. Investigations containing more variables were challenging to students because they required manipulation or strategic decision making in order to collect suitable data.
3. A higher percentage of students could choose correct conclusions from an investigation than students who could choose correct conclusions and explain their results as well.[l]

1.3.15 National Science Foundation

In light of the concept of audience gauging and the general public's understanding of science, studies have already been conducted about this topic. In January 2012, the National Science Board published *Science and Engineering Indicators 2012*. This overview highlights several major U.S. as well as international developments in science and technology. Chapter seven of this publication is titled *Science and Technology: Public Attitudes and Understanding*. This chapter focuses primarily on the public's opinion and comprehension of science.

The first section of chapter seven discusses information sources, interest, and involvement. Today, the internet has become a main source of information for Americans to use for learning about specific scientific issues. Interest in science and technology (S&T) has increased with the advancement of the field. 41% of Americans have reported to be "very interested" in S&T and 50% reported to be "moderately interested."[li] Learning outside of school at informal science institutions such as zoos and natural history museums is not uncommon, but is more likely among Americans with more formal education.

The second section of the chapter is subtitled: *Public Knowledge about S&T*. The National Science Board found that over the past decade levels of factual knowledge of science in the U.S. have been more stable than in previous decades, yet many Americans still answer incorrectly on multiple questions on the scientific inquiry process or basic factual knowledge of science. Levels of factual knowledge of science among Americans are positively related to the number of math and science courses they have taken as well as their formal education level. A greater understanding of the scientific inquiry process was observed in 2010.[lii]

The third section of Chapter seven discusses, in general, the public's attitude about science and technology. In 2010, the majority of Americans (69%) stated that the benefits of scientific research have outweighed the harmful results either strongly or slightly. In that same year 82% of Americans were supportive of the government funding basic research. Nearly three-quarters of Americans in 2009 stated that spending on basic scientific research, engineering, and technology was worth it in the long run.[liii] Americans believe that leaders in the science and engineering fields should be influential in decisions about science-related public policy issues such as stem cell research, genetically modified foods, global climate change, and nuclear power.

The final section in this chapter of *Science and Engineering Indicators 2012* focuses on the public's attitude in regards to specific science and technology issues such as environmental and energy issues, stem cell research, and nanotechnology. According to many Americans, the government does not spend enough on the development of alternative energy sources, and a majority favor having incentives for the use of solar and other alternative energy sources. 62% of Americans favored embryonic stem cell research in 2010, which has always been a hot button issue. 71% favored stem cell research not involving human embryos and over 75% opposed human cloning. Even though funding of nanotechnology has increased as well as the number of products on the market that use it, Americans are still unfamiliar with the science.[liv]

1.3.16 Informal Education

As technology progresses further as time goes on, the public is forever trailing and it can be very difficult to properly educate the general public. One method of combating this is called informal education. Informal education is any learning that takes place outside of a formal learning institution such as a high school, college, or university. Informal education can happen through conversation, talking, listening, and observing others. It occurs through exploring and expanding your experiences and can happen anywhere at any time. Quite often informal education happens among groups of people. There are many informal education institutions such as zoos and natural history museums where people can go to broaden their knowledge in a numerous areas within art, history, and science.

Mark K. Smith, the Rank Research Fellow and Tutor at the YMCA George Williams College, London, and Tony Jeffs, a member of the Community and Youth Work Studies Unit, Department of Sociology and Social Policy at the University of Durham, have done research in the fields of informal education, social pedagogy, and community learning. "They focus on informal education as a spontaneous process of helping people to learn."[lv] Informal education institutions, such as museums, hire education associates and informal educators to encourage the public to engage in learning outside of schools. They do this by presenting the work of others (professionals in the field, scientists, and engineers) to the public in an intriguing manner. When professionals, scientists, and engineers are planning a presentation for an audience, they can refer to how institutions like museums present to the public when gauging their audiences.

Informalscience.org is an online resource and community "for informal learning projects, research, and evaluation"[lvi]. The website contains many sources of information on informal education and audiences such as conferences, hearings, dissertations, journal articles, and projects. One such project is the Fusion Science Theater National Training and Dissemination Program. The lead organization on this project is Madison Area Technical College, and is working "in collaboration with the Institute for Chemical Education at the University of

Wisconsin-Madison, the American Chemical Society (ACS) and area science centers and museums will create a national program to disseminate the FST model which directly engages children in playful, participatory, and inquiry-based science learning of chemistry and physics topics."[lvii] There are two target audiences for this program. The primary being children between the ages of four and eleven and the secondary is a professional audience consisting of undergraduate chemistry students, formal and informal educators, and faculty. The project's website, www.FusionScienceTheater.org is "home of new, innovative, and highly effective ways to teach children science"[lviii]. Fusion Science Theater (FST) performs two types of shows: Science Concept Investigation Show (SCI) and SCI Demos. FST trains groups of five to ten to perform and specific show. The shows can be performed by members of a community for their local audiences. "FST shows are designed to teach accurate, age-appropriate science methodology, content, and/or applications to children in informal settings."[lix]

There are many resources and projects being implemented nationally to positively contribute to informal education, particularly in the science field. One such resource is the Informal Science Education Evidence Wiki headed by the Center for Advancement of Informal Science Education (CAISE). The ISE evidence wiki "exists to support a public discussion of the case for informal science, technology, engineering, and math (STEM) education. The goal is to provide easy to read summaries of evidence that characterize the benefits and outcomes of ISE experiences".[lx] The contents of the ISE evidence wiki include, but are not limited to: afterschool and youth programs, broadcast media, cyberlearning and gaming, public programs, and school programs. CAISE does not only wish to reach out to children with informal science education, but to adults as well. Informal science education encompasses all members of the public, not just school children. Other projects include AISL and Living Lab. AISL, Advancing Informal STEM

Learning, is a program initiative preparing to launch in 2013 and is headed by the National Science Foundation. The synopsis of the program is shown below.

> *The **Advancing Informal STEM Learning** program invests in research and development of innovative and field-advancing out-of-school STEM learning and emerging STEM learning environments.*
>
> *The name of the program has changed from Informal Science Education (ISE) to Advancing Informal STEM Learning (AISL). AISL better emphasizes the priorities of the solicitation and the changes at NSF:*
>
> *a. Advancing - This emphasizes that AISL seeks innovative projects that advance the field and that requests need to go beyond just proposing a new exhibit, program or film.*
>
> *b. Informal - This continues to emphasize that the program is interested in out-of-school learning that makes learning Lifelong, Life Wide (occurring across multiple venues) and Life Deep (occurring at different levels of complexity).*
>
> *c. STEM - This recognizes that the program is not just focused on science, but all of STEM.*
>
> *d. Learning - This term is more appropriate than "education" based on what we know on how people learn. Also, "learning" is more connected with what people do for themselves, compared to "education" which is perceived as something that is done to them.*[lxi]

Living Lab is a program where social science researchers conduct research on the exhibit floors of museums and get trained on science communication by education staff. One goal of Living Lab is to break down barriers between scientists and the public. In order to do this, the National Living Lab Initiative plans to team up with informal science educators and researchers and assist them in their efforts to increase public awareness, understanding, and engagement in the scientific study of child development and learning.[lxii]

Informal educators at museums prepare presentations for the general public, or "everybody." The issue with preparing a presentation for "everybody" is that no two people are the same. People fall into different groups depending education level, understanding of the material, vested interest in the topic, etc. Thus, the “first commandment” of communications is to know your audience. This IQP strives to aid professionals, scientists, and engineers in gauging their audience, just as informal educators do in museums. Marilyn G. Hood of Hood Associates in Columbus, Ohio was a researcher, writer, and editor at a major historical society museum in the 1960’s and ‘70’s. Hood wrote a short paper titled *Significant Issue in Museum Audience Research*, in which she discusses several problems arising from not knowing your audience. She writes, “Without the recipient of the message being the focus of the message, the communication is likely to go astray.” Hood goes on to say that although demographics and participation patterns have been the main pillar of many museum audience studies, they only describe “factual characteristics of people” and don’t take into account personalities and reasons for attending or not attending museums. Hood instead looks at psychographics – “people's values, opinions, attitudes, interests, concept of self, social interaction behavior, expectations, satisfactions, goals, activities, group memberships, social position, and consumption behavior.”[lxiii] People like to feel a sense of belonging and like to know that people care. The same applies when they visit a museum. What Hood got out of her research was that “everybody is a somebody at the museum”[lxiv], and in order to for museums to show that to the public they must ensure that everyone counts and that they care. For professionals, scientists, and engineers, their audience will be more likely to respond to their presentations in a positive way if they show a vested interest in their audience.

2. Methodology

2.1 Interview Methodology

Our Interactive Qualifying Project group chose to interview select faculty members of MIT and UMass Medical School. This was done to gain knowledge on the scientists thought process on our topics so that we may evaluate and compare these qualitative results with other interviews produced with members of the Science museum, Boston. Below are the interview questions.

Interview Questions

1) How would you describe your research or study?
2) To what audience would you say that you were describing your lab study to?
3) Now would you mind telling me how you would describe your research to an average person with high school level science knowledge (the average man)?
4) How would you describe your study to a fellow ________ scientist? Would you change not just the scientific wording but also the English vocabulary within your explanation?
5) As a scientist I understand that research sometimes is only done to help benefit other research or to better understand a small portion of a bigger picture, BUT how would you justify to the common man that your research is beneficial to society?
6) Are there any words in the English language that you try to avoid when writing grants, or publications?
    a. Was there a certain kind of wording or phrasing that you had to use while writing your research proposal? Were there particular topics that you had to pay specific attention to in order to receive the attention of the grant maker?

Question one was asked to gather a general overview of the scientists study and to see if the scientist would consider what audience they were speaking too. Question two was chosen to see if the scientist believed that gauging an audience is important. Question three was selected to see how the scientist would change their overview of the study if they were asked to explain to the layperson. Question four had served two purposes. This question was asked to see if this scientist believed that another fellow doctor would be given the same information or different information than what the first or third blurb described. It was also chosen to see if the scientists would be able to communicate well to the public what is beneficial about their project(s). It is important to be able to explain this information to people even though it may be aggravating for the scientist. Finally, question five was asked so that the views of different scientists could be compared and comparisons could be established between words, phrases, and assumptions that each of the scientists made.

The group also chose to interview members of a museum. Museums hire a team of individuals known as education associates who specialize in informal education and presenting the scientific work of others to the public. Their job is to engage the public in science and help them understand it. The Museum of Science, Boston was chosen as the museum to conduct the interviews. The set of questions selected to be asked focused mainly on audience gauging and misinterpreted speech. The questions are shown below.

Interview Questions for Museum of Science, Boston

1) How do you gauge your audience?
2) Is there a set of rules and guidelines you follow?

3) Has your research and evaluation team studied audience gauging and studies on the topic? Where can we find these studies?
4) If a museum visitor asked you to explain these 3 blurbs to them, how would you simplify them?
5) When training to become and educator at the museum of science what words of phrases from the English language aside from science terms were you told to avoid?
6) In your experiences do you think scientists do a good job conveying their information to the public in a straightforward and unambiguous manner?

Questions one through three were asked to find out the kinds of procedures and guidelines presenters follow when gauging an audience in a museum setting. Question four was asked to see what the educators thought of the blurbs from the scientists. Question five was chosen to see if there was any overlap with words and phrases given by scientists and then the educators. Finally, question six was selected to see if the educators believed from their experiences scientists did a good job conveying their info to the public.

As this IQP's goal is to develop a tool to be used by professionals in the scientific community to convey information about their achievements and to just talk in general about the research they are doing with the public, a key application of said tool will be to also the questions that most people will quickly come to ask as they read or hear about scientific advancements. "Why? What is the purpose of this research? How does this research affect me?" These questions are simple but usually come with not so simple answers. Answering those questions is where the relevant problem lies. We can give them the answers but as we dive into the answer, we run into the problem of how much of the answer will they understand and what may be misunderstood or misinterpreted. So how do we make sure that we get the points across about why people spend their lives dedicated to such research? There is not only the misinterpretation of information as to how the public perceive our reasons for why we do our research but, what kind of research gets funding. There is only so much research that can be done out there since there is a limited amount of funding. So how do scientists get their funding and how do others never get the chance to start?

To collect this kind of data, a good place to start is to have conversations with professionals in both industry and academia and not only talk about the type of research/work that they do but, to also see how they would explain their reasons for doing such work. It would also be a good start to collect information about the experiences they had with asking and receiving grants in order to fund their research. This way, it would be good for not only themselves but for other researchers to have a better chance to not only express the "why" but also the" how" in terms of their research.

Our Interactive Qualifying Project group chose to interview select employees of the Medicinal Chemistry Research and Development Department of a Large Pharmaceutical Company whose name will remain anonymous. This was done to gain knowledge on the scientists thought process on our topics so that we may evaluate and compare these qualitative results with other interviews produced with members of the realm of academia. Below are the interview questions.

Interview Questions for the Industrial Researchers

1) What kind of research are you conducting in your field of science?

2) What made you decide on devoting the time and effort on this particular field of research?
3) How is this type of research significant either to you or to others in your field of science?
4) Do you feel that the general public can understand your reasons for why you do your research? If not, how would you describe your reasons in order to for the general public to better understand you?
5) Have you had any experience writing research proposals for grants before? In industry, is there a similar process for the receiving of funding like how in academia one requests funding by grants?

This series of questions should allow us to get the answers needed to better guide other researchers to be more successful with not only their communication of their reasons but also allow them to have a better chance of receiving their grants.

The first question allows the researcher to get into the feel of their research so we have a basis of context to talk about as the next series of questions are being discussed and answered. This question may be answered quite vaguely do to the nature of the industrial scientists as they are not able to discuss the specifics of the kind of research that they are conducting. However, depending on the way this question is answered, the vagueness of the answer may prove to be beneficial to the better understanding of their research to the general public. They are being forced to explain the work they do without giving away the specifics of what it is that they do, which sounds like the basis of the initial conversation to the question. Question two is the meat of the first goal in which allows us to hear what the researcher has to say about his/her reason(s) for doing such research. Even though the basis of this interview is discussed beforehand, this question allows us to see where the researcher is in terms of how they describe one self and their reasons backing their research. Number three and four now puts the researcher into a line of questioning that makes them thing how exactly is there research important to other people rather than just themselves, by having them think how the research affects either others researchers or the general public. Question five is dependent on the answer to question four. It allows the researcher to self evaluate and determine by themselves if they think that the common person has enough "common" science background to understand what they are doing and why they are committed to such research.

Question five is relevant to the side of grant writing. Due to the unique nature of their employment in a private company, they must receive their monetary resources in some other fashion, from within the company. Question five allows us to see if there is a comparable method for the researchers in industry to receive their resources just like the research scientists in the realm of academia.

2.2 Survey Methodology

Our project group also designed a survey to be taken by the general public. We designed twenty-eight questions in total that would help gather data on audience gauging, public comprehension, misinterpreted speech, and misinformation. The survey was created on surveymonkey.com and is shown on the next page. We distributed the survey via a web link and email.

Many different factors contributed to the formation of the survey and the parameters that went along with this form of information retrieval. The most important point to take into consideration when trying to gather information from the public is to ask oneself, "Why am I choosing this tool to gather information?" A survey was chosen because of its ability to gather a high response rate over a broad demographic. A reasonable, yet representative sample size had to be chosen. 200 was a reasonable sample size (n=200) mainly because of time constraints with our survey. Other factors that went into choosing this sample size were: anticipated response rates, difficulty of survey, and method of distribution. Two of the problems encountered when creating our survey were: money, and distribution to broad demographics. The website that was used to create and distribute the survey was surverymonkey.com. This website required an annual fee to randomly distribute this survey to the public, which could not be paid by the members of the IQP group. Therefore the demographical distribution of the survey leans more towards the Caucasian race. The survey is shown in Appendix A.

Questions one through nine are demographic questions and were used to categorize the data. These questions played a key role in the audience gauging section of the website. The demographic questions allowed us to correlate people's scientific knowledge level based on location, neighborhood, economic status, age, education, etc. Questions ten through seventeen address public comprehension. The primary goal of the public comprehension section of the project was to determine how well the public could understand scientific data presented to them in a variety of forms. Then the group could convey this information to scientists as part of the implementation of the final tool. To do this, members of the public were asked to analyze and interpret several types of graphs as a part of the survey.

Trends were analyzed in the survey data, both overall and across a variety of demographics, in order to determine whether certain groups had better comprehension than others. This data was also used for the audience gauging section as well. The graphs used for our survey were a line graph charting different-colored marble sales over time, one pie chart depicting percentages of total marble sales by color for two different months, and a bar graph showing average marble sales with error bars. These graphs were chosen because it was expected that they would represent three distinct levels of interpretive ability. It was expected for the vast majority of people to be able to correctly read and interpret the line graph, most people to be able to understand the pie charts, but fewer people to know what the error bars on the bar graph represent. Each of the questions about the graphs addressed a specific skill that was evaluated. The questions for the line graph ask our survey participants to recognize linear trends in data. Specifically, we asked them to predict future values for two colors of marbles, one of which varies randomly, the other of which follows a clear, linear trend. Participants who respond with anticipated values for the question about the randomly varying color and participants who respond with incorrect answers or "cannot be determined" for the color with the clear trend are unable to identify trends in line graphs. With the pie charts, it was asked of the participants to determine which month had better purple marble sales without telling them anything about the number of marbles sold each month. Though this is impossible to determine, the percentage of purple marble sales is different between the two months, and we expect this to confuse some people, causing them to choose the answer saying that the month with the larger percentage sold more purple marbles.

Finally, there was a bar graph with error bars. The first question for this graph asked which color of marble sold best overall. Though the answer for this one was Red, as it has the highest average, it was expected that some people to choose Green because its error bar extends the highest. The second question asked which color had the most sales in a single month. The answer here is Green, but again, it was expected that many people would not understand how to read the error bars. These questions offered the group the ability to analyze everything just mentioned but the underlying theme that was evaluated in these questions was our respondents' ability to understand and properly analyze data presented in common graphical formats.

