The Impact of a Socioscientific Issues Teaching Approach in an Undergraduate General Education Science Course

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This Dissertation in Practice explored the impact of deploying a Socioscientific Issues (SSI) teaching methodology in undergraduate general science education. It was motivated by my desire to accrue positive increases in educational outcomes, and to assess its efficacy in developing critical Socioscientific Reasoning (SSR) skills, for my students, and the students of faculty with whom I work. Students could potentially benefit from deploying those skills in the highly charged arena of the current debates surrounding the intersection of scientific knowledge, social issues, and public policy.

The SSI framework has had a significant impact in K-12 education over the last two decades in areas related to the development of functional scientific literacy. The framework is focused on contextualizing science content through real-world scenarios dealing with science, social conflict, and public policy. Its teaching strategies highlight the complexity of issues, the primacy of perspective-taking developed through discussion and productive argumentation, guided inquiry activities aimed at collecting and analyzing data, and skepticism through evaluation of sources and justification of claims. The central organizing principle of SSI is the development and growth of Socioscientific Reasoning – a reasoning method that includes all these components, but adds the social dimensions of tolerance, mutual respect, and moral sensitivity. K-12 research indicates that SSI contributes to positive gains in student content knowledge, reasoning ability, and scientific literacy, as well as understanding and appreciation of complex social situations.

In the last several years, some of the researchers behind the development of the SSI model have attempted to explore its efficacy in the undergraduate university setting. This has included the development and testing of a quantitative assessment tool designed to measure changes in SSR at the undergraduate level. It has been deployed in undergraduate general education science courses.

This study implemented an SSI teaching strategy in a general education astronomy course. It employed the quantitative assessment tool, and qualitative text-based sentiment analysis, to explore the impact on student SSR. Results raise questions about the usefulness of the current SSR quantitative tool. However, AI driven text analysis of student written discussions produces interesting results with actionable implications for my professional practice.

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Preface

It’s often said that it’s not the destination that matters, but the journey. It may be cliche, but it’s true. I’ve only made it to the end of this journey due to my wonderful family and friends, and I am eternally grateful for their support, encouragement, and companionship along the way.

To my advisor, Dr. Alan Lesgold, I owe this victory to you more than anyone. You threw me a lifeline when I needed it most. Your kindness, patience, and good humor are surpassed only by your deep knowledge and razor sharp intellect. I will never forget what you’ve taught me.

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To the Sibs – Julie, Jim, Margaret, Karen, Rich, and Sue – I love you all! What would I ever do without you? Thank you for getting me through – as you always do! Mom and Dad would be so proud of all of you.

To my amazing children, John Nicholas and Anastasya Marie, I love you to the Moon and back! I am so proud of the adults you’ve become. You keep me going every day, and I am so grateful for you both! You both have so much of your mama in you, and she would be so proud of you, too!

Finally, this work is dedicated to the memory of my wife, Christina Marie. You will always be the brightest star in my sky. I wish you were here with us every single day. *“I’d do the stars with you, baby, any time. Hey, babe, what about it?”*

1.0 Introduction

> *"I have a foreboding of an America in my children's or grandchildren's time…when awesome technological powers are in the hands of a very few, and no one representing the public interest can even grasp the issues; when the people have lost the ability to set their own agenda or knowledgeably question those in authority…If we are not able to ask skeptical questions to interrogate those who tell us something is true, to be skeptical of those in authority, then we're up for grabs for the next charlatan - political or religious - who comes ambling along."*
>
> (Sagan, C., 1996, p. 25-26)

Sadly, it can be asserted that it took only twenty years for Carl Sagan's fears to become a national reality in the United States. Nearly one year into the largest pandemic in a century, 1 in 4 Americans still say they will not get a COVID-19 vaccination under any circumstances, while another 30% say they plan to 'wait and see'. Just over 50% also admit that they do not wear masks in public, regardless of the evidence that masks are effective in limiting the spread of the coronavirus therefore protecting themselves and their community (Kaiser Family Foundation, 2021). At the same time, after what was hailed by government security organizations within the Department of Homeland Security as the most secure election in American history, some 36% of the general populace believe that the November 2020 election was not free and fair (Pennycook and Rand, 2021). This despite no evidence being presented, overwhelming evidence to the contrary, and some 60 election fraud cases being lost or dismissed by a range of courts including the U.S. Supreme Court. We live in a time of so-called “alternate facts” when the truth or falsity of claims to knowledge appears to be unmoored from facts, evidence, and reason.

Unfortunately, this statement also applies across a wide range of science related issues that intersect with public policy and have direct and immediate impact on the long-term health and well-being of society (Funk et al., 2015). Beyond the COVID-19 vaccination conundrum already mentioned, this includes areas such as climate change, biological evolution, childhood vaccinations, the use of genetically modified foods, and much more.

But the seeds of this issue were certainly planted much further back in time than the last few years. More than 35 years ago, when I was completing my undergraduate studies, and beginning my career as a science educator, my physics and astronomy professors and my fellow physics majors frequently discussed the public arguments over what was then called ‘creation science’ that were frequently in the pages of Physics Today and other publications. We also debated the merits of the recently published report by the National Commission on Excellence in Education, *A Nation at Risk* (1983). The overall consensus in our small department discussions echoed the shared common wisdom of the day. Clearly, the public understanding of science was rapidly declining. And, just as obviously, the K-12 schools – and more specifically the teachers in those schools – were failing to effectively teach science to American public-school students. In short, Americans were becoming scientifically illiterate, and public education was to blame.

Over my career, I’ve watched as this perspective has led to a plethora of federal and private non-profit science and STEM (Science, Technology, Engineering and Math) initiatives designed to improve science education in the United States. For example – Presidential Awards for Excellence in Mathematics and Science Teaching (1983), Project 2016 (1985), Science Education for Public Understanding Program (1987), Physics First (1990), National Science Education

Standards (1996), National Commission on Mathematics and Science Education for the 21st Century (1999), America COMPETES Act (2007), Educate to Innovate (2009), Change the Equation (2010), The Inspire Act (2017) – just to name a few (U.S. Department of Education, 2021). The list could go on for some length, and I've even had the opportunity to play an active role in a variety of NSF funded STEM initiatives that resulted in a variety of projects and publications over the course of many years. And yet, over nearly four decades, American's loss of both understanding and trust in science has seemed to grow almost unabated and the forecasts of *A Nation at Risk,* and the predictions of Carl Sagan, seem to be frighteningly prescient.

Yet, we as a society are more dependent on science and technology than at any time in human history (Pew Research Center, 2019; National Academies, 1993). With each passing year, the intersection points between scientific knowledge and understanding, and those of public interest and policy, continue to multiply rapidly. It is difficult to see how this combustible mix of ignorance and dependence can long be sustained (Sagan, 1996). Therefore, as a science educator, this particular issue has gnawed at me for a long time. Trying to understand the forces at work in the public understanding of science – or lack thereof – has been a driving force in my career. And, even more importantly, determining what, if anything, I could do about it in my own practice in both formal and informal settings, has been a common thread that runs throughout my work. These questions then, were the genesis of the investigations in this dissertation in practice which seeks to narrow this broad topic to the exploration of actionable research in my own teaching and consulting, and in my own place of practice.

1.1 Problem Area

The dilemma regarding the public's ability to negotiate the understanding of science and its importance for public policy is a complicated issue with many apparent contradictions. As we quickly see the first quarter of the 21st century drawing to a close, we find ourselves in a very surprising and confusing situation. With an intense focus on science and science education since the end of WWII, the U.S. has achieved a very high regard for science in public opinion. About 44% of Americans think highly of science and scientists, and express confidence in science as an institution. In fact, only the military is more highly regarded than the scientific community among the American populace (Funk, 2017).

Even more interesting, approximately 79% of Americans believe that science has made life better, healthier, safer, and more fulfilling. They trust scientists more than most other groups in society, and they believe that scientific research is important and deserving of significant funding. Impressively, these findings have been consistent for nearly 50 years (Funk, 2017; Allum, et al., 2008).

At the same time, when science provides information or conclusions that they do not agree with, Americans are fairly quick to turn on science. This is especially true with regard to areas where science and public policy intersect (Allum, 2008; Bauer, 2008). This has given rise to what has been called a 'science gap' between what the public accepts and what science presents as the current consensus on many issues (Jamieson et al., 2017). We find ourselves with a host of publicly controversial issues – i.e. socially controversial but not scientifically controversial – from evolution, and climate change, to childhood vaccinations, GMO-based foods, and many more. For topics such as these, large segments of the American public reject the overwhelming scientific evidence, and the findings and conclusions of scientists. Often the opinion gap between the percentage of U.S. adults who accept the current scientific consensus on science and technology issues that intersect with public policy and the scientists who do accept them ranges between 30-50 points (Funk, et al., 2015; Miller, 2004).