Questions eighteen through twenty-four focused primarily on the misinterpreted speech section. These questions tested the general public's ability to understand what was being said in excerpts from a source that was supposed to be at the layperson's level of knowledge. People would generally fall into four different categories—1) Accurate 2) Broad 3) Incorrect 4) In the Middle. In questions eighteen through twenty-two tested was the people's reaction to the following words, terms, or phrases respectively: "apparent," "a new analysis," "over time," "debilitating," and "was linked to." In question twenty-three what was being tested was how people would react to the word "ascertain" and because of the confusion when the author actually described properties. We tested to see if people realize that the author contradicted himself by saying that it would take time to determine with certainty the properties of the particle, but also going on to describe important properties. It was predicted that question twenty-three would stray away from four "stereotypes" of people. There would be two options of In the Middle, one option of Accurate, and one option of Incorrect. Finally, in question twenty-four tested was the people's reaction to the terms "channel," "sensitive," and "conclusive."

Questions twenty-five through twenty-seven addressed the misinformation section. Question 25 was intended to see if people knew to recognize a scientific journal (and the paper published in it) is a peer reviewed research paper. Those who answered (a) recognize *Science* and *Nature* as scientific journals, either guessing by the italics, or actual knowledge of their existence. This excerpt was chosen because those are two of the most recognizable names of scientific journals for non-scientists. The second article did cite peer-reviewed papers, but specifically chosen was an excerpt that didn't include their explicit mention to contrast the explicit mention of *Science* and *Nature*. It is difficult to extract whether people definitely know or do not know what peer-review is, but those who chose (a) were at the very least capable of connecting the term peer review with the concept of a paper published in one of the journals. If someone had no idea what peer review meant, there would be only a 25% chance using a random guess (the minimum possible in a 4 answer question) that they selected the option that indicates association of the term "peer review" with the works cited in the journals.

Question 25 refers to two excerpts, but the answers refer to either excerpt, both, or neither, which allows for some overlap in the meaning of a participants response. For example, the two answers "Excerpt I" and "Both" refer to Excerpt I as a selected response to the question, but in different ways (exclusively or not exclusively). The information that needs to be extracted from question 25 is whether or not a participant has knowledge of what sources have undergone the peer review process for publication; therefore the statistics that give this information are not only each response count but some selected combinations of response counts. Some of the statements about a participant's knowledge based on their question answer can only be shown to be true from statistics formed by sets of participants that are not simply all of the participants who chose a specific answer. Statistics are therefore done on sets of participants that have been shown to be equivalent to the set of participants who are referring to an excerpt in the same way (exclusively, not exclusively, or not at all).

Survey Question 25 Experiment

Given two excerpts briefly describing recent scientific research, a participant chooses one of the four responses (a), (b), (c), (d) to question (1) shown above. Results will determine the experimental probability of each response being selected and of statements derived from the responses and questions being true.

Let:

- $n = 136$ be the sample size of the surveyed population
- S be the sample space consisting of the four responses as elements
- The following four statements be measured events, and the events themselves as well as the union of any two or three of them be possible subsets of the sample space.

  Event A: The participant selected option (a) to question 25 of the survey.
  Event B: The participant selected option (b) to question 25 of the survey.
  Event C: The participant selected option (c) to question 25 of the survey.
  Event D: The participant selected option (d) to question 25 of the survey.
- *a, b, c,* and *d* be: the number of occurrences of each event, respectively.
- Statement X be: The participant considers research whose source was a paper published in *Science* or *Nature* to be peer reviewed research.
- Statement Y be: The participant considered research whose source was unmentioned to be peer reviewed research.

The following statements are deduced from the meaning of survey question 25 and the availability and content of information concerning sources in each excerpt as well as the response options' relation to the excerpts.

i. Event A is materially equivalent to Statement X and the negation of statement Y
ii. Event B is materially equivalent to Statement Y and the negation of statement X
iii. Event C is materially equivalent to Statement X and Statement Y
iv. Event D is materially equivalent to the negation of Statement X and the negation of Statement Y

The following statements are derived from the above statements.

$A \vee C \Leftrightarrow (X \wedge \neg Y) \vee (X \wedge Y)$ by substitution for A and C

$A \vee C \Leftrightarrow X \wedge (\neg Y \vee Y)$ by distributivity

$(\neg Y \vee Y)$ is a tautology and truth value is of the above statement is preserved with its omission

$$\therefore \mathbf{A} \vee \mathbf{C} \Leftrightarrow \mathbf{X}$$

v. The union of Event A and Event C is materially equivalent to Statement X

$B \vee C \Leftrightarrow (Y \wedge \neg X) \vee (X \wedge Y)$ by substitution for A and C by Statements ii. and iii.

$B \vee C \Leftrightarrow Y \wedge (\neg X \vee X)$ by distributivity

$(\neg X \vee X)$ is a tautology and truth value is of the above statement is preserved with its omission

$$\therefore \mathbf{B} \vee \mathbf{C} \Leftrightarrow \mathbf{Y}$$

vi. The union of Event B and Event C is materially equivalent to Statement Y

All materially equivalent statements, whether they are derived or experimentally measured events, must have equal probabilities of being true.

Because a participant may only choose one response there can be no intersection of the events defined above, thus the probability of the union of any events is the sum of their individual probabilities. The empty set is not a valid event the sample space itself is not a valid event, thus the probability *p(X)* of any event satisfies $0 > p > 1$.

Question 26 aimed to discover whether or not people knew about panels in academic criticism. Here each false option was aimed to deter those who do not. The word colleague is similar enough to the word peer to draw answers from those who would use the language as a hint. The name Herfst was the first name used in the excerpt and was intended to seem like a valid option as a peer but obviously the author of the paper and not the referee to any reader who knew about panels. The last answer was intended to draw those who did not even recognize what the question is asking.

While question 26 primarily looks for the amount of participants who answered the question correctly, it also yields a set of participants who interpret the question in a specific way that is not reflected by the response counts alone but a combination of two. This set of participants also shows some information about the participant's knowledge of the sources mentioned in the excerpt to be true.

Survey Question 26 Experiment

Given the same two excerpts as used for survey question 25, a participant chooses one of four answers. Results determine the fraction of the sample that chose the most accurate answer (b).

Let:

- n = 136 be the sample size of the surveyed population
- S be the sample space consisting of the four responses as elements
- The following four statements be measured events, and the events themselves as well as the union of any two or three of them be possible subsets of the sample space.

Event A: The participant selected option (a) to question 26 of the survey.

Event B: The participant selected option (b) to question 26 of the survey.

Event C: The participant selected option (c) to question 26 of the survey.

Event D: The participant selected option (d) to question 26 of the survey.

- *a, b, c,* and *d* be: the number of occurrences of each event, respectively.

The experimental probability of Event B represents the probability that a participant answered the question correctly with (b). Response (a) and response (d) are names of authors of the research papers mentioned in the first excerpt. Another relevant subset of the sample space is then the union of Event A and Event D with an experimental probability representing the probability that a participant selected a response that was the name of an author. Because a participant can only select one answer there can be no intersection of events and the probability of the union of any events is the sum of their individual probabilities and the negation of any event(s) is equivalent to the union of the other event(s).

Question 27 was intended to see if people trusted research that they have already established as having been judged for quality in the peer review process and published by a respected source. This was done by reference to the data from question 25, which is why it is similar in form and has the same answers in the same order. The relevant data is not how many people answered with each option, but how many people's answers were the same for question 25 and question 27. This statistic shows the percentage of people that trusted an article because of its citations without explicitly asking them and making them aware that the reason they trusted it may be they trusted its citations.

Question 27 again had to include statistics on combinations of response counts to equate these sets of participants with participants who interpreted the questions in the same way.

Survey Question 27 Experiment

Given the same two excerpts as used for survey question 25, a participant chooses one of four answers. Results determine the fraction of the sample that chose the same answer for Survey Question 25 and Survey Question 27.

Let:

- $n = 135$ be the sample size of the surveyed population
- S be the sample space consisting of the four responses as elements
- The following five statements be measured events, and the events themselves as well as the union of any two or three of them be possible subsets of the sample space.

  Event A: The participant selected option (a) to question 25 and question 27.

  Event B: The participant selected option (b) to question 25 and question 27.

  Event C: The participant selected option (c) to question 25 and question 27.

  Event D: The participant selected option (d) to question 25 and question 27.

  Event E: The participant did not select the same option to question 25 and question 27.

- a, b, c, d and e be: the number of occurrences of each event, respectively.

3. Analysis and Results

In order to compare the information scientists believe the general public understands and the information that the general public actually understands qualitative and quantitative data was evaluated by means of surveys and interviews. The comparison and analysis will be shown along with the qualitative and quantitative data.

3.1 Linguistic Misinterpretation Interviews

The interview questions will be reiterated as to provide the needed background for the results to the answers given by the scientists. The interviews were conducted in the offices of the scientists or over the phone. None of the scientist's names will be used. The interviews conducted with these scientists are shown in Appendix B.

The interviews conducted with the scientists from the University of Massachusetts Medical School and Massachusetts Institute of Technology all served a similar purpose in the eventual goal of the project. These questions were useful in being able to refer to, and then building upon them further in interviews with educators. They were then used to create a relationship with the survey questions.

The questions that were asked to the scientists were carefully worded as to avoid any bias or questioning from the scientists. The first question was asked as a way to ease into the interview and not intimidate the person being interviewed. Asking a scientist to describe their research or study is a fairly trivial request and any scientist should be able to extrapolate on that question. Now what we were trying to do with that question was to see how the scientist would adapt to the person that they were speaking too or if they would question the audience they were gauging. The scientists all conveyed their information well to the group, but if we did not have undergraduate level knowledge in biology it would have been fairly difficult to understand what was being said. This first question was a good precursor to the second question where we asked to what audience they were describing their study too. Here, we were evaluating the scientist's standard as to what the general public understands. Most of the scientists said that they were describing their study to an audience with knowledge in biology and/or virology. The next question went more in depth. The scientist was asked to actually describe their research to the layperson. This question was interesting because most of the scientists being interviewed did a good job adapting their explanations but one of the 4 scientists did not believe in changing their explanation. This question evaluated exactly how a scientist would transform their explanation to a given audience. Next, we asked how they would describe their study to a fellow scientist. This question was placed into the interview so we could see if they would change their answers even for scientists who may or may not specialize in topics similar to the person being interviewed. Three of the four scientists referred back to the first explanation or constructed a more in depth explanation as a sufficient way of describing their study to a fellow scientist. The one scientist who did not do this stated that he/she would have said something that was in between the laypersons explanation and first explanation, because one never knows what the scientist is an expert in. The next question was one that most scientists do not like to answer. How does you're your research effect society? Now most scientists do not like this question because most research is done to help better other research. In a sense, the majority of research is the small portion of a larger picture. Even though this is not a question that scientists liked to answer it had to be addressed. The public likes to know why their tax money is used in research and what it will help with in the future. Surprisingly all of the scientists answered this question well. The final question asked: what words are avoided from the English language when writing grants and publications. This was a very direct question just to see what the scientists believed were words that would not suffice in both grants and publications.

After analyzing all of the answers provided to these questions by the four scientists certain key components needed to be mentioned: The scientists did not pay much attention to actual English linguistics when answering questions. Some did more than others, but the main point that the scientists changed was the scientific language and not the usage of English vocabulary words within their descriptions. When the scientists were asked the question:" Now would you mind telling me how you would describe your research to an average person just walking down the street with high school level science knowledge (the average man)?" Scientists would immediately refer to the science linguistics but never look to change the English linguistics associated with the science. Science, in itself is its own language. If we look at the English language it is a "convenient idealization over a community of speakers" and the English language is similar enough so that it is understandable between those who are fluent in the language.[lxv] So if science is its own language, how can people who are not fluent be expected to comprehend it? Many words have alternate definitions in the language of science than they do to those known to the "life-world" language. A second key point to mention from the interviews was the lack of belief of some scientists to change the way their study was described to different audiences. An important aspect of conveying any source of scientific information is being able to adapt to the audience. When one scientist was asked the question: "To what audience would you say that you were describing your lab study too?" they replied by saying "Everyone. Science is timeless." This cannot be the mentality from a scientist. If every study or scientific finding was described to everyone in the same way then there would be many different interpretations from different groups. Also the museum educators mentioned that from their experiences that many scientists do not want to change the way they speak to different audiences.

The next set of interviews was conducted at the Museum of Science, Boston on 10 July 2012. The first interview included responses from two education associates, or "educators," of the Museum of Science, Boston. The second interview was with a program manager for research and evaluation at the museum who does educational research and program evaluations. Education associates at the museum work mostly on creating presentations and exhibits for the public rather than on their own research. They make the research and work of other scientists and researchers presentable for the public. It is important to note that the Museum of Science, Boston is considered a credible source of information. The museum's goal is to inspire the public to want to learn more. The museum accomplishes this through informal education. Informal education is learning outside of a school setting. The first three questions asked to these interviewees were talked about in a more conversational than interview style. The reason the educators were interviewed was to gain knowledge from professionals about what they see on a daily basis spanning from the average person walking around the museum, all the way to a Nobel Prize winner in Science. These educators were trained to speak to a lay audience but to also maintain scientific validity and inspire people to the world of science. The approach taken in the second half of the interviews was to build off of the answers given by the scientists in the previous section. Again, the questions will be reiterated to help better explain the answers given by the educators. No names will be used.

The first three questions asked had to do specifically with audience gauging. They were asked about how they gauged their audiences, what types of guidelines they follow, and if there had been studies done on audience gauging that the group could reference. A lot of useful information was given to the group on guidelines to follow when presenting scientific information. The fourth question asked to the educators was strictly for the educators to analyze the way in which the scientists described their studies in the previous interviews. The educators mainly looked at the scientific linguistics presented in the description. Some of it was still complex and they believed it needed to be written in a more simple fashion. The fifth question was asked not only to see what words the educators were trained to avoid when speaking to the public, but also to see what kind of techniques they were taught when training to become science educators. They presented us with techniques like the planning pyramid and the story arch, which will be described later. The group wanted to see how professionals are taught to convey complex scientific information to the public in an understandable manner. The sixth question was straightforward and was asked so that we may see what an individual in-between the layperson and a research scientist thought of the job that is being done by researchers in conveying their research and studies to the public. The educator's reaction was not one that favored the scientists. They both believed that scientists were NOT doing a good job.

The key components taken from these interviews were:

1. They believe that scientists need to have a preconceived knowledge of what audience they are speaking or writing too.
2. It is very important to make what is being written or spoken about interesting to the audience. A good way to approach this is to familiarize people with the topic at hand i.e. if speaking about diabetes start off with "diabetes is a global disease that is only expanding, you all probably know somebody who suffers from diabetes." This way people are instantly lured into what is being spoken about.
3. This relates with the second point. When speaking to a crowd or writing a scientific piece it is helpful to convey the information through a story. An audience is more likely to be intrigued with a piece of work if they can follow a beginning, a middle, and an end rather than having facts and data thrown at them.
4. It is understandably difficult to have every person retain information that is conveyed to them, but there are portions of lectures and writings (not necessarily scientifically published work) that must be retainable by all audiences. This is where the "planning pyramid" comes into play. The bottom level of the pyramid

suggests that there should be information conveyed and retained by all audiences. The middle level should include information that most people can retain, and then lastly the high level should include information that is more advanced and can be retained by a few select audience members but should also be mentioned minimally.

3.2 Scientific Justification Interviews

With both sets of interviews, one can see how well researchers from academia and industry understand the purpose to their research and how well one can simplify their rationalizations in order to communicate them to the layperson.

From the interviews with the scientists in Appendix A, academia pushes its focus on just the basic understandings of sciences. All of them seem to mention how it is the mechanisms at the core of their research that they are most interested in. They strive to better understand, in their cases, the basic functions, effects, and the various involvements of biological functions that occur in nature. They apply a sense of scientific curiosity with a defined purpose to their research topics. They also are aware that the research that they do is only a stepping stone that will lead the way to further research and the possibilities of future applications of their research. One must start somewhere and as one scientist states that "We are just laying the foundation," it is the most appropriate description for the kind of research that this particular set of researchers do. The fact that in some form or another, each one of these researchers managed to describe their purpose for their particular research in this fashion gives the impression that they do have the capacity to communicate their justifications in simpler terms.

With the second set of interviews, it can be quickly concluded that they are able to simply justify their research and communicate it well to individuals in the general public. Both of the industrial scientists, since they both worked in the same laboratory, had the same justifications for their work which was described as “for the improvement of modern medicine.” They both realized that medicine is field that people are aware of the most in terms of the health benefits that have come from medicine and the overall improvement of human welfare. As medicinal chemists working for a large pharmaceutical company, they have to handle their explanations carefully because they need to keep a sense of confidentiality that comes with their profession. It seems as though it is the necessity for company confidentiality that pushes them to develop the ability to easily describe their work and the justifications in a way that does not reveal the specificity of their ongoing or previous research. It seems as though researchers involved in industry become accustomed to vaguely discussing their confidential research to others outside their profession while keeping their descriptions as simple as possible.

From the grant writing perspective, scientists in academia are very wary of their use of written speech. They are focused with being as detailed as possible while being careful of how exactly they describe their research ideas. Some of the academia scientists go as far as giving a warning in the use of particular words such as “Significant, Proven, and Novel.” One scientist also begins to mention a way to write publications and grants by making ones writing “less fluffy.” To make your writing “less fluffy,” it can say that one is allowed to give an initial interpretation of the potential of the research in question but not to be as bold as to say that the research will be “the next wonder drug.” Scientists in academia appear to be aware that how well they are able to receive grants is based on their method of writing and how they choose to present makes all the difference.

In the realm of Industry, those researchers have said that there is a similar method to receiving resources for their research. Just like in academia, they must also come up with a research proposal which must then be submitted to review and from there a decision must be made to either scrap the project or have it given approval, allowing for monetary funding and the department to dedicate some of the employees to work on the new project.

3.3 Survey Analysis

Surveys were conducted using surveymonkey.com. There were a total of 27 questions on 3 pages. The surveys were distributed using social networking and email. Shown in the survey results are pie charts and column graphs. The pie charts have a key on the right which show the answers offered in the same order. Coming out of the pie charts are percentages showing what percentage of people answered what questions. The column graphs show how many people exactly pressed which answer on the survey. Appendix C shows the results of the survey.

The survey that was conducted was available for 7 days and was taken by 200 people. Shown below are the results of each question provided from the survey, and what this meant towards the overall goal of the project.

Page 1 of the survey contained demographic questions which we hoped would aid in gauging a number of audiences and with the other two pages of the survey, help determine a baseline of knowledge and their comprehension of the scientific information presented in the excerpts.

Survey Questions 18-24: Linguistic Misinterpretation

Page 3 of the survey dealt with speech and linguistic misinterpretation. As was previously mentioned there were 4 groups that people could fall into based on their answers to these questions. Those 4 groups were: 1—Correct 2—Incorrect 3—In the middle or 4—Broad.

In Question 18 more than 74% of people answered in the group of “in the middle.” The correct answer was C and only 15.1% chose that answer. What was being tested in this question was the public’s reaction to the word “apparent.” The group believed that the word “apparent” might have confused the public. Answer B was chosen 74% of the time, but nowhere in the posted excerpt is Mars referred to as a whole. The very first sentence mentions Mars's north polar sand sea but the word "apparent" is then used in the excerpt. In the correct answer we used the word "probably." The public could not see that the usage of the word apparent implied a chance. This is where the underlying theme of this question was seen. The word "apparent," along with many other words in the English language, which will be discussed further, have real world AND scientific meanings. When one is speaking to somebody and says the phrase: "well, apparently I was wrong" it is implied that this person was finitely incorrect. When examining the word "apparent" in a scientific context like in the phrase: "the wild type genotype of the mouse was apparent." The layperson may think this is a finite truth, but it is actually a probable result. It can be said in the scientific world that the usage of the word "apparent" can mean most likely, or ostensible but not true. If the scientific phrase were to be reworded using the scientific definition of "apparent" it would look like this: "the genotype of the mouse was **most likely** wild type." More words like this will described later on.

In question 19, again, 62% of people answered in the category of "in the middle" and only 27% of people answered "correct." In this question the group was trying to see how people reacted to the term "a new analysis finds." 62% of people interpreted this statement as true. An analysis is not enough to accept something as a supported truth. This set of answers was difficult to select from. Both B and C could have been correct in their own way, BUT what is scrutinized in this question is the fact that people accept this excerpt as true solely based off an analysis. Something can be the best research available at a time and accepted as true, until it is disproven. A good scientist understands that all research is done to help other research, and that is a cycle that is respected. Science can disprove evidence but never prove something. What was depicted in this question was the public's belief in the validity of the statement made about sharks and human beings without any proper evidence.

In question 20 Over 82% of people answered "in the middle" and only about 13% of people answered correctly. In this question we were testing to see how people interpreted the phrase "over time." The answer A did not specify a time. The answer was correct but in this excerpt a certain time was mentioned. Answer C specifically referred to the time in which hypertension started to develop (6 years). It is important as a writer to be clear about what you are saying. "Over time" does not clarify a specific time span. Mentioning exactly what the time was is more precise and clear. Being clear and precise is obviously necessary in scientific writing as to avoid misinterpretation. In this excerpt it can be seen that the author does mention a certain time but it is not clearly depicted that the term "over time" means 6 years. This article served as an informative piece describing the relationship between sodium and blood pressure. The essence of time within this publishing is crucial when describing hypertension. Other examples can be used to show the need for clarity when it comes to describing important concepts or constraints of scientists work: when the term "the subjects" is used in a paper describing AIDS research or any type of lethal disease it is crucial to state exactly how many subjects and what the subjects are. It makes a difference if humans are being tested opposed to mice, or if there are 4 test subjects instead of 400.

In question 21 over 50% of people answered "in the middle" again while only about 5.1% of people answered correctly. In this question the public's reaction towards the word "debilitating" was being tested. The more important theme in this question was to show that the clarity of the introductory sentence was not sufficient. The first sentence must be engaging and clear. Within the answer choices provided there was one option where the exact definition of the word "debilitating" was used. A mere 5% of people chose the answer with the exact definition. If the reader does not understand the first sentence given to them, then the rest of the paper could become very confusing. This first sentence presented in the excerpt would have been completely understandable if the one ambiguous word was removed or better explained. This analysis is not geared towards the word "debilitating" but rather, any word or phrase that could cause confusion within an otherwise easily understandable sentence. The word "debilitating" comes with a reputation that does not show any positive parameters, but only about 5% understood exactly what it meant.

In question 22, 64% of people chose the correct answer, which was D. 25.7% of people had an "in the middle" mindset when answering the question. This question was testing to see how people reacted to the phrase "was linked to." The word "linked" shows a connection between two subjects or objects. The public understood that connection. What is important to take away from this question is that linkage does not necessarily refer to a direct relationship or correlation. This means that when using a word like linked that has no tag of severity attached to it, it is important to state how one subject or object is linked to another.

In question 23 the speaker made a contradiction when describing a particle in his speech. He said that the properties of the particle had not been completely discovered, but he then went on to describe important properties of that particle. In this question what was being tested was the public's ability to notice that contradiction. Surprisingly people did. 80.1% of people chose the correct answer while only 2.2% chose "incorrect." The underlying theme from this question was the difference between the mindset of a scientist and that of the layperson. When a scientist says that the properties of a particle have not been fully discovered this can mean that they have comprised a textbooks worth of information on that particle. This is what happened in this interview posted on the Internet with this scientist. In common language when a person says: “I don't know” this instantly ends the conversation. When a scientist makes the remark “I don't know” this can mean that they don't know enough to make conclusions (inconclusive) but they have plenty of information that they can speak about. In politics this is referred to as flip-flopping, but in science this is a good trait to have. Flip-flopping in science can mean that the person believes that his or her research has a ways to go, or that it can be improved. But from the view of the general public it is important for the scientist to explain why “they don't know,” but yet “they know a lot.”

Question 24 raised confusion amongst the public. The distribution of answers was well balanced. 39.3% of people answered correctly while 31.9% of people had too “broad” of a mindset when answering the question. This question was testing people’s ability to understand the words “channel,” “sensitive,” and “conclusive.” The correct answer (B) uses the exact definitions of these three words in their scientific context. If people understood these words by definition within the correct context of the excerpt then this question would have been simple. This answer also deals with the concept of definitions between life-world language and the language of science. If one does not understand the scientific definitions of these words then it would have been difficult to answer this question. The words “channel,” ‘sensitive,” and “conclusive” have multiple meanings. For a speaker who is broadcasting his speech on MSNBC, which is a website used by many people to hear and read the news, it is important that he/she clarifies which definition is being used as to not cause confusion.

The resulting piece of work was a list of words and terms to avoid along with tips in helping to keep writing unambiguous for the general public. This list was comprised through: background research, surveys, and interviews. The list is shown below.

- **Terms that can cause confusion. Avoid using these terms and if used—EXPLAIN.**
    1. Representative
        a. When used in scientific writing it can be false. Data is not "representative" it is the best-seen data until that point in time.
    2. Significant
        a. Different meaning for the layman but in science it means that the qualitative and/or quantitative data is STATISTICALLY significant. Meaning T tests have been run to determine its significance. A marker of 0.05 or 5% is commonly used as a marker of significance.
    3. Proven
        a. A very dangerous word that can be misleading to the public. This word should almost never be used because the result is again the best that has been seen for that time.
    4. Trend
        a. Another word that has a different scientific meaning that what it has in the English language.
        b. Aside from different possible definitions, this word is very vague when there is no quantity or level of "severity" assigned to the word.
    5. Hypothesis vs. Theory
        a. In society these two terms are commonly mistaken or used incorrectly. A hypothesis is an experimental design that has been created to be tested. And a theory has been tested and is generally accepted as true. If using

one of these words try to clear up any confusion that can arise from the usage of the word.

6. Theoretically
    a. Although the word means "based on theory" many people use this word incorrectly and do not understand that it must be based off of theory.
7. Channel
    a. This word can cause confusion even in just the science world. It can mean "A pathway through a protein molecule in a cell membrane" or a "pathway of information" or the "deepest part of a river or harbor" and even more definitions.
8. Apparent
    a. This word can cause an audience to believe that something is finite or "for sure" even though the actual definition is "appearing as such, but not necessarily so"
9. "Analysis shows" or "studies show" or any phrases of that sort
    a. This is showing or describing incomplete evidence. It is important to say exactly where the presented information came from.
10. "Over time"
    a. This is a very ambiguous term. Make sure to specify exactly how long "over time" is.
11. Debilitating
    a. This word sounds severe and people will generally place severity with this term when it actually just means "impairment of vitality and strength"

12. Sensitive

    a. This word has multiple definitions and can be confusing to the public. It is difficult to put this word into a context where people will definitely understand it.

13. Inconclusive or Conclusive

    a. This word is simply confusing. A lot of people do not understand the definitions

14. Ascertain

    a. Another confusing word which means, "To make certain, or discover with certainty." Many people do not understand this definition.

- **A few keys to writing understandable scientific work.**

  1. Try to tell a story. When writing scientific work that is to be published that is a difficult task, but it is a good way to gauge your audience. The most important part of writing this story is to build strong introductions and strong conclusions.
  2. As simple as it may sound, never contradict yourself. This will confuse the reader for the entire paper or presentation if even just one small point is contradicting.
  3. If you question whether or not somebody will understand a term or a phrase…it means you should not use it.

Survey Questions 25-27: Source Evaluation

Survey Question 25 Analysis

Table 1. Responses to Survey Question 25

Response	Number of Responses	Percent of Responses
a	96	70.6
b	6	4.4
c	18	13.2
d	16	11.8

The table above shows the response count for the four options to Survey question 25. The analysis described in the survey methodology section takes the statistics from these results in the form they appear in above and in combinations of them to deduce the results in the form of a participant's statement of knowledge of the peer review process in regards to the sources mentioned in the survey question excerpts. The table below summarizes the relevant ways in which a participant's knowledge regarding the question can be interpreted and the probability distribution of a participant belonging to one of the sets of participants formulated in the experiment's methodology.

Table 2. Probability of Relevant Events in Survey Question 25 Experiment

Event	Experimental Probability	Experiment Outcome	Statement With Value "True"	Meaning of Statement
A	$p(A) = \frac{a}{n}$	070.6%	X and not Y	The participant considers **only** the research described in the two excerpts whose source was a paper published in *Science* or *Nature* to be peer reviewed research
B	$p(B) = \frac{b}{n}$	4.4%	Y and not X	The participant considers **only** the research described in the two excerpts whose source was unmentioned to be peer reviewed research
C	$p(C) = \frac{c}{n}$	13.2%	X and Y	The participant considers research whose source was a paper published in *Science* or *Nature* **and** research whose source was unmentioned to be peer reviewed research
D	$p(D) = \frac{d}{n}$	11.8%	Neither X nor Y	The participant considers research whose source was a paper published in *Science* or *Nature* **and** research whose source was unmentioned to **not** be peer reviewed research
A or C	$p(\mathrm{A} \vee \mathrm{C}) = \frac{a+c}{n}$	83.8%	X	The participant considers research whose source was a paper published in *Science* or *Nature* to be peer reviewed research
B or C	$p(\mathrm{B} \vee \mathrm{C}) = \frac{b+c}{n}$	17.6%	Y	The participant considers research whose source was unmentioned to be peer reviewed research
D or C	$p(\mathrm{D} \vee \mathrm{C}) = \frac{d+c}{n}$	25.0%	Both X and Y, or neither X nor Y	The participant considers the research in the two excerpts to be **equal** in whether or not they are peer reviewed research

Table 2 best portrays the analysis of the responses to Survey Question 25. The four events that represent a participant's selection of a response as well as the three selected unions of two events that represent a participant's selection of one or the other of the specified two responses are chosen to be analyzed based on their relation to Statements X and Y. While these two statements cannot directly be measured to be true by the sampling experiment like the statements that are observed outcomes of the experiment, it necessary to introduce them and to derive their relation to measured events to obtain information about the participant's opinion of the two excerpts that is consistent with and accurately reflected by the sampling experiment.

The two events which best represent a participant being familiar with scientific journals as peer reviewed sources are Event A and the union of Event A and Event C because both associate with Statement X being true. This shows that most of the participants at 83.8% at least recognize the excerpt with reference to two well-known journals to contain peer reviewed sources and of that 83.3% of total participants, most of them at 84.2% recognize the other excerpt to not contain reference to a peer reviewed source.

The examination of Event B and the union of Event B and Event C yields a similar discussion about the participants who choose the excerpt that does not mention a source to be describing peer reviewed research. A considerable amount of the sample at 17.6% does not recognize that this excerpt does not contain sufficient information about the research to deem that it has been peer reviewed, but of that 17.6% of total participants 75.0% of them also do consider the excerpt that references two to well-known scientific journals to be describing peer reviewed research. This shows that 4.4% of the participants recognized neither the sources mentioned in the first excerpt as just cause for the research described to have been peer reviewed, nor the lack of mentioned sources in the second excerpt as just cause for the research described to not have been peer reviewed.

Because Event C means that both Statement X and Statement Y have an equal truth value of true and Event D means that both Statement X and Statement Y have an equal truth value of false, the union of these two events yields a percentage of participants who would equate Statement X with Statement Y. This percentage is shown to be exactly 25%. All of the percentages that are discussed above as results represent the probability that a participant selected at random will have the opinion of the excerpts in terms of Statement X and Statement Y associated with that percentage.

Survey Question 26 Analysis

Table 3. Responses to Survey Question 26

Response	Number of Responses	Percent of Responses
a	30	22.1
b	73	53.7
c	7	5.1
d	26	19.1

Table 4. Probability of Relevant Events in Survey Question 26 Experiment

Event	Experimental Probability	Experiment Outcome	Meaning of Event
B	$p(B) = \frac{b}{n}$	53.7%	The participant correctly answered Survey Question 26
¬B	$p(\neg B) = \frac{a + c + d}{n}$	46.3%	The participant did not correctly answer Survey Question 26
A or D	$p(A \lor D) = \frac{a + d}{n}$	41.2%	The participant's response to Survey Question 26 was the name of an author of the research described in the excerpts

Unlike Survey Question 25, Question 26 has one correct response that separates the sample space into two discrete subsets, one of which is Event B and the other is the union of the remaining events. Participants were most likely to answer Question 16 correctly. At 53.7% of the sample answering the question correctly, it shows that the experimental probability of Event B is more than twice as large as the probability of answering the question correctly guessing at random.

The significance of the union of Event A and Event D is that it indicates that a participant not only did not select the correct response as a possible referee in the peer review process of either article but also does not recognize the anonymity of academic review panels by selecting people involved with the publications mentioned. These two answers were designed to draw participants who did not know the answer to select them by the likelihood that they associated the term "peer" with names of scientists who were described as having worked together or in the same field.

Survey Question 27 Analysis

Table 5. Responses to Survey Question 27

	Different Response	Same Response A	Same Response B	Same Response C	Same Response D
Responses	50	77	3	3	2
Percent of Responses	37.0	57.0	2.2	2.2	1.5

There are three events that yield statistics useful to the interpretation of this experiment. First, is Event E whose probability is represented by the fraction of participants who did not select the same response to Question 25 and Question 27. The union of Events A through E represents the four ways in which a participant could have selected the same response to Question 25 and Question 27 and the probability of a randomly selected participant being part of this subset is the sum of the probabilities of the discrete Event A, Event B, Event C, and Event D. Because Event A makes up such a large fraction of this union, it is also an event worth analyzing and discussing.

Table 6. Probabilities of Relevant Events

Event	Experimental Probability	Experiment Outcome	Meaning of Event
A	$p(a) = \frac{a}{n}$	57.0%	The participant selected response (a) to Question 25 and Question 27
E	$p(E) = \frac{e}{n}$	37.0%	The participant did not select the same response to Question 25 and Question 27
Not E	$p(\neg E) = \frac{a+b+c+d}{n}$	63.0%	The participant selected the same response to Question 25 and Question 27

Survey Question 25 establishes which of the two provided excerpts any given participant has selected as an example of an article describing research that has been peer reviewed. Survey Question 27 then establishes which of the two provided excerpts any given participant considers to be trustworthy and unbiased. Comparison of the two questions can then yield information about whether or not a given participant considers research that they had previously selected as peer reviewed to be trustworthy. If a participant has not selected the excerpt(s) that they chose to be about peer reviewed research as the most trustworthy and unbiased, then that participant does not consider peer review alone as requirement for trustworthiness. This statistic is described by Event E, in which the answers to Survey Question 25 and Survey Question 27 are different.

37.0% of the survey sample does not consider research that they deemed to have been peer reviewed based on an article excerpt to be trustworthy and unbiased.

More people however do select the research that they deemed to have been peer reviewed based on an excerpt from an article about it to be trustworthy and unbiased as 67.0% of the survey sample selected the same answer to Survey Question 25 and Survey Question 27. Of this subset of the surveyed population, 90.1% chose the same response (a) rather than the same response (b), (c), or (d). This is consistent with the hypothesis outlined in the methodology section for these two survey questions, as response (a) was designed to be the most accurate response to both.

Survey Questions 13-17: Public Science Comprehension

The second part of the survey dealt with data presented graphically, testing our respondents' ability to analyze a line graph, a pie chart, and a column graph with error bars. In general, respondents did well with the line graph and column graph, but had problems with the pie chart and error bars.

Our line graph questions gauged respondents' ability to identify and predict trends. The first question asked participants to predict the next data point in a randomly varying series, while the second asked them to predict when a steadily decreasing series would fall to zero. As shown in Table , 75% of respondents answered the first question, Question 13, correctly with "cannot be determined," and though only 66% chose the correct answer of "January" for the second question (shown in Table 8), another 12% answered "December," which implies that they had a good idea of what the correct answer was, but may have been off in counting. These results show that about three-quarters of the population will understand data presented in a line graph.