As the power grid crisis in Texas during February 2021 has so clearly demonstrated, as human dependency on science and technology continues to grow, our failure as a society to understand and apply scientific and technical information appropriately is likely to have severe long-term practical and social consequences (Bursztyn, et al., 2020; National Academies, 2017).

Unfortunately, this is also not just a passive problem. In other words, the problem exists not only due to issues such as a lack of engagement by the public with scientific topics, or poor communication by the scientific establishment. These are significant issues. However, the problem is also driven by misleading coverage of science-based issues – whether through design or ignorance – by the American media (Bursztyn et al., 2020). In addition, there are active attempts by partisan political, religious, and other cultural and social organizations to deliberately erode the public confidence in the scientific consensus by using cultural identity issues.

Two well documented examples of this have been the conservative Christian organization the Discovery Institute's use of their 'wedge strategy' to undermine the teaching of biological evolution in public schools, and the fossil fuel industry's active campaign to highlight and deliberately mischaracterize scientific uncertainty in order to plant doubt concerning anthropogenic global warming and climate change in the minds of the general public. These efforts have also been used to provide rationale for action (and inaction) by policy makers (Jamieson, et al., 2017).

A more recent example of the poisoning of the well with regard to the public understanding of science and technology leapt from the news headlines covering the Texas power grid collapse mentioned earlier. On February 18, 2021, the *Washington Post* news organization reported that Texas Governor Greg Abbott said in a national television interview that, "This (the power grid failure) shows how the Green New Deal would be a deadly deal for the United States of America. Our wind and our solar got shut down, and they were collectively more than 10 percent of our power grid, and that thrust Texas into a situation where it was lacking power on a statewide basis. ... It just shows that fossil fuel is necessary."

Yet, the governor's arguments were contradicted by his own Texas State Energy Department, which outlined how most of Texas's energy losses came from failures to winterize the power-generating systems, including the fossil fuel pipelines that were responsible for the majority of the State's energy supply. This, however, did not stop other politicians and some news outlets from echoing Abbott and repeatedly blaming clean energy sources for the crippling of the Texas power grid. Unfortunately, many Americans effected by this crisis were unable to sort scientific fact from self-serving political fiction. When the public and policy makers cannot even agree on the basic facts surrounding the intersection of science and society, it is extremely difficult to see how successful resolution of the problems could be possible.

With so many examples around us, anyone currently involved in science education is likely to find themselves confronted with the science gap and its associated implications. It has certainly appeared in my own experience, around such topics as climate change, the age of the universe, the Moon landings, and many more. I have attempted to address these issues in my own courses through the application of various strategies such as Nature of Science (NOS) instruction and best practices in STEM instruction (McComas, et al., 2000). Research (Jamieson, et al., 2017; Zeidler et al., 2002, 2005) has suggested that it may be possible through such efforts to provide instruction that can help to mitigate the factors that cause the science disconnect in the adult U.S. population.

Some of that research also suggests that this can be accomplished even at the undergraduate level, as opposed to the idea that it is too late to address such understanding at the college level (Romine et al., 2017). It was the desire to see if this applies to my own undergraduate teaching practice that has led me to investigate the teaching strategy known as the Socioscientific Issues (SSI) approach to science teaching, and that motivates, and is the focus of, this study. In short, I wanted to see what I, as a classroom instructor, can offer my students that may help them avoid the trap of the public science gap. I also am a faculty developer, supporting other instructors in their teaching practice. What I learn for my own teaching, I hope to also use to support others.

1.2 Problem of Practice

My problem of practice was to investigate whether it is possible to address the so-called 'science gap' that has been found in U.S. populace through the use of instructional strategies in my own undergraduate, general education science courses. I explored the impact of a specific instructional model that is designed to address a wide variety of factors that have been identified as relevant to the public's disconnect from the scientific consensus around the intersection of science-based problems with the implementation of public policy. These factors include scientific content, critical thinking, analysis of evidence, and the ability to engage in productive science-based argumentation and debate with those who may not share your specific cultural experiences or identities, in order to make actionable decisions that lead to problem resolutions.

Specifically, this Dissertation of Practice investigated a potential approach to overcome these factors that contribute to the public disconnect with science and technology by engaging my undergraduate general education students in a Socioscientific Issues (SSI) learning experience.

The intent is to cause them to engage intellectually, emotionally, and cooperatively with the disciplinary content, as well as with their fellow students, in order to seek solutions to potentially controversial public and social issues that actually matter to them and to their communities.

In this study, I applied an instructional paradigm that has been proposed for understanding and countering the factors that help create the science gap (Zeidler, et al., 2005). The SSI model offers a different framework from previous deficit and cognitive models for improving the public understanding of science. These earlier models, which are explored in the literature review, tended to focus on some, but not all, of the potential contributing factors. For example, focusing on content knowledge and application skills only. Or, in other cases, only addressing cultural and identity issues among students.

The SSI theoretical model, on the other hand, views emotional engagement with “things that matter” to people and groups as a way to *motivate* science learning and understanding and, potentially, the acceptance and application of scientific consensus - all in the interest of solving meaningful, real-world problems – i.e. advancing scientific literacy (Sadler et al., 2007; Zeidler et al., 2005; Zeidler & Kahn, 2014). According to the National Science Education Standards, “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (National Academies, 1996).

To this end, SSI is an evidence-based framework for modeling and addressing real social issues that include a significant scientific or technological component in the classroom. It is focused on potential student gains in discipline specific content knowledge as well as the understanding of the nature of science, and the application of scientific concepts and reasoning to solve real-world problems (Sadler et al., 2007; Zeidler et al., 2005; Zeidler & Kahn, 2014). It does this through a *positive* lens, viewing emotional and philosophical conflicts as a starting point for engagement, not an ending point. It recommends engaging differences directly, rather than maneuvering away from them.

In seeking these positive gains for my students, through this Dissertation of Practice I used an SSI teaching approach to engage my students in what I hoped were personally meaningful, and potentially controversial, real-world problems that caused them to actively engage with the issues. For example, SSI addressed a socioscientific issue such as anthropogenic global warming and climate change by asking students to learn relevant scientific content and then engage in meaningful interactions with each other in an attempt to reach a consensus concerning how to apply that knowledge to solve specific problems cause by climate change. SSI is a form of guided inquiry that shapes student interactions through meaningful, open-ended questions that require thoughtful responses and may engender disagreement and debate among the students. The goal is to reach a deeper appreciation of the content and the problem by being able to understand and appreciate the different perspectives that students bring to the issue. In doing so, students come to understand what they know about a problem, how they know it, what different ways people approach the issue, and what is most likely to lead to consensus and resolution.

1.3 Inquiry Questions

This Dissertation of Practice investigated a Socioscientific Issues (SSI) teaching approach used to engage students in meaningful, real-world problems that often involve conflict related to group identity issues and other socially based conflicts. Sadler and Zeidler (2004) flesh out a working definition of SSI as involving the deliberate use of scientific topics that require students to engage in topics that are usually socially controversial in nature. They require a degree of scientific reasoning, as well as moral reasoning, or the evaluation of ethical concerns, in the process of arriving at decisions regarding possible resolution of those issues. The intent is that such issues are meaningful and engaging to students, require discussion, and the use of evidence-based reasoning, and provide a context for understanding scientific information (Sadler & Zeidler, 2004).

Using this understanding of SSI, this was action research that investigated the following research questions as they apply to my own undergraduate science teaching practice:

Inquiry Question 1. What specific changes, if any, occur to students' awareness, attitudes, and beliefs regarding scientific knowledge and process when they engage in a Socioscientific Issues approach to studying science?

For this study, the dimensions of awareness, attitudes, and beliefs were evaluated through the five aspects of Socioscientific Reasoning (SSR) - Complexity, Perspective-Taking, Inquiry, Skepticism, and the Affordances and Limitations of science, where these terms are defined as follows by Romine et al. (2017):

- <u>Complexity</u>: the ability to perceive and reason through the complexity inherent to SSI.
- <u>Perspective-taking</u>: the ability to analyze an issue and potential solutions from the perspectives of different stakeholders.
- <u>Inquiry</u>: the ability to recognize information that is not available regarding an issue as well as the ability to consider ways in which that information may be generated.