How many Purple marbles do you expect to be sold in August?	
Answer	Response %
5	2.9%
6	12.1%
7	9.8%
Cannot be determined	**75.3%**

Table 7 - Question 13

When will the Red marble sales fall to 0?	
Answer	Response %
August	1.1%
December	12.1%
Next January	**66.1%**
Cannot be determined	20.7%

Table 8 - Question 14

The responses for the question about the pie chart (Question 15, shown in Table 9) were perhaps the most surprising. The question presented two pie charts representing marble sales by color as percentages of total marble sales. Only percentages were listed on the charts, with no numbers for total sales or for sales for any particular color. With this information, participants were asked whether more purple marbles were sold in September (where 21% of marble sales were Purple) or October (with 24% Purple marble sales). Only 51% of respondents gave the correct answer of "cannot be determined," with 47% answering "October." This shows that about half the population cannot tell that, outside of a single context, higher and lower percentages do not necessarily mean higher and lower actual numbers. Researchers should therefore be careful when using percentages and pie charts, particularly without context for the size of the samples in each one.

Were more Purple marbles sold in September or October?	
Answer	Response %
September	1.7%
October	46.9%
Cannot be determined	**51.4%**

Table 9 - Question 15

The final two questions in this section asked our participants to read a column graph with error bars. As expected, most people did well with Question 16, which asked only about the column graph and had nothing to do with the error bars. Nearly 80% of our respondents got this question correct, as shown in Table . However, our participants did have some trouble when asked about the error bars specifically. As Table shows, only 40.5% of our respondents answered Question 17 correctly, just barely more than the 38.7% who thought that the answer could not be determined. These results were not surprising either, as many people do not deal with error bars on a regular basis, and therefore do not know what they represent.

Which color of marble sold the best overall in 2010?	
Answer	Response %
Blue	1.7%
Red	**78.9%**
Green	2.3%
Purple	0.6%
Cannot be determined	16.6%

Table 10- Question 16

Which color of marble sold the most in a single month?	
Answer	Response %
Blue	2.9%
Red	13.9%
Green	**40.5%**
Purple	4.0%
Cannot be determined	38.7%

Table 11 - Question 17

Survey Questions 1-12: Demographics

In the survey, the purpose of the first nine questions was to filter responses with other questions of the survey to find correlations between the public's knowledge and different demographics within the public. This would aid in forming the audience gauging section of this project. The raw survey data can be found in Appendix C. The unfiltered results of the demographic questions can be viewed in the appendix under Question (2) through Question (9). Question (10) through Question (12) deal with the public's interest in science and resources available to the public. The results of these questions are also shown in the appendix. The results of Question (2) through Question (9) show the spread of demographics obtained from the survey.

Due to limitations such as time, money, and dissemination constraints, certain demographics are more apparent in the results than others. Results of the survey show that 57.4% of people who took the survey were female and 42.6% were male. Out of 200 respondents, 170 of them were Caucasian. That's 85.9% of the people who took the survey. 47.7% (95) of the respondents listed "student" as their current employment status. 49.5% (98) of the respondents listed "some college, but no degree" as their highest level of education suggesting that the majority of those who listed student as their current employment status are college students. There was a broad range of responses for approximate average household income. The minimum number of responses for any of the options under the household income question was nine. The household income question had a total of 189 responses showing that 11 respondents chose not to answer. The majority of respondents, 56.6% to be exact, live in a suburban neighborhood, followed by rural at 21.2%, inner city at 16.2%, and finally country at 6.1%.

After looking at the options chosen for Question (3), "In what state or U.S. territory do you live?" it was decided to divide the country in five regions: West, Southwest, Midwest, Southeast, and Northeast. To tabulate responses of people from different regions of the U.S., a filter was applied. Because this IQP group attends WPI, which is located in Massachusetts, it appeared that many of the survey responses came from the Northeastern region of the country likely due to distribution methods and constraints. To filter responses from the Northeast, each state and territory belonging to the Northeast had to be selected and combined using "or" logic. States and territories belonging to the Northeast included Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and the District of Colombia (D.C.). After applying the filter, results showed that 94% (188) of the 200 respondents were from the Northeast. With a mere 6% (12) from the other four regions of the U.S., it was decided that for the purpose of this data analysis with the demographic questions, only results from the Northeast would be used. The 6%, only consisting of 12 responses would not be enough to draw sound conclusions from the results.

To stay within the results gathered from the Northeast, the next filter was combined using "and" logic with the first. This second filter filtered results from respondents who were Caucasian and from the Northeast. 80% (160) of the respondents were Caucasian and from the Northeast. Since the majority of the respondents came from these demographics, much of the data analysis was done on this group. A brief overview of demographic statistics on this group is to follow. For this overview, the percentages shown are of how the majority of respondents answered. 56.3% (90) of Caucasians who live in the Northeast live in a suburban neighborhood. One of the biggest factors that this IQP group took into account when deciding on target audiences was education level. For Caucasians living in the Northeast, the majority of respondents, 49.4% (79), had completed some college, but no degree. Charts showing the spread of education level for Caucasians living in the Northeast can be found in Appendix C. Question (10) asked, "On a scale from 1 to 5, 1 being the least, how interested are you in science?." For Caucasians in the Northeast, there was a steady increase on the scale from one to five. The majority of respondents in this group, 41.4% (58) selected "5" on the scale meaning they were very interested in science. The nature of the public's science background was also asked about in Question (11). 53.9% (76) of Caucasians in the Northeast had completed their college's science requirement. 25.5% (36) had obtained a college degree in a scientific field. 20.6% (29) had only completed high school basic science. All respondents from this group had some sort of science background. No respondents selected "none" as their choice for science background. Question (12) asked which resource was most available to the respondent. For 72.1% (101) of Caucasians in the Northeast, interactive websites were the most readily accessible resource, which comes as no surprise since this is the age of technology and the majority of this group were college students who probably have their own computers, and if not, definitely have access to the Internet through their colleges.

A look was also taken at all other ethnicities living in the Northeast other than Caucasians. To do this, a custom filter was created using "and" and "or" logic. The filter formulated responses of individuals living in the Northeast AND who were Hispanic OR African American OR Native American OR Asian/Pacific Islander OR other. 13.5% (27) of 200 respondents fell into this group. After filtering these responses, a closer look was taken at the education levels of this group. 50.0% (13) of this group had completed some college, but no degree. 30.8% (8) had earned a High school degree or equivalent. 11.5% (3) had completed a Bachelor degree. Only 3.8% (1) had earned a Professional degree or Doctorate degree. A bar graph depicting the spread of education levels of this group can be found in the appendix. In the group of Caucasians living in the Northeast, none had completed a Professional or Doctorate degree. The highest level of education was a Master's degree.

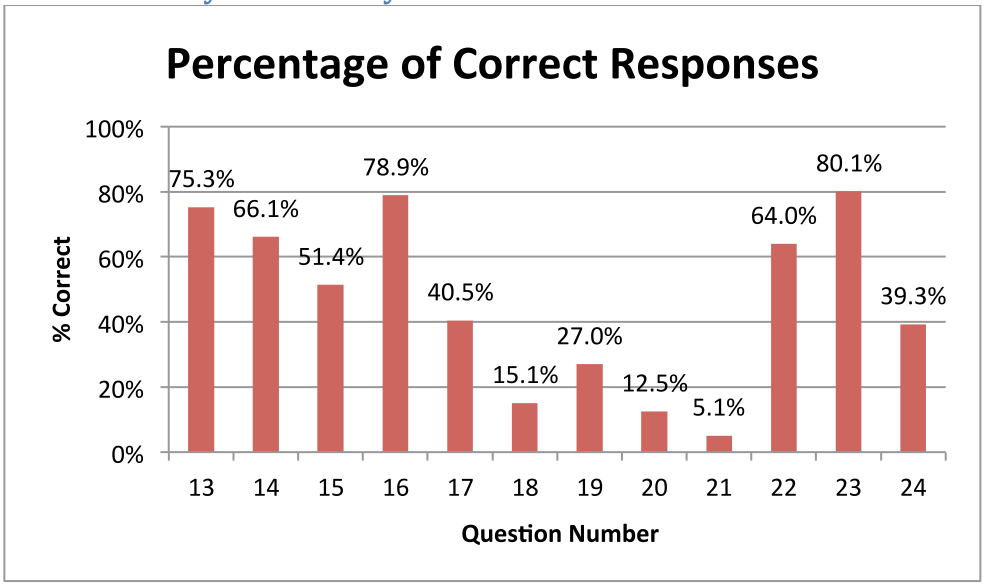
In order to analyze the demographics in comparison with the other questions of the survey other custom filters had to be created. The first custom filter of this part of the analysis was designed to filter the responses of Caucasians who lived in the Northeast and who had answered all of the questions correctly on the survey that dealt with the public's comprehension of science portion of this project. The public comprehension questions on the survey were Question (13) through Question (17). These questions were basic comprehension questions that dealt with interpreting a scatter plot, pie charts, and an error graph. In order for an individual to have answered all five of these questions 100% correctly they would have had to answer as follows: [Question (13)] D) Cannot be determined, [Question (14)] C) Next January, [Question (15)] C) Cannot be determined, [Question (16)] B) Red, and [Question (17)] C) Green. People seemed to struggle the most with Question (15) and Question (17). The filter showed that only 8.0% (16) answer all five public comprehension questions correctly. 81.3% (13) of the 16 who answered correctly had completed some college, but no degree. Of the other three individuals who answered all five questions correctly, one had a high school degree or equivalent, one had a Bachelor degree, and one had a Master's degree. The majority of respondents who got these questions correct were college students. No Hispanics, Native Americans, or Asian/Pacific Islanders got 100% correct, and only one African American did. (A bar graph in Appendix C shows the distribution of education levels of Caucasians who answered these questions 100% correctly.)

The next filter was created to filter the responses of Caucasians who lived in the Northeast and who had answered all of the questions right that covered linguistic misinterpretation. The linguistic misinterpretation questions were Question (18) through Question (24). The correct responses to these questions are C, B or C, C, B, D, D, and B respectively. 0.0% of respondents from this filter answered all six questions right. In fact, after removing Caucasians who lived in the Northeast from the filter and just filtering any individual who answered all six questions correctly, it still turned out that none of the 200 respondents accomplished this, showing that linguistic misinterpretation is a major issue and happens more often than not.

The third filter tabulated responses from Caucasians who lived in the Northeast and who had answered correctly the three questions on the survey that dealt with misinformation. Question (25) through Question (27) dealt with misinformation and the public's understanding of the peer review process. The correct answers to Question (25) through Question (27) are A) I, B) Experts in the field of influenza research, and A) I. This filter showed that 16.5% (33) respondents did answer all three questions correctly. (A bar graph in Appendix C shows the distribution of education levels of Caucasians who answered these questions 100% correctly.)

After applying the three filters it was decided next to determine education level of individuals based on the neighborhood in which they lived. As previously mentioned, 56.6% of the 200 respondents live in a suburban neighborhood, followed by rural at 21.2%, inner city at 16.2%, and finally country at 6.1%. Of those individuals living in a suburban neighborhood, 55.4% (62) had completed some college, but no degree, 20.5% (23) had earned a Bachelor degree, and 13.4% (15) had earned a high school degree or equivalent. 38.7% (12) of those living in the inner city had completed some college, but no degree, 25.8% (8) had earned a Bachelor degree and 22.6% (7) had earned a high school degree or equivalent. 45.2% (19) of those living in a rural neighborhood had completed some college, but no degree, 26.2% (11) had earned a high school degree or equivalent, and 9.5% (4) had earned a Bachelor degree. The trend varied slightly in individuals who lived in the country. 41.7% (5) had completed some college, but no degree, 25.0% (3) had earned Associate's degrees, and 8.3% (1) had earned less than a high school degree, a high school degree or equivalent, a Bachelor degree, or a Doctorate degree. Bar graphs in Appendix C show the spread of education levels for each type of neighborhood.

Overall Survey Score Analysis



The above graph shows the responses to survey questions designed to have one correct answer. These questions were used to gauge the public's current knowledge of science and their ability to interpret presented scientific results. The graph shows that of the problem areas, as stated in the introduction, linguistic misinterpretation (questions 18 through 24) is the most significant factor in failed communication between scientists and the public. It can be seen that questions 13-17, which addressed public comprehension, yielded surprisingly high percentages of comprehension in MOST questions but not all. The website being designed will address all the five problem areas in the eventual goal of assisting scientists in successfully and effectively communicating their work to the public.

4. Discussion

In discussing misinterpreted speech, it can be seen that the surveys, interviews, and background research all were used to assist in developing the final list above. The reasoning behind the background research was to determine if any research had been conducted on linguistic interpretation in association with scientific writing. There has been research done in linguistic and speech studies and interpretation, and also research in scientific writing techniques.

What was found was that there was not a substantial amount of research done linking the two fields. This IQP group decided that the next step in this process of creating the scientific education tool was to link the background research with the science specific qualitative research done through the surveys and interviews.

The interviews with the scientists, as a whole provided the expected results with the answers that we received from the survey. The understanding from the public when trying to retain information conveyed to them was not sufficient, and that is displayed within the results of our survey. The scientists displayed within the interviews that the main modification to their explanations of their research was scientific linguistics and scientific information. On the contrary, discovered within the surveys was that the public seemed to, at some points understand the science being explained, but ambiguity was caused by the words used within the English language. At times this ambiguity was because of a lack of knowledge strictly dealing with English definitions, and at other times it was because of multiple definitions between the scientific and the English language. This was a contradictory theme between the two forms of research.

Next we looked at the interviews conducted with the educators in comparison with the interviews with the scientists. The educators scrutinized the explanations provided by the scientists, but again the modifications were applied to the scientific portion of the explanations and not the English linguistics. The educators then went on to discuss the importance of creating a “story” when conveying information to the public as to engage them in the writing. The educators then stated that an emphasis must be placed on the introduction and conclusion. In the introduction it is good to use examples or relate the topic to the audience that is being gauged. The educators focused primarily on audience gauging which was something that a scientist did not agree with. One of the scientists believed that “science was timeless” and that gauging an audience was not an important aspect of conveying information to the public. The educators addressed this problem when they mentioned from their experiences that some scientists do not want to gauge an audience differently and change the way they describe their information.

Overall, as a group we can look at this set of survey question and say that these excerpts within the survey questions (that were taken from a website that is commonly used by the layperson) were not properly conveying their information to the public (Questions 18-24). It is extremely important to be clear in the language usage in scientific writings and that is not being done. As can be seen from the results of the survey, people do not seem to understand the scientific information that is being conveyed because of the language usage surrounding the facts and linguistics. Many times the science is understandable until a word is used that causes misinterpretation of the scientific information being conveyed (i.e. question 18). This is the underlying information that has been shown from the survey and because of this we constructed the list that was previously mentioned. This list will be included in the website so that scientists can gain an understanding of how to properly convey scientific information to the public.

Overall, we can look at this set of survey question and say that these excerpts that were taken from a website that is commonly used by the layman were not properly conveying their information to the public. It is extremely important to be clear in the language usage of scientific writings. As can be seen from the results of the survey, people do not seem to understand the scientific information that is being conveyed because of the language usage surrounding the facts and linguistics. Many times the science is understandable until a word is used that causes misinterpretation of the scientific information being conveyed (i.e. question 18). This is the underlying information that has been shown from the survey and because of this we constructed the list that was previously mentioned so that scientists can gain an understanding of how to properly convey scientific information to the public.

In regards to scientific justifications, upon review of the interviews done with researchers in both academia and industry, we can see researchers in either academia or industry have the ability to communicate their reasons backing their research whether they are personal reasons or just the justifications that make their research worth the effort. However, there was a difference in the amount of time it took scientists from opposing fields to find the underlying message from their explanations. Academia scientists continued to explain their research as they were describing their justifications and only after they were winding down into a conclusion to their answer to the interview question, they then explain how they are doing the initial research needed so others can continue and further improve on their work. In comparison, the scientists in industry were quick to the point and the answers were short and gave the necessary information within a few sentences. Even though the contrast between the academia and industry was not very surprising but, it was quite surprising as to how much of a contrast they were. It was expected to see that both realms of the scientific community would be well versed in discussing their research and their justifications in great detail but seeing if the scientists are able to explain their justifications simply enough for most of the general public to understand. It was surprising to see that the industrial scientists were able to do this easily and quickly. This is mostly likely due to the fact that they must keep company confidentiality while somehow communicating to others that are not within the company employing. Based on the speed that the industrial scientists answered the questions, it can be seen that they had these answers on hand which implies that they have had to answer a similar set of questions before. These scientists had to think of these answers with confidentiality in mind.

As with their explanations of the justifications for their research, both groups of scientists were also aware of what had to be done in order to gather the resources for their research to begin or to proceed. The academic researchers gave us an idea of what are certain methods of writing grants and certain points that should be avoided, it was also discovered that the industrial researchers also had to go through a similar process. Even though the source of the funds may be different, it appears that general process is the same. With this similarity in mind, we can assume that what we learned from the academic researchers can be applied to how the industrial researchers propose their research ideas.

While keeping in mind the linguistics used in communicating scientific work, one must also consider the scientific knowledge and terminology known by the general public. The examination of the public's knowledge of scientific information validity yielded interesting results. Most of our surveyed population was able to determine whether or not presented information cited a peer reviewed source based on its publication. Furthermore, most of the people who determined whether or not the information presented cited a peer reviewed source also determined non-cited information to not qualify as conclusively checked for quality. Although this indicates that the trend is that public is able to check for sources, the amount of people who would call non-cited information peer-reviewed (17.6%) is non-trivial. There is also indication that significant portion (while still a minority) of the sampled population (25%) saw no significance in the reference to published sources. The specific problem of misinformation as stated in the introduction is thus verified to exist among the public, however source evaluation does not seem to be the main cause for poor evaluation of trustworthiness.