- Skepticism: the ability to identify potential sources of bias that may influence information or the presentation of information about an issue or potential solutions.
- Affordances & Limitations of Science: the ability to determine how scientific knowledge and processes may contribute to the resolution of an SSI and to recognize dimensions of the issue that cannot be addressed by science.

This study used an existing, validated instrument created by Romine, et al. (2017) that measures the first four of these aspects – complexity, perspective taking, inquiry, and skepticism.

Inquiry Question 2. How do students understand and engage with socially relevant scientific course content when using an SSI approach in an undergraduate course?

In this context, 'engagement' refers to the exploration of real-world problems, the recognition of social dimensions, risks and benefits, and application of ethical considerations, as well as the ability to use multiple perspectives in order to support reasoning, argumentation and decision making (Topçu, et al., 2018). This was quantified through the application of the same core SSR Aspects as defined above – complexity, perspective-taking, inquiry, and skepticism.

2.0 Review of the Literature

When culturally or socially controversial issues such as the age of the universe, cosmic and biological evolution, and climate change arise, the general public often cannot, or do not, apply scientific information or processes to the real-world problems and implications associated with these topics (Bauer et al., 2007; Bauer 2008, 2009). Traditionally, this failure to grasp, accept, and/or apply science has been largely attributed to a cognitive deficit model, i.e., a lack of scientific knowledge and critical thinking skills which have resulted from poor science education (Miller, 2004; Allum, et al., 2008). As a result, the public-school system – and especially public-school teachers – have been routinely blamed for this situation.

The vast majority of educational initiatives undertaken in the U.S. to address this supposed lack of scientific literacy have been predicated on this deficit paradigm (Kahan, 2007; Sadler et al., 2004). In the last decade however, the deficit model has been joined by an additional model in an attempt to understand the science gap. This paradigm is called the Cultural Cognition model (Kahan, et al., 2011). This model suggests that rejection of scientific consensus emerges not from a deficit of scientific information, but instead from cultural identity issues among the members of the public (Kahan et al., 2011; Jamieson, et al., 2017). The model describes individuals' and groups' engagement with personally significant, real-world problems as an *impediment* to the understanding and acceptance of scientific consensus because emotional issues bring group differences and conflicts to the fore. Cultural identity and group membership trumps scientific information in the competition to win acceptance (Kahan et al., 2011), (Jamieson, et al., 2017). For example, under the Cultural Cognition framework an individual perceives a question such as, "do you accept climate change?" to actually be the question, "who are you?". In order to answer such a question, the individual does a subconscious cost benefit analysis for the question. Instead of wrestling with scientific information and its application, they instead are trying to determine what they personally stand to gain or lose from the proposition. A person living in rural Georgia, may decide that to “believe in climate change” carries no immediate benefit to their life. However, they calculate that such a stance might immediately alienate them from family, friends, their church, their political community, and their wider local community. In their calculation then, the choice is easy. It is far easier, and less socially costly, to listen to their in-groups and deny climate change rather than to accept the scientific consensus (Kahan et al., 2011; Jamieson et al., 2017). Note that the Cultural Cognition model is certainly supported when the public is confronted with issues that are either too complex or too remote for them to easily understand. However, because the central decision is about personal identity and the associated costs and benefits, not scientific reasoning, even individuals with high science literacy are susceptible to the rejection of scientific consensus that does not support their calculation (Jamieson et al., 2017; Funk et al., 2017).

Interestingly, these two frameworks – deficit and cultural cognition - both use a negative lens to evaluate the problem of the science gap. The deficit model is focused directly on failure – the failure of students, the failure of teachers, and the failure of the American educational system in general. The cultural cognition model rejects the deficit view and is bolstered by research that indicates that even individuals and groups with a significant and sophisticated understanding of science will reject scientific consensus when it conflicts with their personal identities. This model instead frames emotional, philosophical, and cultural issues as the *barriers* to scientific literacy that cannot be easily overcome. For this reason, the Cultural Cognition model recommends steering *away* from these direct conflicts in addressing science education (Kahan, 2007, 2011). For example, if you are trying to address the impact of climate change in a coastal community, work assiduously to avoid any mention of climate change or global warming. Instead, steer the discussion to flooding mitigation. In other words, bypass the factors that have become entangled with cultural identity, and move directly to actionable solutions where consensus carries no challenge to identity or cultural and social price. However, this fails to address the very real possibility that long term solutions may depend on culturally controversial action, like limiting carbon emissions from fossil fuels.

The SSI paradigm is fundamentally different in that it addresses both scientific literacy issues as well as cultural conflicts in seeking to apply science and technology to the problems of real communities. In this way, it embraces the need to study content while navigating social and cultural conflict. Through the *positive* lens of SSI, what the other models perceive as barriers are now transformed into the tools for the hard, but necessary, work of establishing a broadly accepted understanding of the problem, analysis of data, and consensus on potential solutions and the actions needed to implement them.

2.1 General Findings

SSI Framework

According to Dana Zeidler (2003), the Socioscientific Issues (SSI) educational model is best described as "a sociocultural approach to teaching and learning about how moral and ethical issues can be a means to foster the formation of epistemological sophistication and character in the pursuit of scientific literacy". Sadler and Zeidler (2004), flesh out a clearer working definition of SSI as involving the deliberate use of scientific topics that require students to engage in dialogue, discussion, and debate. These topics are usually controversial in nature. In addition, they require "a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues. The intent is that such issues are personally meaningful and engaging to students, require the use of evidence-based reasoning, and provide a context for understanding scientific information" (Sadler & Zeidler, 2004).

Zeidler maintains that SSI is distinguished from both the standard approaches of Science, Technology, Engineering, and Math (STEM) pedagogy and the Science, Technology, and Society (STS) movement because the SSI movement focuses on empowering students to consider how science-based issues reflect moral principles in their own lives, as well as the physical, social, and cultural world around them (Zeidler, et al., 2005). He characterizes SSI as a research-based framework that provides a working model that shows how theoretical and conceptual links between key psychological, sociological, and developmental factors are central to science education. In other words, it addresses the concerns of both the deficit and cultural cognition paradigms while moving beyond their limited perspective.

The SSI model has shown indications of helping to counter the false narratives, and insincere argumentation patterns – sometimes called fake outrage – that can occur when scientific issues are viewed through cultural perspectives. Specifically, it allows an opportunity to address how individuals react when anomalous data is presented in conflict with their own scientific beliefs in contrast to how they react when the social, moral, and ethical beliefs held by others are in conflict with their own convictions (Zeidler, 1997).

Sadler et al. (2007), argues that students benefit from engaging in socioscientific inquiry in several ways. Research indicates that SSI can serve as a useful context for teaching and learning science content. Studies have also documented student gains in discipline specific content knowledge as well as the understanding of the nature of science. SSI is also seen as a way to address citizenship education within science classrooms (Sadler et al., 2007; Zeidler et al., 2005).

Science Literacy

The SSI framework emerged from the STS studies movement (Zeidler, 2016). However, SSI has received much attention as a more effective means of enhancing scientific literacy and developing informed citizenship (Zeidler et al., 2005). SSI investigates scientific literacy from a cross-cultural perspective. It explores students' epistemological patterns of reasoning about SSI and identifies potential interactions of cultural and scientific identity. This gives SSI a rationale with implications for research and pedagogy (Zeidler, Herman, et al., 2013).

Scientific literacy has been identified as a key goal of science education in the United States, as well as many other countries (Zeidler, et al. 1989, McComas, et al. 2000, NRC 2012), A person is considered scientifically literate if they acquire science knowledge essential for life, appreciate science information provided from media sources, hold appropriate attitudes toward science, and make reasonable decisions where scientific knowledge is relevant and needed (Zeidler & Kahn, 2014, Sadler & Zeidler, 2005, Sadler, 2004).

Within this definition, the ability for informed evidence-based decision making is crucial in achieving scientific literacy. Developments in science and technology bring about not only convenience and enrichment of our daily lives, but also many kinds of risks in society and, frequently, the knowledge and technology to recognize these risks and mitigate them. In order to achieve this, the public must be aware of these of risks, have access to appropriate scientific information, and be able to analyze evidence in order to make appropriate decisions.

Some examples of such problems that demonstrate an intersection of science, public interest, and public policy are fracking, mandatory vaccination, climate change, GMO based foods, and the nature of science education. These problems involve different kinds of risks, and lead to a wide variety of tensions among the public and policy makers (Jamieson et al., 2017). To deal appropriately with these socioscientific issues, a scientifically literate person should be able to understand science content related to the emerging SSIs, to make judgments on risk and uncertainty related to the issues and, finally, to make appropriate decisions on them. Since people could certainly reach different conclusion in spite of the same evidence, the SSI framework puts special focus on the process of decision making. SSI provides a theoretical framework to reconsider what a "functional view" (Zeidler, 2003) of scientific literacy entails, by examining how nature of science issues, classroom discourse issues, cultural issues, and science-technology-society-environment case-based issues contribute to habits of mind about socioscientific content.

Within this framework, SSI instruction looks at a number of essential parts that contribute to the decision-making process. These include:

1. Students demonstrating conceptual scientific understanding.
2. Students relating science content to the real world.
3. Students considering nature of science (NOS) themes associated with the issue.
4. Students focusing on risks and benefits of the issue.
5. Students focusing on social dimensions of the issue (e.g. political/economic).
6. Students engaging in higher order practices.
7. Students negotiating social dimensions of the issue.
8. Students assessing risks and benefits of the issue.
9. Students collecting and/or analyzing scientific data related to the issue.

10. Students confronting the ethical dimension of the issue.

Decision-making is the key competence taught in SSI education. Much of the research on SSI teaching and learning has dealt with students' reasoning as a process of decision-making and examined the various factors in decision-making listed above. In order for students to successfully make decisions they need to consider the given situation, identify the problems, establish possible options and criteria, collect data, evaluate each option, explore ethical considerations and, finally, choose the most appropriate course of action (Zeidler et al., 2014). SSI researchers also argue that thinking in scientifically responsible ways requires features of character. Responsible science depends upon the character of both the scientist and the public at large, and that character includes reflexive judgment applied to scientific knowledge and ethical standards. The process of decision making, therefore, is complex and should be understood from a holistic viewpoint (Zeidler, 2014; Kahn, 2014; Sadler & Zeidler, 2005; Sadler, 2004). My use of instruments, as described in the Methods section are based on those designed by Topçu, et al. (2018) and Romine, Sadler, et al., (2017) and reflect this holistic paradigm.

Nature and Process of Science (NOS)

While SSI and Nature of Science frameworks share a variety of goals such as demonstrating conceptual scientific understanding, relating science content to real world problems, the collection and evaluation of data, and even decision-making, they have major differences at their core. NOS views knowledge about science content, nature, and process as fundamental to the decision-making process. However, there exists significant research that indicates that scientific content, and the nature and process of science are not sufficient to guarantee appropriate conclusions and applications in problems where science and society intersect. Instead, issues of culture and identity must be taken into account in studying the decision-making process (Zeidler, 1997; Applebaum et al., 2010; Kahan, et al., 2007; Zeidler & Herman, et al., 2013; Jamieson, et al., 2017). In fact, it is often the case that greater knowledge of scientific content, and the nature and process of science, often leads individuals to become more extreme in their rejection of scientific consensus when it conflicts with what they perceive as their culture and identity. (Jamieson, et al., 2017) and (Zeidler, 2007), showed that science content knowledge is often treated as decontextualized information in the decision-making process and that students focused on this information irrespective of their views on the nature and process of science. Sadler, (2004), contended that NOS was related to decision-making but only in context, i.e., when the science connected to meaningful issues in students' own lives.

Additionally, students considered more diverse options in problem solving when that exercise occurred in the context of open-ended discussion and indirect instruction. Students also tended to use more information in open-ended tasks and specific instructional situations such as role-playing or solving real-world problems (Sadler, 2004; Chambers, et al., 2004). The SSI approach provides several strategies that helpful to enhance students' participation in decision-making by including issues of culture and identity. These include open-ended discussions, focused and relevant issues, collaborative argumentation (small group), case studies, and indirect instruction about appropriate decision-making strategies (Zeidler & Kahn, 2014).

Science, Technology, Engineering, and Math (STEM)

SSI also shares many characteristics with what has come to be known as "mainstream" Science, Technology, Engineering, and Math (STEM) instruction. These common characteristics include the key components that we have already seen in NOS. For example, demonstrating conceptual scientific understanding, relating science content to the real world, considering the NOS themes associated with the issues in question, and focusing on risks and benefits of the issue. However, Zeidler (2016), questions STEM-related science education goals, as typically represented and discussed in the literature. Specifically, Zeidler likens the current practice of STEM to a deficit framework. As we have seen before, the deficit model assumes that all issues related to the science gap, and similar concerns flow from failures. Failure on the part of students to learn and understand enough science content, failure of the STEM teachers to properly communicate this knowledge, and failure of the educational system to prioritize STEM content, among others.

For Zeidler, SSI is offered as an alternative conceptualization and instructional model to the deficit model of current STEM practices. In SSI, instruction is not focused on filling deficits – though, to be sure, content knowledge is still central. Instead, SSI uses a positive lens that leads to instruction that highlights what is already present. This includes students' perceived identities, their buy-in to relevant real-world issues, and their perspective on how STEM issues are culturally situated in their lives. Sadler, (2004) and Zeidler (2004), posit the ability to negotiate and resolve socioscientific issues as integral components of true scientific literacy. Importantly, these issues cannot be satisfactorily resolved without specific attention to cultural and identity-based factors.

Among the factors to emerge as relevant dimensions of socioscientific decision-making are moral considerations, personal experiences, family biases, background knowledge, and the impact of popular culture (Zeidler, 2014; Kahn, 2014; Jamieson et al., 2017). SSI, therefore, is designed to allow students to investigate their own conceptions of the nature of science and scientific content through their reactions to evidence that challenges their beliefs about those socioscientific issues.

Students are given activities and issues that cause them to reflect on their own beliefs, construct valid arguments, and defend their evidence, reasoning, and opinions. As might be expected, findings suggest that the reactions of students to anomalous socioscientific data (with regard to their preconceptions) are varied and complex. Research also indicates - again, as would be expected - that there will be notable differences in the reasoning processes of K-12 students compared to college students (Zeidler et al., 2002). However, there has been very little actual work done with undergraduates. In this regard, this study is therefore both particularly valuable for my own practice, and potentially of value to other university faculty with whom I work on the professional development of their individual teaching practices.

2.2 Literature Review Summary

The SSI paradigm provides an approach to teaching practice that may allow me to successfully address my problem of practice. As stated earlier, research (Jamieson, et al., 2017; Zeidler et al., 2002, 2005) suggests that it is possible to provide instruction that can help to mitigate the factors that cause the science gap, and that this can be done even at the undergraduate level. It is the desire to accomplish this in my own teaching practice that has led me to SSI. In a sense, I am interested to see if SSI can have an impact that might help to "inoculate" my students against some of the issues that drive the creation of the "science gap".

A survey of the existing literature has shown that, though there is a relative dearth of data concerning undergraduate teaching, SSI presents a workable model for my intended application. SSI posits that the key to eliminating the science gap is a science literate citizenry. SSI also accepts a clear definition of scientific literacy. A scientifically literate individual acquires science knowledge essential for life, appreciates science information provided from media sources, holds appropriate attitudes toward science, and makes reasonable decisions where scientific knowledge is relevant and needed (Zeidler, 2014; Kahn, 2014; Sadler & Zeidler, 2005; Sadler, 2004).

The model for SSI instruction is clearly defined in terms of the components that must be included to move students toward scientific literacy - demonstrating conceptual scientific understanding, relating science content to the real world, considering NOS themes that impact real-world issues, understanding associated risks and benefits of the issue, taking into account the personal, social, cultural, and ethical considerations that situate a problem in the community.

All of these factors are called into play to facilitate the core goal of teaching decision-making in the context of socioscientific issues. This learning objective is taught in the SSI framework by focusing on small group work around open-ended issues that are of importance to the students. But, finding a way to enhance students' abilities in decision-making requires that the instructor be aware of the factors influencing decision-making and their effects. This is the key to SSI. SSI separates itself from NOS, STS, and mainstream STEM instruction in that it does these things through a process that includes the students' personal experiences, cultural perspectives, their identities, and the associated intersectionality that each brings to the table. In this way, SSI provides a unique lens and a practical set of tools for implementation and success.