The next problem being discussed is misinformation. Having determined that the public is not wholly unable to recognize a credible source, we then looked into how the public determines the credibility of the source. By showing that only about half of the population knew enough about the publication of journals to describe the participants of the peer review process, it can be concluded that some of the majority of the population recognized peer reviewed quality control did so blindly, trusting the term “peer review” without knowing exactly what it is.

The problem of information is then attributed to the discrepancy between what a layperson considers to be a valid source, and what the researchers presenting information and sources are citing as valid sources. Most of the survey participants said they would trust information that they also said they considered to be peer reviewed, but again, a significant portion did not (37%) associate trustworthiness with research’s currently accepted method of quality control.

The problem of misinformation must then be reformulated. The public mostly recognizes citation of quality controlled sources. The public almost recognizes this as basis for trustworthiness. It is inconclusive whether or not the public knows why they trust methods of research review. Solutions offered then must take the form of addressing the problem on all three of these bases. Firstly, researchers can make known the origin of their work and the medium of its publication to first establish a standard of credibility. It is then necessary to present the conclusions of their breakthrough research as fact not simply because they have performed the research but because it yielded results that have been interpreted as valid and significant in order to have been accepted for publication. It is not feasible for a researcher who is presenting their work to also present information solely on source credibility. To educate the public on source evaluation while also presenting research it would also be beneficial.

The final problem area that was researched in depth during this IQP was the issue of engaging one’s audience. The difference between effectively conveying scientific information to the public and ineffectively conveying scientific information is contingent upon successfully gauging the audience. The survey intended to grasp the public's subject matter expertise in understanding the presentation of scientific data (i.e. bar graphs, pie charts, and error bars) and proper sources of information. It also helped determine the public's ability to interpret commonly misunderstood language used in science. Demographics play a key role in audience gauging. Results from the survey show that the majority of correct responses were those of Caucasian college students living in a rural neighborhood. In general, respondents from inner city neighborhoods had fewer correct answers. The survey confirmed this IQP group's assumption that in order to present scientific information to the public in a comprehensive way, the scientist must tailor his presentation to meet the standards (subject matter expertise) of his particular audience. The audience gauging section of the website will breakdown the results of this IQP group's mini study (the survey) by demographic which will help scientists gain a better understanding of the public's scientific comprehension level. The website will also contain responses from the interviews conducted at the Museum of Science, Boston. These responses give advice on engaging the layperson in scientific presentations. Finally, this section of the website will present helpful links for scientists to turn to for further information on audience gauging and tools to determine the public's general knowledge level based on demographics.

Because of the use of simple random sampling in the survey, these experimentally determined probabilities only apply to our sample. While these probabilities are only quantitatively valid for our surveyed sample, they are qualitatively useful for viewing trends in a population that contains our sample and approximate the results that would be obtained from a homogenous sample defined by our survey's largest demographic. They are therefore most useful in making statements about the public's awareness of the peer review process in academic writing for a similar sample group, which is described by the survey's demographic information. The same survey with a more diverse sample would have sufficient sample sizes of homogenous subgroups for stratified sampling with the above experiment performed on each stratum yielding probabilities valid for the experiment's population.

After the collaboration of all five of the group members' topics, a website is currently being created to aid in scientific education of the public and scientists. From our findings, the Internet does not contain any sources that incorporate all of these critical aspects of scientific education, so the creation of this tool will, in the future help to provide necessary information to scientists and the public.

The problems presented in the five topics that were focused on have been shown by survey method and interview method to be issues that cause trouble. They have not been dealt with properly in the communication of science to the public. The previous research that has been conducted is not helping to the required level that it needs to as to lessen ambiguity in scientific writing. The main theme amongst this IQP lies in a very basic premise: Scientists think differently than the layperson. Within this scientists need to understand that the language they speak is not one that the general public is fluent in. For a scientist to become an adequate writer they must understand that they speak a language that layperson does not understand. Scientific writing, like any writing should be engaging. Writing on the level of the layperson and making the work interesting by implementing a relation to most of the audience being engaged will start to make the writing correctly interpreted and properly conveyed. In the future this IQP group wishes for this interactive website to become a place that people visit and use frequently, and scientists refer to when they question the general public's level of knowledge. It is intended for the guidelines set forth by this Interactive Qualifying Project to influence and change scientific work and gear it more towards the general public's level of knowledge.

6. Appendices

Appendix A: Survey

"Dear *John Smith*,

Attached is a link to a quick 10 minute survey that my group and I have created to help aid us in completing our Interactive Qualifying Project at Worcester Polytechnic Institute. The survey will be completely anonymous. Nobody will know who answered what questions and in what way. You are not required to answer all of the questions on the survey although it would help to fully complete the survey. I hope that you have a little bit of time to complete this for us. Thank you very much for your time.

Project group member name and IQP Group"

IQP - Science and the Public

1. What year were you born?

2. What is your gender?

- Female
- Male

3. In what state or U.S. territory do you live?

4. Please describe your neighborhood

- Inner city
- Rural
- Suburban
- Country

5. What is your marital status?

- single, never married
- married
- divorced

- separated
- widowed

6. What is your approximate average household income?

[▾]

7. What is your race/ethnicity?

[▾]

8. What is the highest level of school you have completed or the highest degree you have received?

[▾]

9. Which of the following categories best describes your employment status?

[▾]

10. On a scale from 1 to 5, 1 being the least, how interested are you in science?

- 1
- 2
- 3

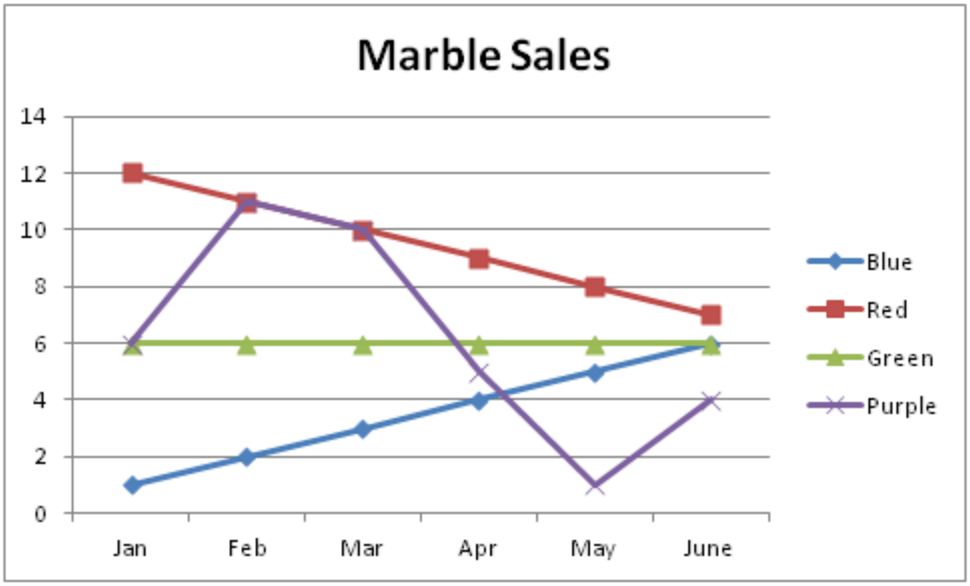
11. What is your science background?

- High school basic science
- College requirement
- College degree
- None

12. Which resource is most available to you?

- Interactive website
- Database
- Public Speakers
- Museums
- Books
- Magazines
- Print Outs

The following scatter plot depicts marbles sales over the course of several months



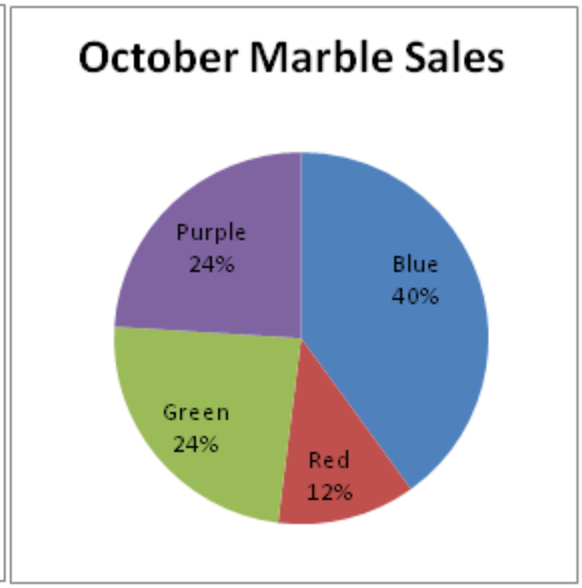
13. How many Purple marbles do you expect to be sold in August?

- ○ 5
- ○ 6
- ○ 7
- ◉ Cannot be determined

14. When will the Red marble sales fall to 0?

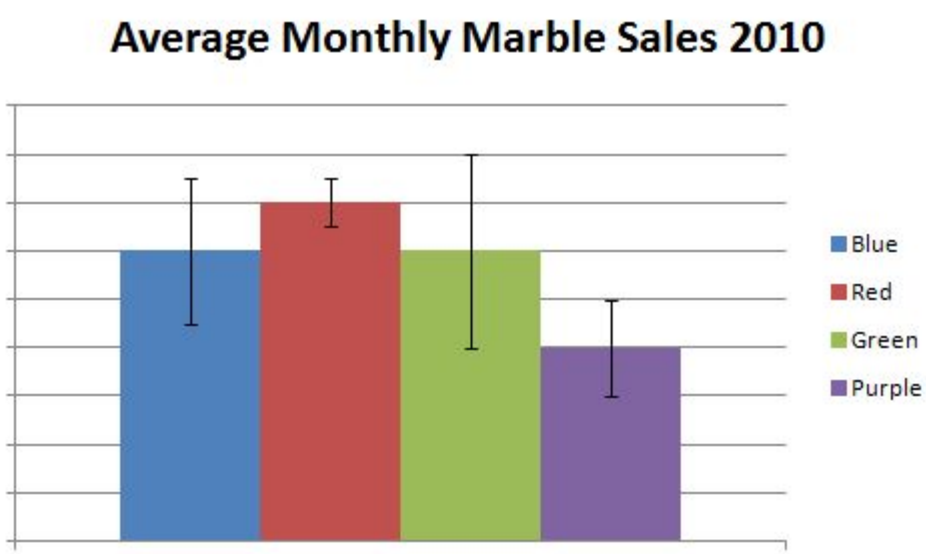
- ○ August
- ○ December
- ◉ Next January
- ○ Cannot be determined

The following pie charts depict marble sale percentages for September and October



15. Were more Purple marbles sold in September or October?

- ○ September
- ○ October
- ● Cannot be determined



16. Which color of marble sold the best overall in 2010?

- ○ Blue
- ● Red
- ○ Green
- ○ Purple
- ○ Cannot be determined

17. Which color of marble sold the most in a single month?

- Blue
- Red
- (selected) Green
- Purple
- Cannot be determined

****Posted excerpts are cited from online articles and do no express any opinions or findings from WPI and this Interactive Qualifying Project****

"Traces of sand avalanches are apparent in the north polar sand sea of Mars, one of the largest sand seas in the solar system, with an estimated area of about 325,000 square miles (840,000 square kilometers), more than six times the size of the Mojave Desert in California. This evidence comes in the form of deep wedge-shaped hollows several yards across in dunes that perch above fan-shaped deposits. Presumably sand that once filled the hollows cascaded down in avalanches, leaving the deposits."

18. What is the author saying about sand avalanches on Mars?

- Massive sand avalanches are occurring on Mars
- There are traces of sand avalanches on Mars
- There are probably traces of sand avalanches in the north polar sand sea
- Because of the evidence found sand avalanches on mars have definitely occurred and can occur again.

"Peer far enough back in the human family lineage, and you'll find a fishy ancestor that looked surprisingly like a shark. In fact, this now-extinct fish was among the first to split from sharks, whose bones are made of cartilage, to evolve into a line of tough-boned species that includes everything from bony fish to human beings. A new analysis finds that this controversial class of animals was more shark-like than expected."

19. What is the author saying about sharks and human beings?

- Humans evolved from sharks
- Humans may have evolved from a species that was similar to sharks, but an analysis is not enough to distinguish this.
- Humans may have evolved from a species of fish that broke off from a shark's lineage whose bones are made of cartilage.
- Because of this analysis we can say that humans are an ancestor of the shark.

"Researchers found that, over time, people who ingested more sodium had more uric acid and albumin in their urine. The higher the levels of uric acid and albumin, the more likely those people were to develop high blood pressure if they continued on high-sodium diets, the investigators found. Over the approximately six-year period of the study, 878 new cases of hypertension (high blood pressure) were discovered."

20. What is the author saying about the relationship between sodium and blood pressure?

- The people who have a high sodium diet are more likely to have high blood pressure
- The people who have a low sodium diet are also likely to have high blood pressure
- The people who have a high sodium diet for 6 years or more are more likely to develop hypertension.
- The people who have a high sodium diet for 3-5 years are likely to develop hypertension.

"Some people experience debilitating side effects when taking opioids, while others have no problems. Similarly, some people can take these medications for months with little chance of addiction, while others are at risk within weeks."

21. What is the author saying about the side effects of opioids?

- Some people are not affected by opioids while others are affected.
- Some people are not affected by opioids while others experience impairment of vitality and strength.
- Some people are not affected by opioids while others experience hindrance in their memory and attention span.
- Opioids eventually negatively affect people.
- Some people are massively affected by opioids while others are not at all.

"A "medical food" called Limbrel, which doctors prescribe to treat osteoarthritis of the knee, was linked to several cases of liver disease in a small study, but the effects so far seem to be rare and easily reversible."

22. What is the author saying about the relationship between the food "Limbrel" and liver disease?

- Limbrel is directly linked to liver disease.
- Limbrel is weakly linked to osteoarthritis.
- In the small study done it is shown that Limbrel causes liver disease but it is reversible.
- In the small study done it is shown that Limbrel rarely causes liver disease and it is reversible.

"We've observed a new particle, we have quite strong evidence. To ascertain its properties is still going to take a little bit of time. On the other hand we see that it decays to 2 photons for example, which means it is a boson (a particle with integer spin). This is roughly 130 times the mass of a proton."

23. What is the speaker saying about the properties of this "particle"?

- ( ) It is going to take more time to determine with certainty the properties of the particle
- ( ) The particle decays to 2 photons, it is a boson with integer spin and it has roughly 130 times the mass of a proton
- ( ) There is strong evidence that it's properties have been determined with certainty
- ( ) Both A and B

"We studied a number of other channels that were reported but these are less sensitive and the results are less conclusive at the moment."

24. What is the speaker saying in this excerpt?

- ( ) They studied a number of different sources but they were not good and the results do not help with the study.
- ( ) They studied a number of other pathways of information that were published but this information was less controlled and the results were not final and deciding at the moment
- ( ) They studied a number of other sources of information that were published but these sources were less authorized and the results were not valid at the moment.
- ( ) They studied a number of other people that were reported but these people were less sensitive and their results were not good.

I) Currently, avian H5N1 influenza, also known as bird flu, can be transmitted from birds to humans, but not (or only very rarely) from human to human. However, two recent papers by Herfst, Fouchier and colleagues in *Science* and Imai, Kawaoka and colleagues in *Nature* reveal that potentially with as few as five mutations (amino acid substitutions), or four mutations plus reassortment, avian H5N1 can become airborne transmissible between mammals, and thus potentially among humans. However, until now, it was not known whether these mutations might evolve in nature."

II) "Researchers have started to unveil the genetic heritage of Ethiopian populations, who are among the most diverse in the world, and lie at the gateway from Africa. They found that the genomes of some Ethiopian populations bear striking similarities to those of populations in Israel and Syria, a potential genetic legacy of the Queen of Sheba and her companions."

25. Which of the above excerpts refers to peer-reviewed research as a source?

- (•) I
- ( ) II
- ( ) Both
- ( ) Neither

26. Which of the following would be a referee in the peer review process of the research described in either article?

- ( ) Herfst

- [x] Experts in the field of influenza research
- [ ] The Queen of Sheba
- [ ] Kawaoka and colleagues

27. Based on the above excerpts, which article do you think is more likely to contain trustworthy and unbiased information?

- [x] I
- [ ] II
- [ ] Both
- [ ] Neither

Appendix B: Interviews

Scientist 1

Question 1) How would you describe your research or study?

Answer 1) "*We study proteins that have metal cofactors like iron nickel cobalt, structural biology like x- ray crystallography and other biotechnical techniques to try to understand how the proteins do what they do. A number of them catalyze a lot of challenging chemical reactions so we are really interested in understanding details of that chemistry.*"

Question 2) To what audience would you say that you were describing your lab study too?

Answer 2) "*Well, people I think with some background that understand what a protein or an enzyme a number of people…high school is changing a bit they are starting to do a bit of biochemistry so they can understand that a little bit more but some one would have to understand science to understand that.*"

Question 3) Now would you mind telling me how you would describe your research to an average person just walking down the street with high school level science knowledge (the average man)?

Answer 3) "*I'll say that inside your body there are proteins that do…help you live, that deliver oxygen from lungs to cells. Proteins are chemists inside the body that carry out different functions from digestion, all these kinds of things. Some of those proteins do some pretty amazing stuff they can convert one molecule to another molecule. We are interested in understanding, kind of looking at that molecular detail inside the body kind of zooming in to try to, to see and visualize these molecules doing this interesting chemical reaction."*

Question 4) How would you describe your study to a fellow scientist? Would you change not just the scientific wording but also the English vocabulary within your explanation?

Answer 4) "*The first blurb, even a lot of smart scientists, who knows what their science background is so I won't go in depth until they say…"Oh I know about that.""*

Question 5) As a scientist I understand that research sometimes is only done to help benefit other research or to better understand a small portion of a bigger picture, BUT how would you justify to the common man that your research is beneficial to society?