At the same time, although enhancing the ability of students for decision-making is regarded as a key component for achieving scientific literacy, there is little agreement about how to assess students' decision-making (Romine, et al., 2017). A large number of factors are connected to decision-making and tracking those factors can be difficult. I have decided to approach the assessment of the SSI instruction in my course through the use of a key instrument discovered in the literature and developed by leaders in SSI education. This is the case-study based

QuASSR (Quantitative Assessment of Socio-Scientific Reasoning) Pre/Post survey developed by Romine, et al. (2017). This instrument explores a range of socioscientific reasoning components and was specifically designed for, and validated in, the undergraduate science environment. In addition, I explored a qualitative data source through the textual analysis of student discussion posts. This analysis contains three important aspects – word frequency, basic sentiment analysis (positive/ negative/ neutral), and higher-level sentiment analysis in the form of using AI-driven coding models to rate the SSR Aspects detected in student dialogue. The details for all of these approaches are elaborated in the Methods section below.

3.0 Methodology

3.1 Research Statement

This Dissertation of Practice was structured as action research. Action research is a philosophical and methodological research approach frequently used in the field of education. It is designed to create transformative instructional change through the linked processes of gathering data, critical reflection, and taking action. Specifically, it is a research study meant to improve my own instructional practices and the learning outcomes of my students by focusing on the use of SSI instructional methods and the ways in which students respond to this type of instruction.

Action research is characterized by four features. These include having (1) a practical nature, (2) an emphasis on changing the system being investigated, (3) an iterative character that allows for adaptation during the research, and (4) the active participation of practitioners (Denscome, 2014). My inquiry fits this description very well. I am interested in systematically investigating possibilities for change within my practice to provide benefit for my own students. My working hypothesis is that exposure to SSI-based instruction would improve students' SSR abilities as measured by the QuASSR instrument.

While this dissertation was focused on my own practice, it could also contribute to the discussion concerning the use of SSI at the undergraduate level; an area of research that is relatively new and quite sparse in the literature. In addition, this dissertation may help in the further development of best practices in undergraduate STEM education at Pitt through the sharing and application of findings across the University through the Center for Teaching and Learning.

This project is part of a larger research trajectory that examines the most effective instructional models on which to base science communication strategies when personal identity issues conflicts with social expectations in membership groups such as families, churches, political parties, and local and regional communities. In our highly technical, but increasingly fractured society, we are in need of new tools and approaches that allow the objective evaluation of problems, the acceptance of evidence-based solutions, and the will and confidence to take action. Failure to address this issue is likely to continue to result in social and political gridlock, and severe long-term consequences. This study is meant to be one small contribution to this much broader research agenda.

3.2 Inquiry Design

This Dissertation of Practice used an action research, inquiry design in order to investigate the impact of an SSI teaching model that will enable me to take specific steps within my own courses in order to improve and advance my own teaching practice and, potentially, the teaching practice of other STEM faculty with whom I work as a faculty developer.

The SSI activities used in the course were created based on the design, and teaching and learning models, proposed by Sadler (2011) and Sadler et al., (2017). Specifically, this included the Common Ground model of SSI, and the SSI Teaching and Learning model. The scenarios and perspectives for the activities exemplified fundamental examples of best practices in the SSI tradition. This instruction model highlights the importance of designing activities with an eye to clear roles for students and teachers, as well as attention to the focus of the activity, the learning environment, and the teaching and learning strategies. In this way, the model is very similar to a variety of process oriented, inquiry-based learning approaches. This facilitated the modification of activities to fit the SSI approach.

The activities also used the common ground model that focuses on finding the intersection of multiple perspectives with the scientific approach. This model lends itself very well to issues such as climate change, which will be one of the topics that students investigate. In addition, the Teaching and Learning Model shows the simple, but critical, steps to be followed during the actual process in which the students are engaged (see Figure 1).

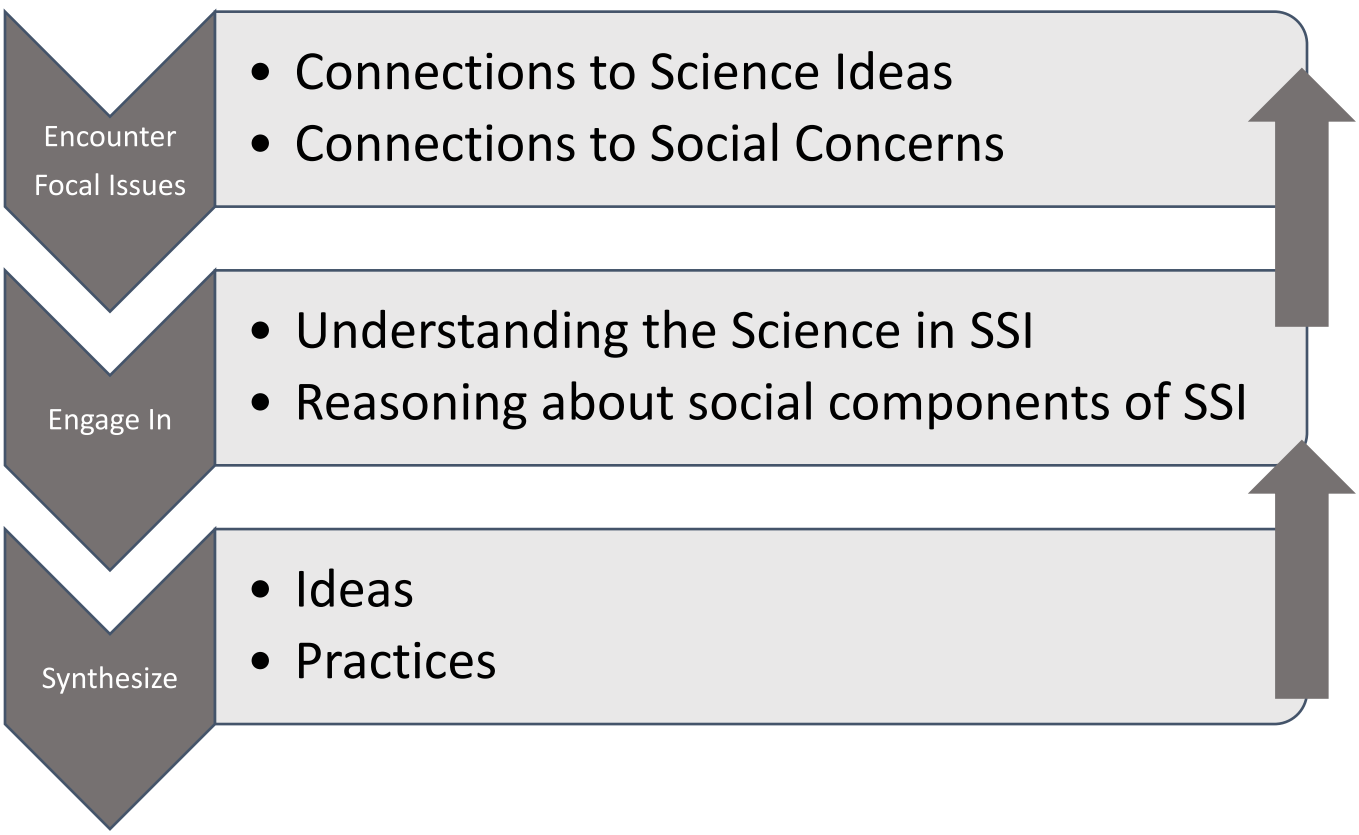


Figure 1 The SSI Teaching and Learning Model

(After Sadler, Foulk, et al., 2017)

3.2.1 Overview

This investigation explored the application of SSI teaching strategies to an undergraduate, general education (Gen Ed), large enrollment science course (LEC) at the University of Pittsburgh (Pitt). The undergraduate students in this course constituted an N≅170. The course studied involved two separately taught sections of the Fall 2020 offering of Astronomy 88: Stonehenge to Hubble, which is offered through the Department of Physics and Astronomy. I have been teaching this particular course at Pitt, among others, for 14 years. For this study, I collaborated with a departmental colleague. He was the instructor of record and handled all aspects of the course with the following exception. I taught the unit on the Nature and Process of Science included in the syllabus, providing two SSI based homework activities, and posting and monitoring discussion board prompts and questions for both the lecture and activity sections. All instruction occurred online and asynchronously – i.e. using pre-recorded lectures, and an anonymous message board approach to discussions - due to the limitations imposed by the current pandemic. The purpose of the activities and discussion boards was to allow students to practice the use of principals covered in the lecture with relevant real-world problems, and to discuss the topics and ask questions with the instructors and each other, as well as to share results of their investigations.

Astronomy 88: Stonehenge to Hubble is a self-contained course for students not majoring in the physical sciences, and it is primarily conceptual and descriptive in nature. The course is divided into three main sections – History of Astronomy, Observational Astronomy, and Current Advances/High Interest Topics.

3.2.2 Participants

As a Gen Ed course that fulfills the science requirements, the student population covered all undergraduate levels from 1st - 4th year. Students often come to the course with a wide range of majors and career goals. The things that they usually have in common are that they are non-science majors, they need the course to fulfill a requirement, and they selected the course based on the fact that it fit their schedule and, perhaps, it was somewhat appealing in terms of content.

<u>Recruitment Strategy</u>

Inquiry questions #1 and #2 were explored through the use and analysis of anonymous pre and post surveys, The study also involved gathering data from artifact analysis. Specifically, automated textual analysis of anonymous discussion board posts set up for the lectures and homework activities.

Participants for the pre and post surveys were recruited from the entire class enrollment of 170, over the two independent course sections of 120 and 50 students, respectively. This was done through an in-class announcement, and a reminder at the start of the first recorded lecture. This was followed by a link to an anonymous Qualtrics survey which was posted into the course's online platform, and which include the recruitment script included in Appendix A. Each class section then received exactly the same instruction and activities and the students were treated as one sample. Additionally, anonymous discussion boards with discussion prompts and space for asking questions was provided for the lecture section and each of the two homework assignments. Students could opt in or out of these discussions as they chose.

3.2.3 Instruction Delivery

Due to the ongoing COVID-19 pandemic, the two sections of Astronomy 88: Stonehenge to Hubble that were used for the purpose of this study were taught completely online, with an asynchronous delivery method. In other words, students could access the course materials and complete activities on their own schedule, and at their own pace, as long as all work was completed by the assigned dates. The University of Pittsburgh makes use of the Canvas learning management system for online course delivery, and therefore this course was presented using this technology platform.

The course was divided into a series of topical modules or units that were delivered sequentially throughout the semester. Each module was further subdivided into lectures, where each lecture represented the equivalent of one week of class instruction. As such, each lecture was designed to follow the university's instructional guidelines where one week of instruction corresponds to 75 minutes of "in-class" time. Best practices in instruction design, and my own teaching experience, indicate that course material delivered by video is more easily digested by students when the videos are designed to have a length of ~10-15 minutes. Following this guide, I divided my content to be delivered in 3 sections that consisted of a total of 5 videos of ~15 minutes each.

Students were supplied with a detailed PowerPoint presentation used in the lecture, but also including additional supplementary material, the 5 video lecture files, and the directions and required data for two homework activities that were meant to follow the instruction. Figure 2 below shows the way in which the material was presented to students within the Canvas platform, including all instructions and links to the materials provided.

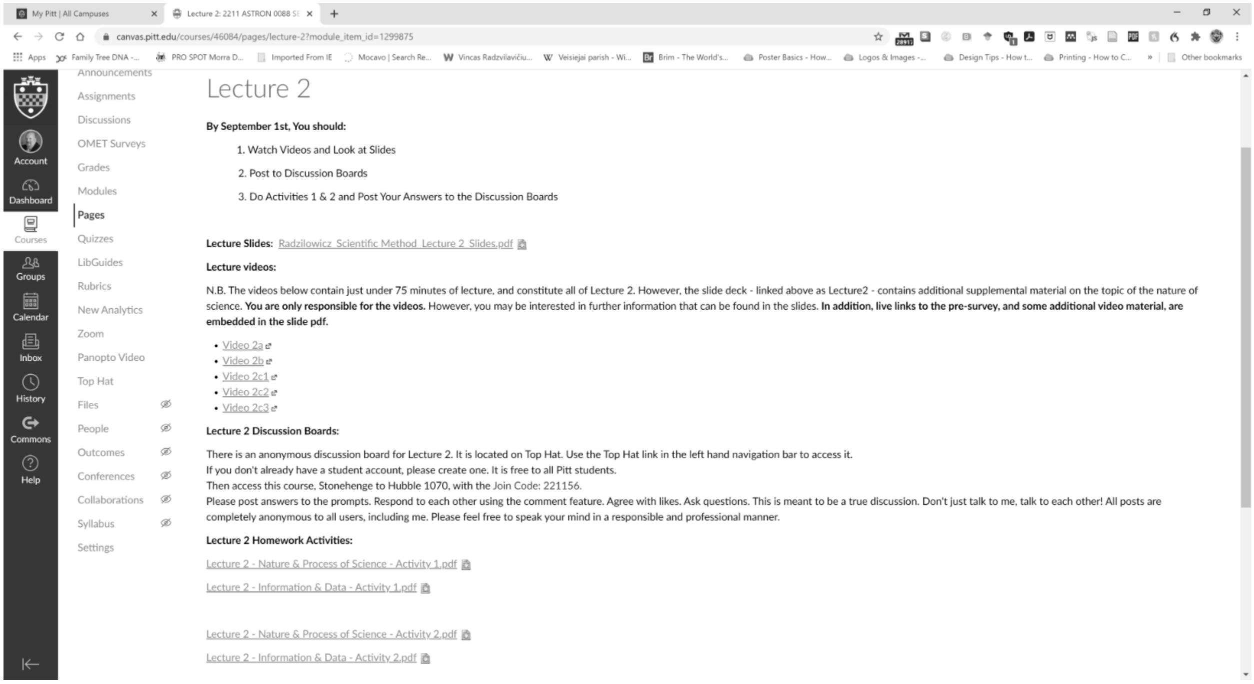


Figure 2 Student Instruction Interface

The lecture was delivered as "Lecture 2 of Module 1" in the course. What this means is that the instruction was delivered in what would have been considered the second meeting in a traditional face-to-face course. The first module of the course was entitled "Our Place in the Universe, and the Scientific Method". "Lecture 1 of Module 1" was an introduction to the nature and structure of the course as a whole, as well as a brief survey of our current understanding of Earth's physical location within the visible universe. This was delivered by the instructor of record. This allowed my Lecture 2 instruction to be delivered prior to the more detailed material to follow so that students would develop an understanding of the nature and process of science before learning how those principles were applied to astronomy.

Lecture 2 was presented under the title of the Scientific Method and addressed the following topics:

1. What is Science?

2. Philosophical and Practical Foundations of Science
3. Understanding the "Scientific Method"
4. The Power of Prediction and Consilience
5. Evidence, Convergence, and Consensus
6. Scientific Knowledge: Tentative & Reliable
7. Reproducibility, Self-Correction, and Advancement
8. Application, Policy, and Society

The delivery of this lecture content was then followed by the two homework assignments on current SSI topics. These assignments followed the SSI Teaching and Learning Model referenced earlier. They also included the use of anonymous discussion boards to allow students to relay their conclusions and to discuss these with each other.

As pointed out by Hancock, et al., (2019), currently there is little guidance given to teachers in selecting focal issues for SSI-based teaching and learning. Instead, there are several SSI instructional frameworks in the research literature (Zeidler and Kahn 2014). However, instructors are not offered much regarding the actual selection of topics to be used. As a result, little is known about how teachers choose and format an appropriate SSI issue for their course.

On the other hand, Zeidler and Kahn (2014) also point out that the SSI literature emphasizes that selected SSI topics should be current, controversial, relevant to students, have connections to science content being taught, and allow for open discussion among learners, and involve ethical choices and decision-making. Zeidler and Sadler (2009) also characterize SSI as complex, ill-structured authentic problems with undetermined solutions that require moral reasoning and challenge students' normal expectations.

In keeping with these guidelines, typical examples of SSI topics have included Animal Testing and Fracking (which formed the basis of the first version of the QuASSR). Note that neither of these topics depend on the acceptance or rejection of scientific consensus with regard to the science content. Instead, they deal with ethical issues and risk/benefit issues related to science and the broader community in which it is conducted. Using this framework, I selected the following two topics for the SSI activities to be used in my investigation. They both meet the criteria specified in the literature, and are current and important topics connected to the course content:

Activity I. Climate Change:

An activity that investigates both the existence and causes of Climate Change by looking at data temperature and ice melt changes as they are related to solar radiation and carbon dioxide levels.

Nature & Process of Science – Activity 1

Claims:

1. Global warming has not occurred since the time of the industrial revolution.

2. The main cause of global warming from the time of the industrial revolution to the present has been natural changes in the amount of solar radiation from the Sun.