Answer 5) "*Yeah well there are different projects that have different applications, the research in my lab, the proteins have metals in them, some of them have medical applications and some of them have environmental applications so from perspective of the environment we study these proteins that have metal catalysts, they have cool metals they have nickel they have iron they have cobalt, sort of the middle part of the periodic table and these enzymes come together and* *they can take two molecules of CO2, greenhouse gas, and they can convert it to an acetate molecule which then can be used by an organism to get energy in one pathway or make other kind of biomass and a lot of people now are interested in pathways that take CO2 out of environment because it is a common pollutant that's associated with say coal or other kinds of generation of energy and make it into another molecule that could actually be a biofuel. So you are taking a pollutant greenhouse gas and making it into something that can be used to create energy. And microbes do this, they can live on CO2 we understand exactly what they are doing so we are looking at the enzymes trying to see exactly what they are doing exactly how they work and how you can then, we do the basic research but there are people at MIT in chemical engineering that we are collaborating with that they try to engineer that micron pathway to generate useful products, so that's one application."*

Question 6) Are their any words in the English language that you try to avoid when writing scientific work or publications?

Answer 6) "*Things like something is proven, proven is a dangerous word, you have a theory or a hypothesis or you think you understand how something works and that is all based on the data that is available at that time. There could be a new technique that comes out where you would say…wow we weren't seeing the big picture here. To say something is fact something is proven…is not true it is the best you can do at that time. Those kinds of words are dangerous that can lead to non-scientists and look at the process and get frustrated. In science you have models they are never really fact. Stay away from words that suggest it is a done deal. I like to use significant when there is data to support its use, when there is a big enough difference between what you're studying and the negative control. SIGNIFICANT=STATISTITICS. There* *are words like that that have common meaning but actually have more correct scientific meaning. There is a more scientific definition of trend. If you plot your data and there is a significant trend or correlation, correlation is another word that has kind of a general meaning and a scientific meaning. One wants to be careful with words like that. Representative is another one. You often show representative data. To me representative means normally what you see or average. Some people will in papers show an EM image, and they say this is representative, but it is really the best they've ever seen that is not representative. Scientists even use that word incorrectly. It should mean normal average and it's often just said I'm going to show you some data now and I'm going to use the word representative but it's actually the best data. That's one of my pet peeves."*

Scientist 2

Question 1) How would you describe your research or study?

Answer 1) "*Basically we are looking at the molecular mechanisms that underlie the development of insulin resistance in diabetes. We are doing that by studying mice that have a systemic deletion of the gene klf-15, which encodes a transcription factor."*

Question 2) To what audience would you say that you were describing your lab study too?

Answer 2) "*Probably not a lay audience, because I used some terms that a lay audience would not be familiar with."*

Question 3) Now would you mind telling me how you would describe your research to an average person just walking down the street with high school level science knowledge (the average man)?

Answer 3) "*I guess I would assume some basic knowledge; we are looking at the role of a gene called klf-15 and basically what role it plays in the development of type II diabetes.*"

Question 4) How would you describe your study to a fellow MIT scientist? Would you change not just the scientific wording but also the English vocabulary within your explanation?

Answer 4) "*I would describe it the same way I did in the beginning.*"

Question 5) As a scientist I understand that research sometimes is only done to help benefit other research or to better understand a small portion of a bigger picture, BUT how would you justify to the common man that your research is beneficial to society?

Answer 5) "*It's basic science research, so at this point whatever I learn about klf-15 and its role in diabetes I cannot apply in a clinical setting but what I am doing right now is trying to find out this data for in the future perhaps when people have the kinks worked out in gene therapy and potentially they can use virus or some other delivery system so they can increase or decrease the levels of klf-15 in humans then at least well have all of the background info on what klf-15 does. We are just laying the foundation.*"

Question 6) Are there any words in the English language that you try to avoid when writing scientific work or publications?

Answer 6) *"One thing you want to avoid, this is novel, if it weren't novel you would not be publishing it and other times you should avoid saying this is really interesting, obviously it should be interesting. For instance you can use the word significant, for someone in the science field they view the word significant as statistically significant, but there is a more generic term in the general public but scientists see a difference between this group and that group. What does significant mean? If you haven't done the stats then not a heck of a lot. Make sure you explain the word."*

Scientist 3

Question 1) How would you describe your research or study?

Answer 1) "*I can certainly discuss one study where we are analyzing the importance of cytokines and cytokine signaling as well as lymphocytes and the development of inflammation of type II diabetes and the overall rate of development of type II diabetes and as well as the development of the symptoms that contribute to type II diabetes such as insulin resistance."*

Question 2) To what audience would you say that you were describing your lab study too?

Answer 2) *By virtue of the fact that I used words such as cytokines cytokine signaling and lymphocytes I would have to say that at a minimum I would have to be speaking to a higher level undergraduate who has at least taken immunology courses so that they would understand that terminology.*

Question 3) Now would you mind telling me how you would describe your research to an average person just walking down the street with high school level science knowledge (the average man)?

Answer 3) "*I would make it more general I would say I am studying how…certain key components of the immune system are actually involved in the development of type II diabetes."*

Question 4) How would you describe your study to a fellow scientist? Would you change not just the scientific wording but also the English vocabulary within your explanation?

Answer 4) *"It would be much more in depth, given the substantial body of literature, which now strongly correlates the development of inflammation in various organs with the development of insulin resistance during obesity and the development of type II diabetes we are specifically looking at the key aspects of the immune system such as cytokine signaling and in this particular case the importance of the receptor gamma in associated cytokines and their role in possibly either attenuating or accelerating the development of inflammation. Furthermore we are taking a more general approach in looking at the role of lymphocytes through the use of accommodation activation gene knockout mice and how lymphocytes may contribute to again either the protection from or acceleration of inflammation and development of insulin resistance. KEY DIFFERENCES I WOULD HIGHLIGHT WOULD BE: I would be more specific in terms of what key elements I would actually be examining both in terms of what I am describing in the immune system as well as what I am describing in context of type II diabetes because I think in terms of the general layperson when you describe such things as inflammation they start getting outside their realm of understanding what that means because I think the general public may not understand that fat tissue may be inflamed or liver tissue can be inflamed and how that might impact the function of those organs as opposed to inflammation understanding they could get a "rash." Certainly in context of the immune system because of its extreme complexity I don't think many people are aware how the immune system functions in terms of the* *interconnectedness between the adaptive and the innate immune systems and how lymphocytes play a role as the primary adaptive immune cell but also their ability to regulate the innate immunity."*

Question 5) As a scientist I understand that research sometimes is only done to help benefit other research or to better understand a small portion of a bigger picture, BUT how would you justify to the common man that your research is beneficial to society?

Answer 5) "*Well I think with any disease or model of disease the level of impact on society needs to be considered and if you look at the level of impact of diabetes and the fact that it is a worldwide fast growing trend that is going to contribute to astronomical healthcare costs loss of quality of life at earlier ages you have to realize that type II diabetes that we are facing right now is a very severe. Or I should say the study of type II diabetes and understanding the effects it has on the body are critical to try to mitigate that loss of quality of life and the resulting impact not just on a personal level but on a societal level. When considering healthcare systems. There a number of different levels it could affect society. Certainly if you consider the individual their quality of life will suffer with type II diabetes so our ability to understand exactly what is going on in these patients is critical. Certainly their family is going to suffer and they have to deal with these kinds of situations and take care of this individual when their quality of life starts suffering then you consider it at a community and society level and you realize our healthcare system as it stands now does not work as a pay as you go scenario but it is more of a you pay a certain amount and the overall society kind of shoulders the burden and at least that's how our current healthcare system works. So if you start having all these patients burdening the healthcare system that is going to burden everybody."*

Question 6) Are there any words in the English language that you try to avoid when writing scientific work or publications?

Answer 6) "*Make it less fluffy when writing a publication you do have a little bit more leeway in the discussion of writing your thoughts on what that data means, but you have to be careful when writing a grant or application if you start waxing and waning about how this data and this grant application and the results are going to be the next wonder drug to cure everything under the sun then that will turn reviewers off. In a paper you can say this is interesting this could have ramifications in the clinical realm because you are not….you already have the funding so you are at liberty to discuss what this data means because you have displayed all of the data where they can make their own conclusions. Certainly you must consider target audience when writing because you are dealing with a critical peer review system, people who are just as knowledgeable if not more knowledgeable than you in that field are going to be reviewing your work critically and seeing if this is important enough and seeing if this data were done properly that experiments were done in a rational efficient and well thought out manner and whether this data will contribute to the field. In contrast if I am writing an article for the general public then in that situation the level of critical peer review is going to be I think less but give that you want to be extremely more careful about how you are writing something so that you avoid any misinterpretation because generally for those types of articles you are not presenting all of the data you are responsible for summarizing that data to the general public and telling them why this is important or not because of that you now have a greater role of being impartial in terms of the interpretation of the data but also to try to put any type of personal spin on it which is not directly and questionably underpinned by the results of the actual data.*"

Scientist 4

Question 1) How would you describe your research or study?

Answer 1) *"General area of research is called inorganic synthesis, we bring new molecular substances into existence and we investigate their physical properties with an eye to eventually possible applications in areas like catalysis."*

Question 2) To what audience would you say that you were describing your lab study too?

Answer 2*) "Anyone who would be interested in the substances we are creating, (then asked about different age groups and levels of knowledge)—absolutely not science is timeless.*"

Question 3) Now would you mind telling me how you would describe your research to an average person just walking down the street with high school level science knowledge (the average man)?

Answer 3) *"Well we make molecules in the laboratory, which is a process, a little bit like cooking, we devise new recipes were making new molecular substances. Make an analogy to what a chef does in creating new dishes."*

Question 4) How would you describe your study to a fellow scientist? Would you change not just the scientific wording but also the English vocabulary within your explanation?

Answer 4) "*It would absolutely be more in depth."*

Question 5) As a scientist I understand that research sometimes is only done to help benefit other research or to better understand a small portion of a bigger picture, BUT how would you justify to the common man that your research is beneficial to society?

Answer 5) "*Well it depends on which project you are talking about I can tell you about one where we made a discovery recently of molecular recognition of reduction of the O2 molecule and this is potentially applicable in next generation lithium air batteries for automotive transportation.*"

Question 6) Are there any words in the English language that you try to avoid when writing scientific work or publications?

Answer 6) "*In general communication skills are very important and they are not trivial so it is indeed possible for people to invent ways for people to write about science in ways that are ambiguous or misleading whether intentionally or not, there is no limit for ways of doing that. Words like significant must be referenced in context. FINDINGS ARE SIGNIFICANT BECAUSE OF X, Y, AND Z.*"

Museum of Science: First Interview

Question 1) How do you gauge your audience?

Answer 1) *The education associates may not always know their audience's level of knowledge before presenting so the best approach to determine the audience's background on the material is to ask how familiar they are with it. From there it can be determined how in depth they need to go to cover the information so that the audience has a basic understanding. They said that when presenting to an audience, for anyone about twelve years old and up, they expect a "basal level of knowledge." For adults, especially, there is information that they expect them to already know. For example, words like "DNA" and "cell" are not considered new vocabulary that needs to be* *explained. The educators pointed out that it's extremely important to know a lot more background on the topic they are presenting than they will ever have to give. Also, as educators, since they are presenting the work of others and not their own, they are not always experts on the topic and so it is a very big deal to be able to say, "I don't know the answer," rather than give the audience false information.*

Question 2) Is there a set of rules or guidelines you follow when gauging your audience?

Answer 2) *There are several rules and guidelines that the educators at the museum follow. When presenting to an audience they never introduce more than three new scientific terms. They also follow a story arch. By creating a story that ties everything together and has a beginning, middle, and an end, the audience can stay interested longer. One of the educators said, "It sounds better if you're not just reciting facts and figures and things, but you're actually telling a story to someone so it makes it more, almost conversational." They mentioned it is sometimes good to have personal anecdotes too: "Using 'I' and stories isn't necessarily a bad thing. Being able to bring it back to yourself and making you seem more human is definitely a bonus."*

Props and demos are very useful when necessary and appropriate because it sticks in the minds of the audience members better. However, don't create props and demos for the sake of props and demos because it may just be overkill. At the museum they use "carrots" to keep the audience engaged. A "carrot" may be a prop, a demo, an interesting fact, or an activity that they mention at the beginning of a presentation and return to at the end to keep the audience's attention. One example they mentioned was of a presentation on weather and climate and at the beginning they mentioned that at the end of the presentation they would turn off all the lights and create their own lightning show. That was the "carrot" that kept the audience members around.

Another guideline to follow is that if a question is asked at the beginning of the presentation, make sure it is answered by the end.

A huge point the educators talked about was PowerPoint presentations. They said they were not very appealing to audiences and that, "researchers who don't have a lot of experience with laypeople will just read their slides." When they use PowerPoint presentations they put as few words as possible on the slides and try to use only pictures if they can. If scientists and researchers have issues with creating appealing PowerPoint presentations they can start off with a slide show that has all words and eliminate the words as they have pictures and stories to replace them with.

Question 4) If a museum visitor asked you to explain these 3 blurbs to them how would you simplify them?

Answer 4) *As far as actual vocabulary goes from the blurbs they mentioned the words "x-ray crystallography," "proteins," "catalyze," "biotechnical," "systemic deletion," "type I and type II diabetes," and "development" as words to explain more in depth. A key point that was mentioned was to start with a sentence to familiarize people with the topic being spoken about.*

Question 5) When training to become and educator at the museum of science what words of phrases from the English language aside from science terms were you told to avoid?

Answer 5) *Always void words that advocate specific decisions or are politically incorrect such as "gay." Aside from those do not use words like "created," "design," "stupid" "non-trivial," "important," even "good or bad." Also do not ever take sides.*

Question 6) In your experiences do you think scientists do a good job conveying their information to the public in a straightforward and unambiguous manner?

Answer 6) *Scientists do not do a good job conveying information to the public. Another thing they said they noticed was that a lot of the scientists do not want to be good at conveying their information to the public.*

Museum of Science: Second Interview (excerpt)

Question 3) Has there been studies on audience gauging and informal education and where can the group go to reference these studies?

Answer 3) *There has been a lot of studies done on audience gauging and especially informal education. The program manager was able to refer us to many sources of information for this topic. One source was Livinglab.org. Living Lab is a program where social science researchers conduct research on the floors at the museum and get trained on science communication by education staff. The Living Lab website is a useful tool to learn more about the program and its goals and initiatives. Informalscience.org has many projects, dissertations, journal articles, and conferences on audiences and informal education that is available online.*

Question 5) When training to become an educator at the museum of science what words or phrases from the English language aside from science terms were you told to avoid?

Answer 5) *The planning pyramid. When presenting information to the public verbally there is a pyramid that can be used to convey the information well. When presenting scientific information to an audience there will be a "bottom level" of information—information that everyone should understand, a "middle level" of information—information that some will understand, and a "high level" of information—information that very few will understand. This information should* *minimally be mentioned…the words hypothesis and theory are often used and many people do not understand the difference or how those words can be used correctly. Also "theoretically" has a scientific meaning and a general public meaning.*

"Scientific knowledge, like all knowledge, involves a disclosure (saying) of something to somebody. It deals with meanings that are social entities, embodied in language, altered or fulfilled in experience…" (Crease, Robert; Hermeneutics in natural sciences: Introduction)

Industry Medicinal Chemist 1

Question 1) So tell me a little about the research that you are conducting here.

Answer 1) *Simply put we work on the discovery of new medicines in its simplest forms. We search for small molecules that can cause some interaction involving unmet medical needs. We then strain the biological target for certain points of interaction and the strain a series of small molecules that interact with the target. We then try to optimize those small molecules weeds into safe and effective therapeutic agents.*

Question 2) What made you decide on devoting the time and research on this particular topic

Answer 2) *In industry, something that is known to affect the target like a natural product is where we begin. We would start with that natural product and begin to develop a reverse synthesis in order to synthetically synthesize it. From there we would try to improve it.*

Question 3) How is this significant to you or to others in your field?

Answer 3) *It's one of the few fields that you can immediately see a positive impact on human life. It's harder to see that quick of an impact on human life in other fields of chemistry.*

Question 4) Do you feel that the general public can understand your reasons for why you do your research?

Answer 4) *I believe so, they can see how medicine affects them in their daily lives. They are able to see and measure how better off they are with the discovery of new medicines.*

Question 5) Have you had any experience writing research proposals for grants before? In industry, is there a similar process for the receiving of funding like how in academia one requests funding by grants?

Answer 5) *Yes, you do have to argue for resources just like in academia. There is still a limited amount of resources available just like in academia. Your project has to be viewed as a top tiered project in order to get funding in order to pursue it.*

Industrial Medicinal Chemist 2

Question 1) So tell me a little about the research that you are conducting here.

Answer 1) *While other chemists the department work on the discovery of new compounds, I focus more on the scale up of intermediate compounds. The others are sort of on the leading edge while I work on pushing larger amounts of certain compounds forward in whatever synthetic sequence they have been working on while I work on optimizing the chemical reactions that happen at each step.*

Question 2) What made you decide on devoting the time and research on this particular topic

Answer 2) *For what I do, it allows me to worry more about just the chemistry involved without so much as trying to discover what molecules have what kind of biological effect on this particular enzyme in this particular location in the body. I just get to do chemistry.*

Question 3) How is this significant to you or to others in your field?

Answer 3) Scale ups are always crucial especially when you have a whole department working on just a single project. With everyone working only 2 or 3 steps in the chemical synthesis sequence at the time, everyone requires starting materials in order to do a wide variety of modifications to the compound in question. Also, in the grand scheme of things, medicine is a field that always needs good chemists and a field of research that could always use improvements seeing as we actually end up putting these chemicals into people.

Question 4) Do you feel that the general public can understand your reasons for why you do your research?