3. The main cause of global warming from the industrial revolution to the present has been an increase in greenhouse gases in the atmosphere during that time, caused by human activity.

Task: (Total Activity time ~30 minutes)

1. Examine the information and data provided to you as it relates to the claims above

    o Interpret and analyze the information.

    o Evaluate the relevancy and reliability of the information.

2. Choose a claim above that you will support or refute based on the given information.

    o Justify your position by summarizing your evaluation of the evidence as it relates to each claim.

    o Explain what additional information you would need (if any) to convince you to change your position.

    o Be prepared to answer questions and defend your analysis.

3. Present your Argument to the Class on the Discussion Board:

1) Which claim do you support or refute (base your position solely on the data provided)? Justify your position by explaining why the information best supports/refutes this claim over the others. Discuss why the data is, or is not, reliable.

2) Explain what additional information you would need (if any) to convince you to change your position.

3) Explain what additional information you would need to convince you to support one of the other claims presented.

4) Answer questions posed on the board and defend your analysis.

Activity II. Thirty Meter Telescope (TMT) Mauna Kea Construction Controversy:

An activity that investigates the causes and implications of the battle over the construction of a new "next generation" telescope at the astronomical research complex on the summit of Mauna Kea in Hawaii that pits local indigenous people against astronomers and local governments.

Nature & Process of Science – Activity 2

Claims:

1. The Thirty Meter Telescope (TMT) is an important scientific tool that will expand our knowledge of the Universe. This is much more important than the old superstitions or land claims of a small group of Natives. It should be built as planned.

2. Mauna Kea is sacred to Native Hawaiians, and the land is theirs. The Mauna Kea Observatories organization have been poor stewards of the mountain. They have not kept their promises to protect the land. Enough is enough. The TMT should be moved to another location.

3. Science and culture should be able to coexist. There are Native Hawaiians, acting in good faith, on both sides of the issue. They should try to negotiate a compromise that allows construction to move forward under strict environmental guidelines for all of the Mauna Kea Observatories.

Task: (Total Activity time ~30 minutes)

1. Examine the information and data provided to you as it relates to the claims above

o Interpret and analyze the information.

o Evaluate the relevancy and reliability of the information.

2. Choose a claim above that you will support or refute based on the given information.

o Justify your position by summarizing your evaluation of the evidence as it relates to each claim.

o Explain what additional information you would need (if any) to convince you to change your position.

o Be prepared to answer questions and defend your analysis.

3. Present your Argument to the Class on the Discussion Board:

1) Which claim do you support or refute (base your position solely on the data provided)? Justify your position by explaining why the information best supports/refutes this claim over the others. Discuss why the data is, or is not, reliable.

2) Explain what additional information you would need (if any) to convince you to change your position.

3) Explain what additional information you would need to convince you to support one of the other claims presented.

4) Answer questions posed on the board and defend your analysis.

3.3 Inquiry Methods and Evidence

This study used a mixed-methods design. Each of the two inquiry questions below used a different data gathering and analysis process. Research Question #1 was investigated using a Pre/Post survey method and a quantitative data analysis designed for the QuASSR instrument. Research Question #2, on the other hand, was investigated by a qualitative approach. Specifically, this was done using textual analysis, in visual and list form, for the student responses provided to various prompts on an anonymous discussion board. The details of these approaches are explained below.

3.3.1 Pre/Post Surveys

Research Question #1: What specific changes, if any, occur to students' awareness, attitudes, and beliefs regarding scientific knowledge and process when they engage in a Socioscientific Issues approach to studying science?

In investigating research questions #1, evidence for a change or shift in attitudes, awareness, and beliefs as expressed by the five aspects of SSR (defined above) were measured by a baseline of these characteristics gathered from the students before the use of the SSI approach in the course, followed by a second measure of these parameters administered after the SSI activities were completed. The most common approach for gathering this type of evidence is the use of pre and post course surveys. This inquiry therefore used such an approach. Students were asked to take an anonymous survey before the SSI course material was delivered. After the use of the SSI lecture and activities, the identical survey of attitudes, awareness, and beliefs regarding scientific knowledge was again administered. The survey used was the Quantitative Assessment of Socio-Scientific Reasoning (QuASSR) developed by Romine, Sadler, and Kinslow (2017). The actual survey is attached in Appendix A.

Although there have been several approaches to the measurement of SSR, the QuASSR is an instrument specifically developed and validated in an undergraduate college context, and this is my reason for selecting it over other potential instruments. The QuASSR contains 11 multiple-choice, two-tiered items, and is based on theory suggesting a multi-tiered aspect structure for SSR as described above. It was developed in the context of pre-post measurement within a 1-week SSI-based instructional activity (Romine, et al., 2017). This study is similar in form and context, with lectures on the nature and process of science followed by two different SSI-based activities. The QuASSR instrument was also specifically designed to be used in the Qualtrics Survey System, and it was deployed in the same manner in this study. I believe all these factors made it a logical instrument choice for this study.

3.3.2 Student-Artifacts: Anonymous Discussion Boards

Research Questions #2: How do my students understand, and engage with, socially relevant scientific course content, and each other, when using an SSI approach in my undergraduate classroom?

Since the course delivery was precluded from a face-to-face interaction by both its online format and asynchronous design, this question was investigated through the use of anonymous discussion boards. Having used discussion boards to facilitate the sharing of information between students and between the students and the instructor over many years, I was confident that meaningful information could be gained through this approach. Again, I decided to rely on best practices from instructional design to guide how I gathered this data. One of the key factors for success in online discussion boards when possibly sensitive or contentious issues are being discussed is anonymity for the students. This is largely driven by the fact that online discussion boards are recording the interactions in a permanent form. That's quite a bit different than the face-to-face environment where instructors can avoid recording and students don't need to be concerned that their comments might follow them for years to come.

At first glance, this might seem to create another problem. How can students expect to be fully engaged if they are anonymous? While that was not a trivial concern, the pandemic made it necessary to consider trade-offs. I made the determination that this was a logical way to proceed based on the fact that SSI identifies decision-making as the key competence to be taught (Sadler & Zeidler, 2005; Sadler, 2004). And, in that context, while decision-making is a complex process, for the SSI model one of the most important components is being able to understand the multiple perspectives of a problem as represented by all of the various stakeholders (Zeidler et al., 2014). While online discussion forums might not have been an ideal approach, I believe it clearly still satisfied the aspects of decision-making and perspective sharing that are fundamental to SSI. The anonymous nature of the posts does not hinder these aspects, and potentially enhances them by encouraging students to share their honest perspectives without concern for any possible repercussions.

Unfortunately, though the Canvas platform has a built-in discussion board function, that feature does not allow for anonymous posts. As a result, I chose to use the Top Hat application – which does contain an anonymous discussion feature - to gather this data. While Top Hat is a separate instructional application, it has a full integration version available for Canvas, and Pitt has chosen to implement this integration. What this meant, was that the students were able to access Top Hat from within their normal course shell in Canvas and could then use the application as if it was simply a feature of Canvas. This solved the problem in a clean and simple way.

The anonymous discussion boards were configured in Top Hat as a series of 9 prompts. The prompts were divided into 3 groups of 3 prompts each. Three prompts were devoted to questions of a general nature concerning the Lecture 2 content material. The remaining 6 prompts consisted of 3 devoted to Activity I (p.32), and 3 devoted to Activity 2 (p.34), as shown below in Table 1.

Table 1 SSR Discussion Board Prompts

Scientific Method	Activity I: Climate Change	Activity II: TMT
• Did the information in the Lecture 2 Videos change your ideas about what science is or how it works? If so, how? • It is often said that scientific knowledge is neither good nor bad in a moral sense; only people can decide if the application of that knowledge can be good or bad. For example: Science can be used to learn about atomic and nuclear physics. With that knowledge, people can build power stations or weapons. We must decide what is good or bad. Do you agree? Why or why not? Can you give examples to back up your position? • We are in the midst of the most serious global pandemic in 100 years. Global, national, and regional scientific and health organizations (e.g. World Health Organization (WHO), U.S. Centers for Disease Control and Prevention (CDC), PA Department of Health) have recommended social distancing and the use of cloth masks as effective ways to prevent transmission of COVID-19. However, significant segments of the U.S. population are deliberately ignoring these guidelines. This has been especially true of young adults on college campuses. Are you following the recommended guidelines? Why or why not? Do most of your fellow students follow the guidelines? What do you think are the reasons?	• Which claim from the Activity Sheet do you support or refute (base your position solely on the data provided)? Justify your position by explaining why the information best supports/refutes this claim over the others. Discuss why the data is, or is not, reliable. • Explain what additional information you would need (if any) to convince you to change your position. • Explain what additional information you would need to convince you to support one of the other claims presented.	• Which claim from the Activity Sheet do you support or refute (base your position solely on the data provided)? Justify your position by explaining why the information best supports/refutes this claim over the others. Discuss why the data is, or is not, reliable. • Explain what additional information you would need (if any) to convince you to change your position. • Explain what additional information you would need to convince you to support one of the other claims presented.