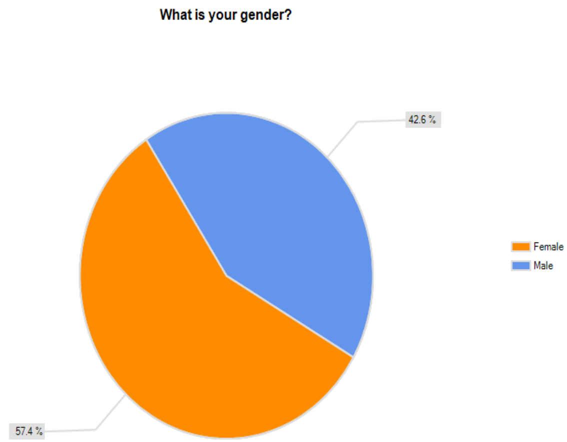
Answer 4) *Sure they can. You need building blocks in order to move forward. And I think most people can understand the benefit of medicine.*

Question 5) Have you had any experience writing research proposals for grants before? In industry, is there a similar process for the receiving of funding like how in academia one requests funding by grants?

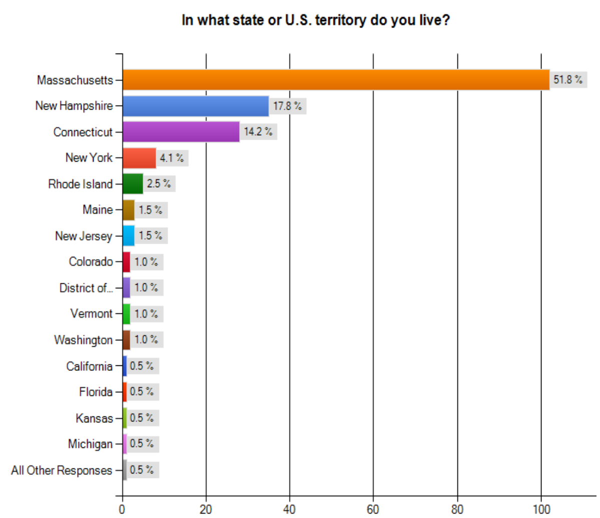
Answer 5) *Yes, we do. The company only has so much money to spend on only a handful of projects and we have to be able to show that there is some promise to whatever project or projects that we may have in mind and want to pursue.*

Appendix C: Raw Survey Data

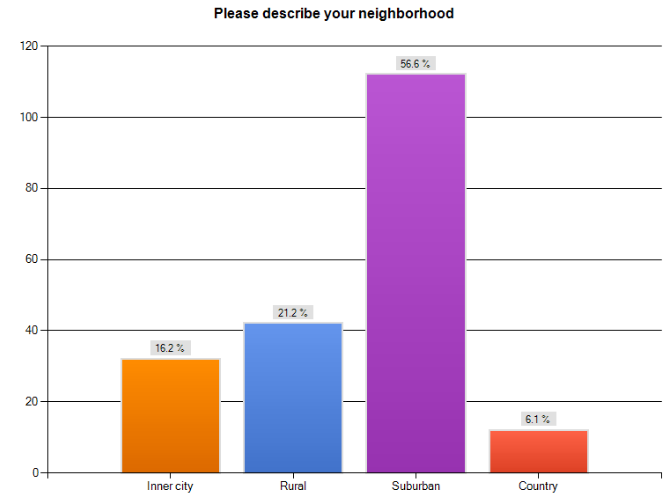
Question 2



Question 3



Question 4



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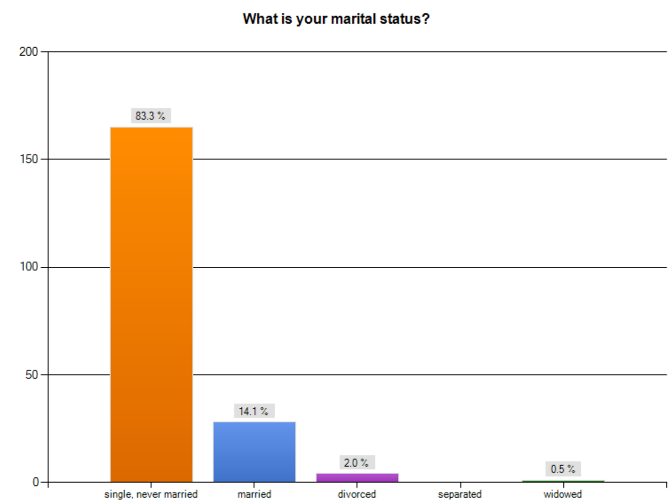

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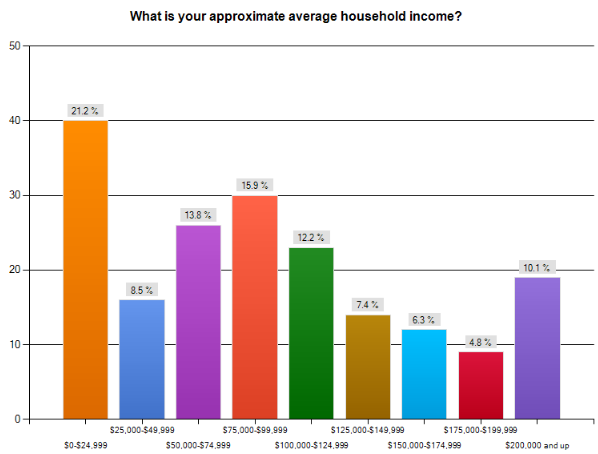

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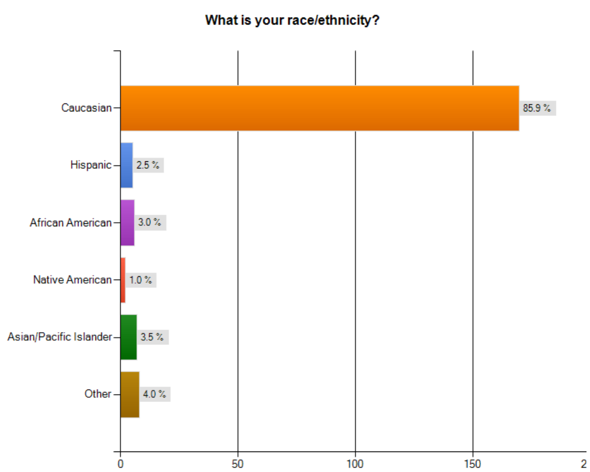

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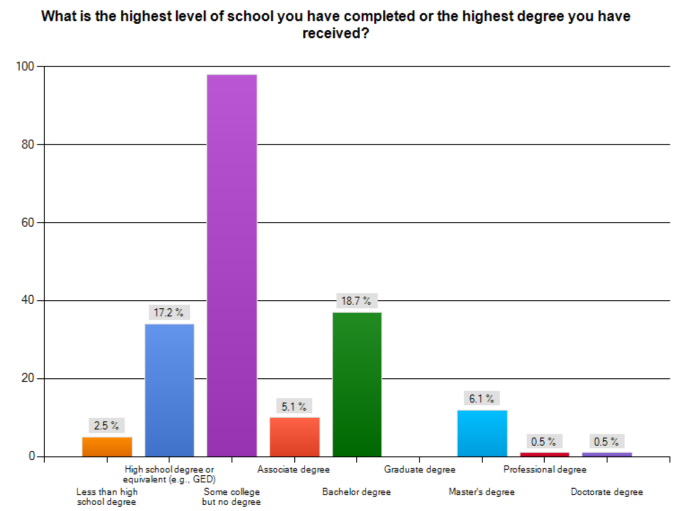

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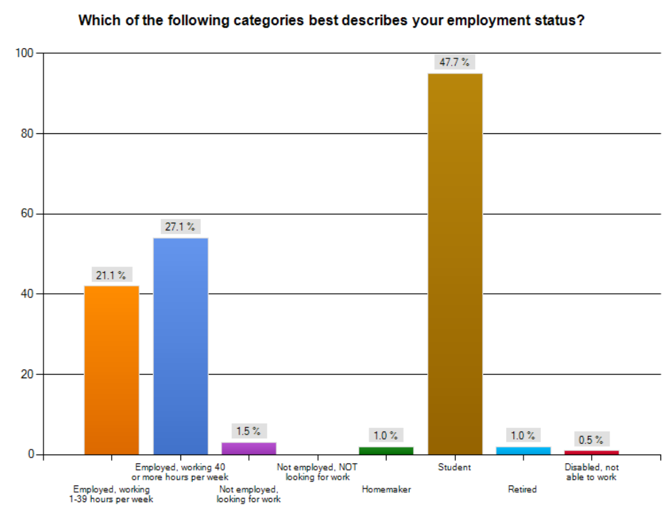

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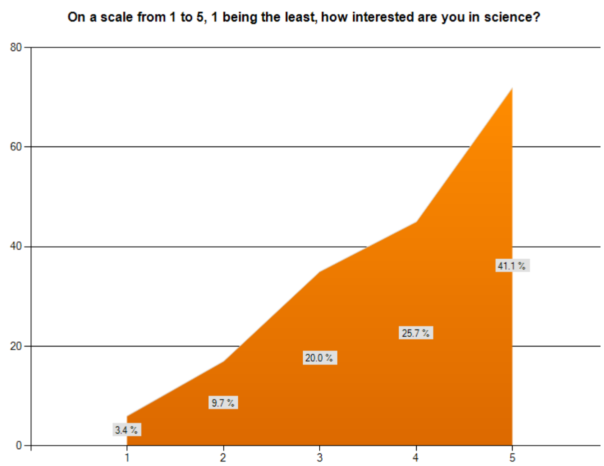

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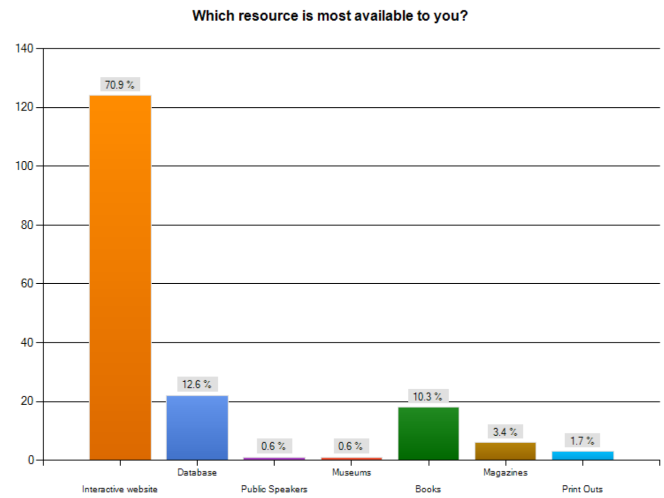

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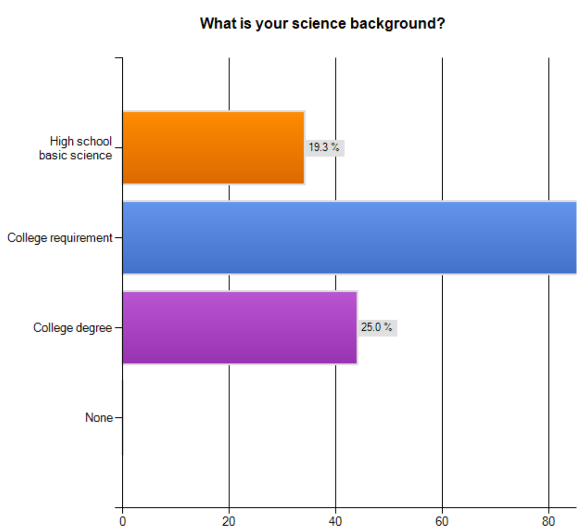

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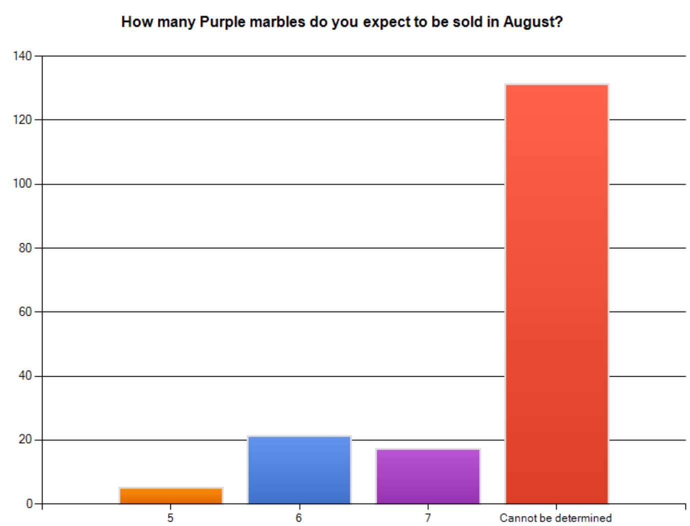

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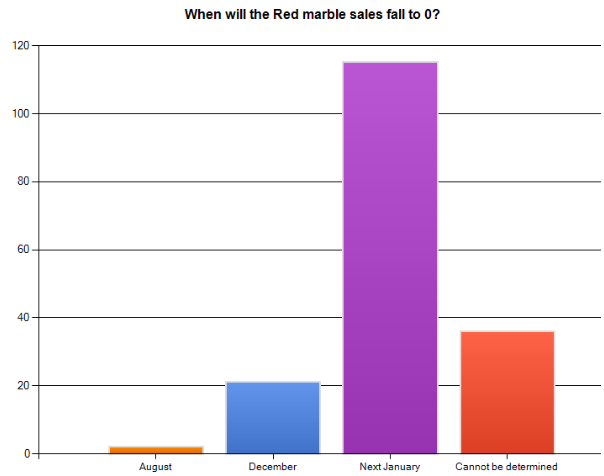

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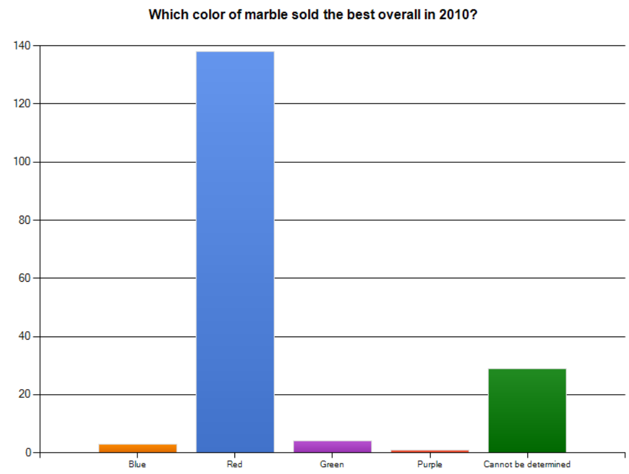

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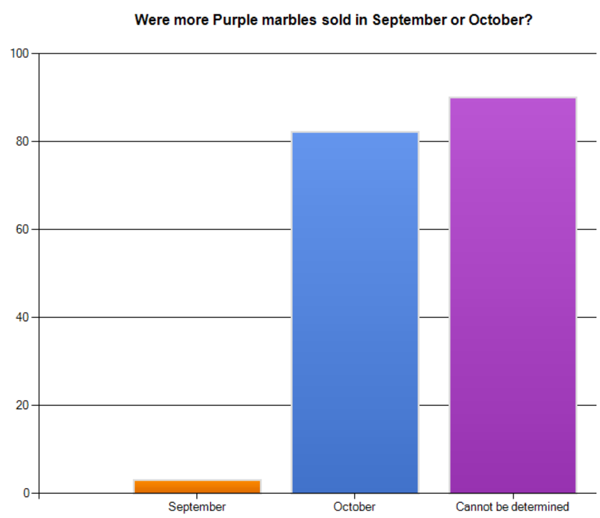

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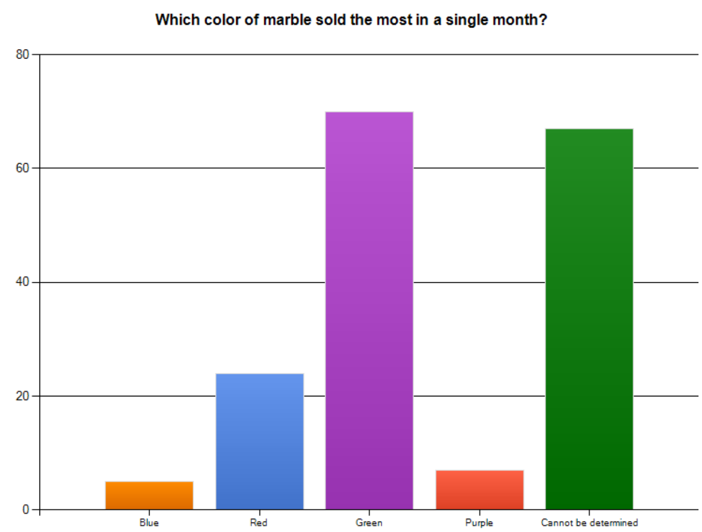

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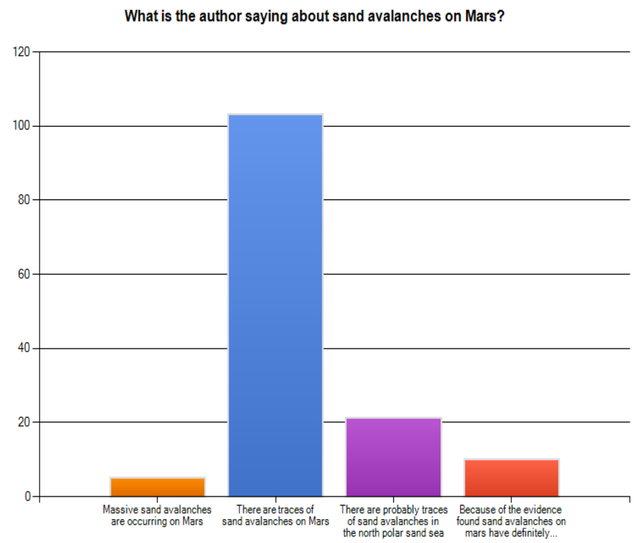

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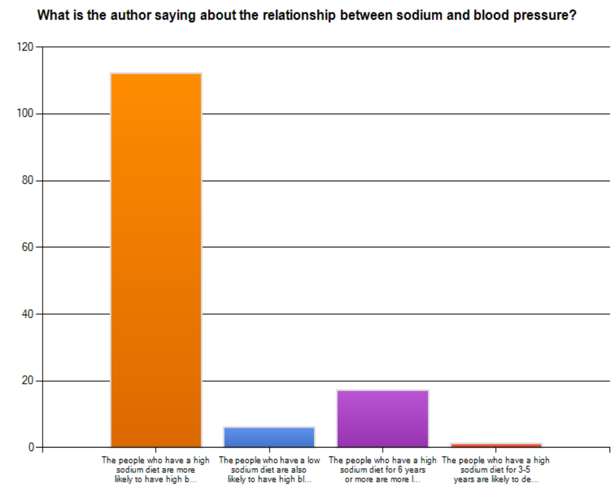

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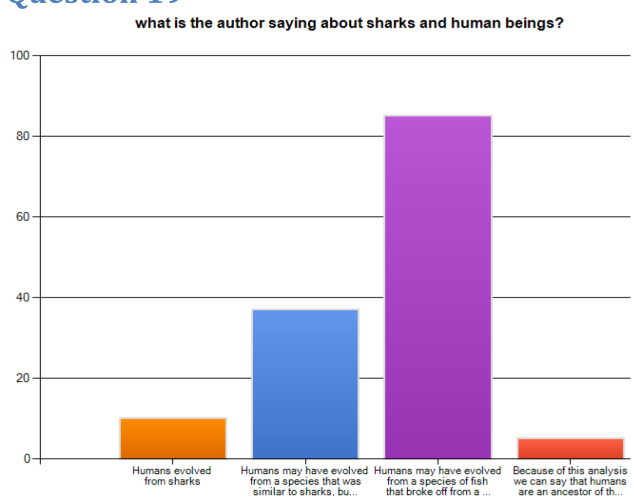

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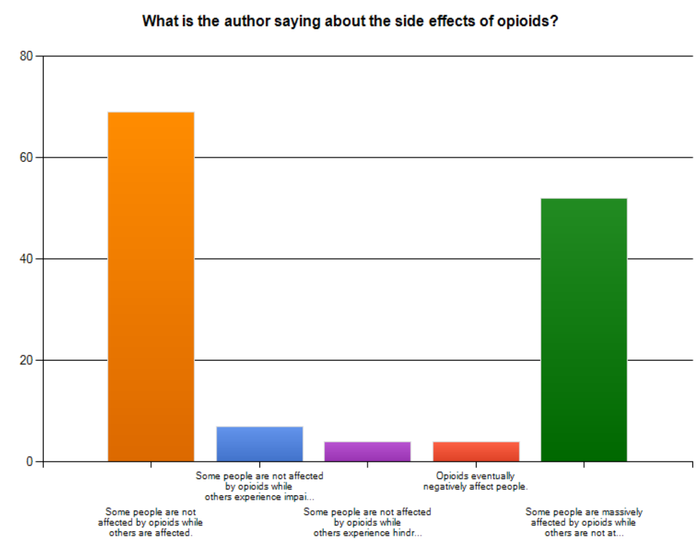

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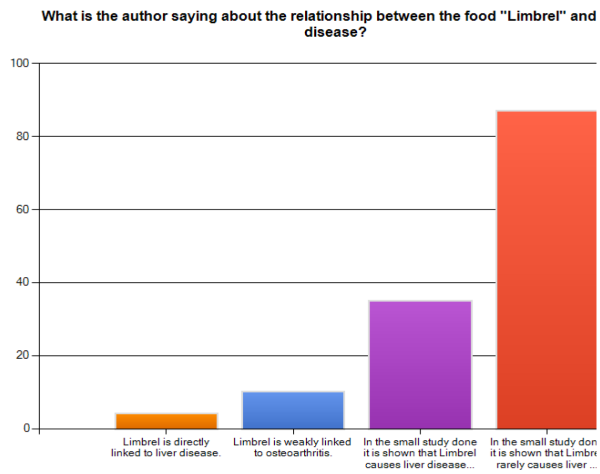

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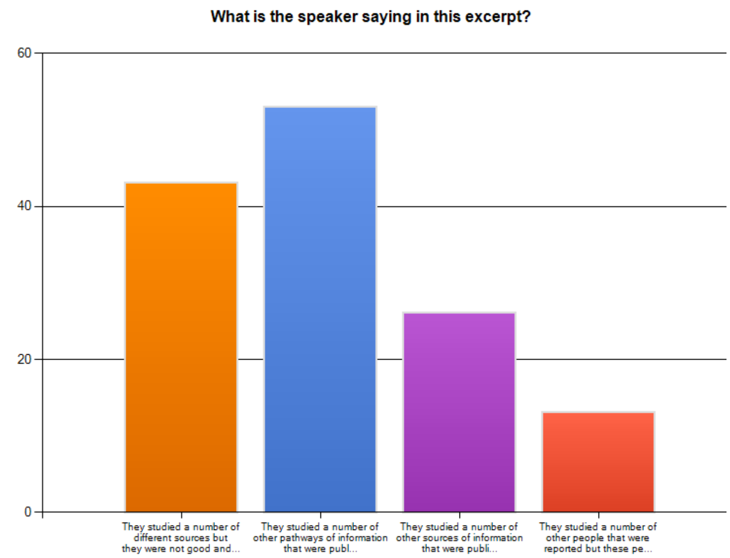

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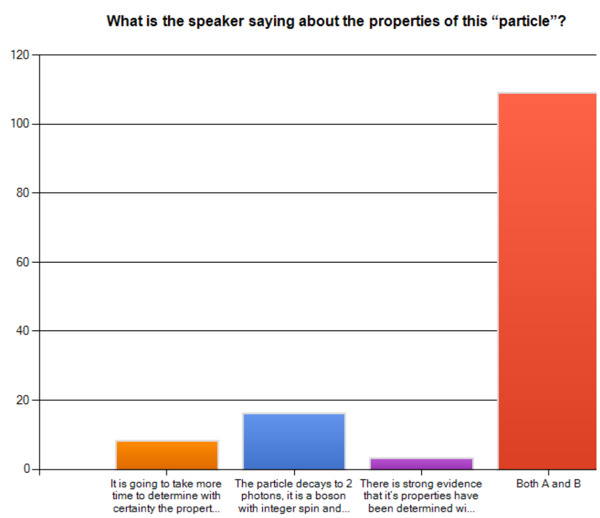

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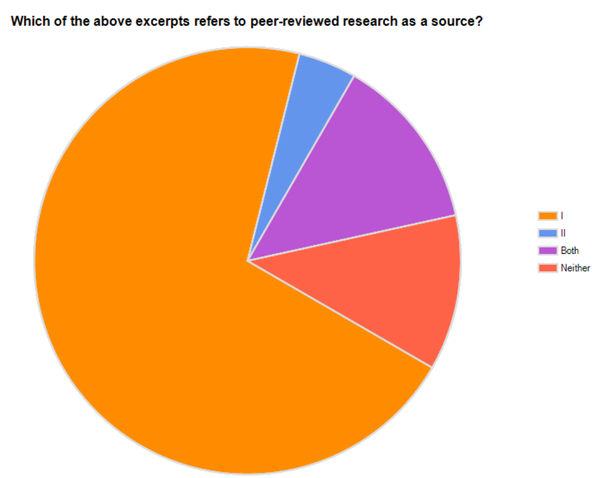

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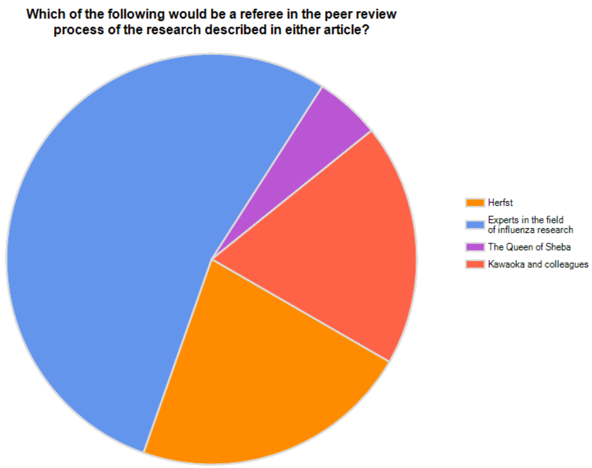

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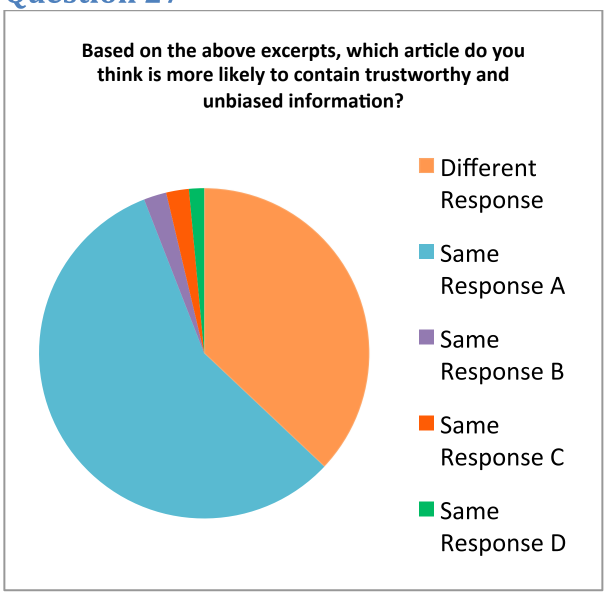
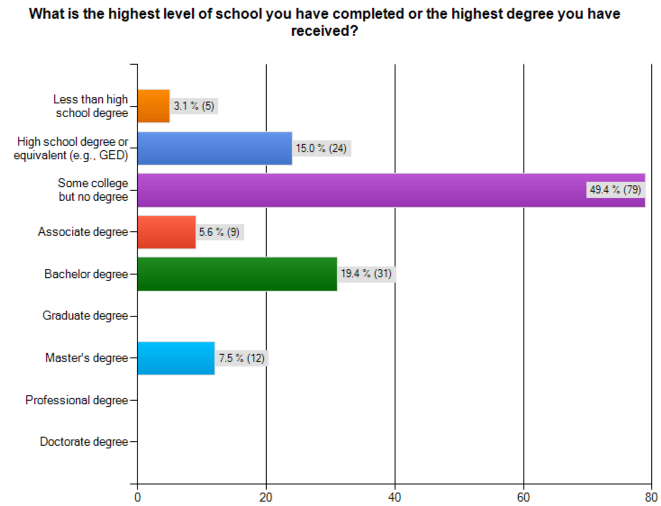
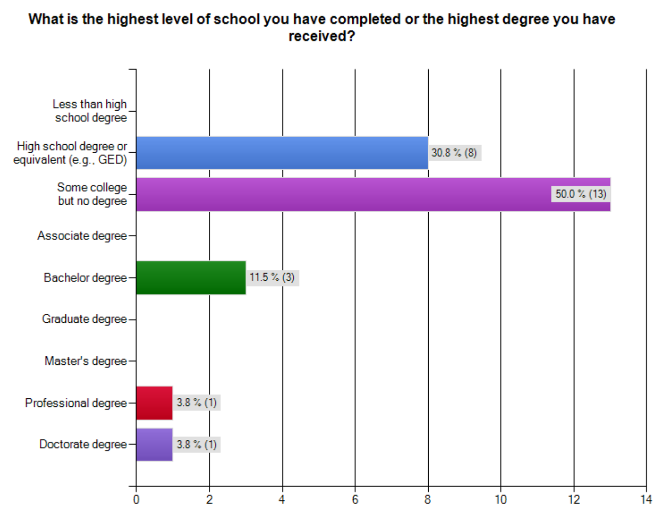


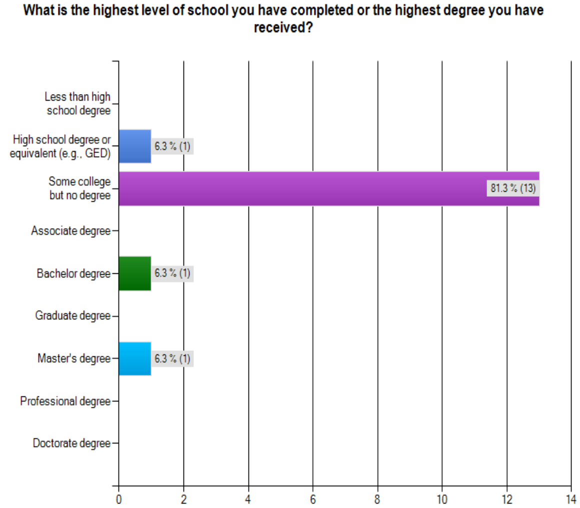
Education Levels of Caucasians in the Northeast



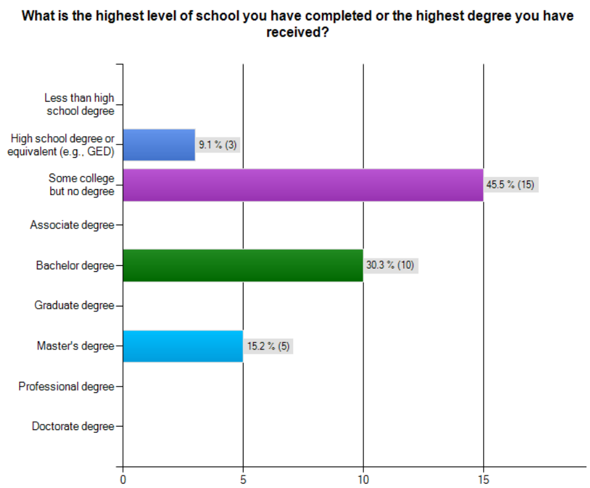
Education Levels of all other ethnicities living in the Northeast



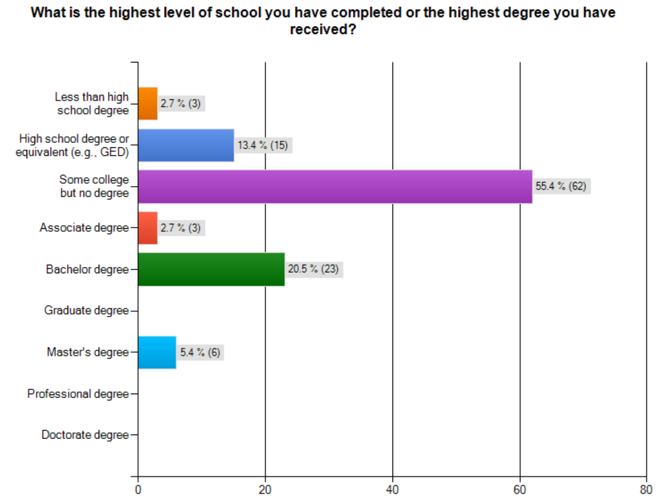
Education Levels of Caucasians scoring 100% on Public Comprehension section



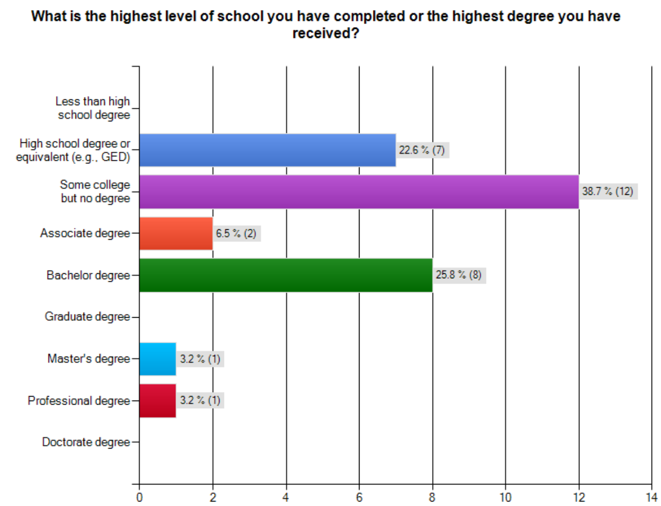
Education Levels of Caucasians scoring 100% on Misinformation section



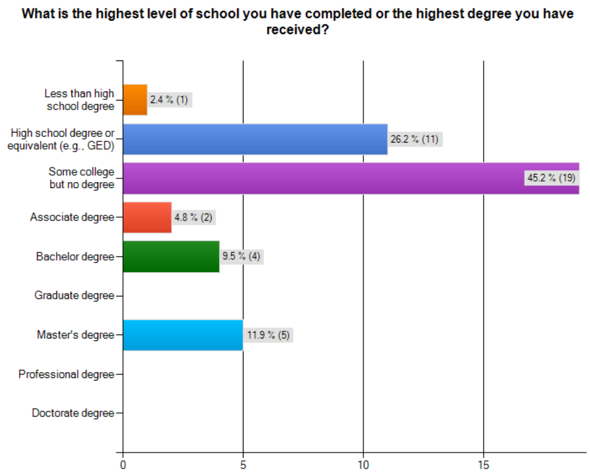
Education Levels of Suburban neighborhood



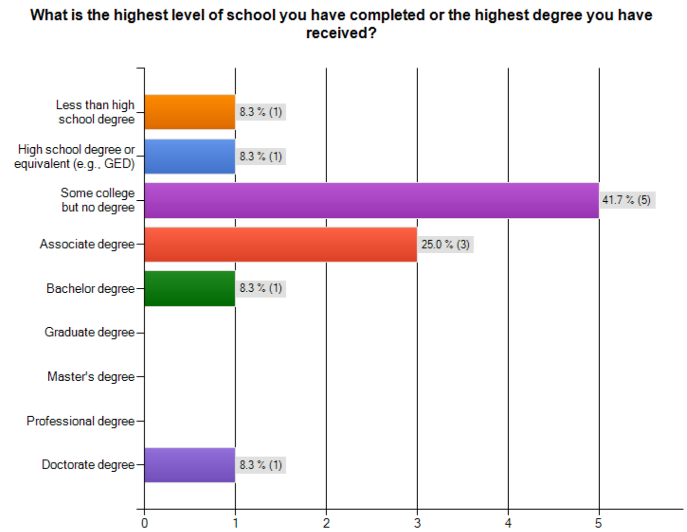
Education Levels of Inner City neighborhood



Education Levels of Rural neighborhoods



Education Levels of Country neighborhoods



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ENDNOTES

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[ii] Gautam
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