3.4 Analysis and Interpretation

For Pre and Post Surveys, I followed the scoring rubric and analysis approach used by Romine, et al. (2017). The instrument was designed for online administration that allows for adaptive testing – hence the use of the Qualtrics system which enabled tiered results. In the first tier, a student responds to a yes/no question (e.g., Is the issue complex?). A second-tier question asks him/her to select the reason that best corresponds to his/her response to the first-tier question. Second tier questions have three response options. These responses are based on patterns of reasoning observed in previous interview and open-ended surveys of SSR (Sadler et al., 2007; Sadler, Klosterman, et al., 2011). To capture varying degrees of SSR competencies (as opposed to a simple right/wrong scoring model), QuASSR uses a scaled model to assess student answers based on three-levels, where: 0 = low SSR, 1 = moderate SSR, 2 = high SSR. Multiple questions target each SSR aspect or dimension: complexity—two items, perspective-taking—two items, inquiry—three items, and skepticism—three items. An additional item targets affordance & limitations of science and asks students to take a position on the issue.

3.4.1 Quantitative Analysis of Survey Data

Analysis of the surveys involved calculating the total mean survey scores as well as the change in mean scores between pre and post surveys. The mean scores and change scores were plotted on frequency graphs. Because of the need to use anonymous surveying throughout the pandemic inspired design of this study, the pre/post data does not represent paired responses. That is, it is not possible to link pre intervention scores with post intervention scores for particular students. As a result, this survey data set precludes the use of paired t-test analysis that is common for this type of surveying. In addition, there is a fairly large difference in the sizes of pre and post samples. This was anticipated and is accounted for in the calculation of final results and will be discussed in the chapters below. What is important at this point is that it also limits the type of paired analysis available. Instead then, I relied on the means and survey margins of error for a very simple and straight forward comparison of pre/post results. Then, in order to dig more deeply into the basis for mean total results, the pre and post mean scores for each item were also calculated and plotted on frequency graphs in order to assess the significance of the individual results for each question. This allowed me to see if there was an overall change in SSR among students, as well as pinpoint the areas that contributed, if any, to that change.

3.4.2 Qualitative Analysis of Discussion Data

Analysis of the discussion board text was done with the Word Cloud online application provided by wordclouds.com. This analysis was done using visual (word cloud) representations of student response data as well as word frequency lists. The purpose of this qualitative analysis was to unearth insights concerning the focus of student interest, discussions, and understanding. It also allowed for the investigation of student emotions (positive, negative, and neutral) within the text data to see how students felt about the concepts, issues, and resolutions. In order to tie the analysis specifically to the SSI model, this was done by looking at the word frequencies – whether visual or list – for demonstrations of the five aspects of Socioscientific reasoning (SSR) that are integral to the QuASSR analysis used in the quantitative data analysis as identified by Romine et al. (2017). These are:

Complexity: the ability to perceive and reason through the complexity inherent to SSI.

Perspective-taking: the ability to analyze an issue and potential solutions from the perspectives of different stakeholders.

Inquiry: the ability to recognize information that is not available regarding an issue as well as the ability to consider ways in which that information may be generated.

Skepticism: the ability to identify potential sources of bias that may influence information or the presentation of information about an issue or potential solutions.

Affordances & Limitations of Science: the ability to determine how scientific knowledge and processes may contribute to the resolution of an SSI and to recognize dimensions of the issue that cannot be addressed by science.

By using these same filters it was possible to not only gain insight into how the students are understanding, and engaging with, the socially relevant scientific course content in the activities, and each other, but also to look for connections between what they choose to share about their SSI process with any impacts seen on the QuASSR analysis.

4.0 Results

Results are presented below in the form of the analysis of pre/post survey results and text analysis of the post activity discussion boards. Data is provided for overall cumulative scores as well as individual item scores for the survey analysis. In the case of the text analysis, word clouds and word frequency lists are provided for each set of individual prompts, as well as for cumulative results in each of three prompt categories.

4.1 Survey Analysis

The pre/post surveys used in this study are the QuASSR instrument developed by Romine et al., (2017). The instrument was specifically designed to be delivered by the Qualtrics Survey System. Therefore, all pre and post surveys were conducted using Qualtrics, and were distributed to participating students through anonymous Qualtrics links provided in their Canvas course shells and through student roster email distribution. Of the 170 students enrolled in the two sections of the course, 129, or more than 75% participated in the pre survey. On the other hand, participation in the post survey dropped to 98, or slightly less than 58%. While there is a considerable drop-off between pre and post participants, it should be noted that these are very significant participant rates for a voluntary survey which carried no specific incentive for students. It is likely that this response rate can be attributed to the fact that all activities of this study were seamlessly rolled into the course design and made participation easy, in spite of the fact that students were clearly and frequently reminded of the voluntary nature of all aspects of the intervention and surveys. What follows are frequency graphs and tables for the Total Survey Scores (Figure 3 and Figure 4).

#	Field	Min	Max	Mean	Std Dev	Variance	Count
1	Score	4.00	20.00	14.81	3.17	10.08	129

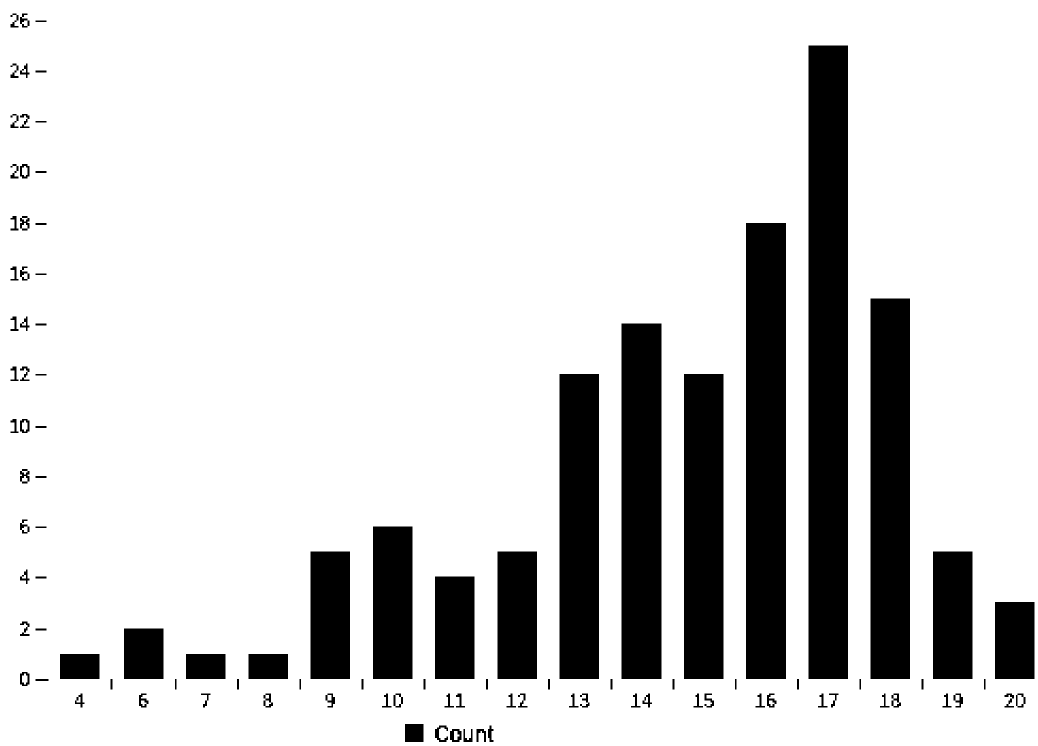


Figure 3 Total Pre-Survey Score

#	Field	Min	Max	Mean	Std Dev	Variance	Count
1	Score	0.00	20.00	13.37	5.21	27.11	98

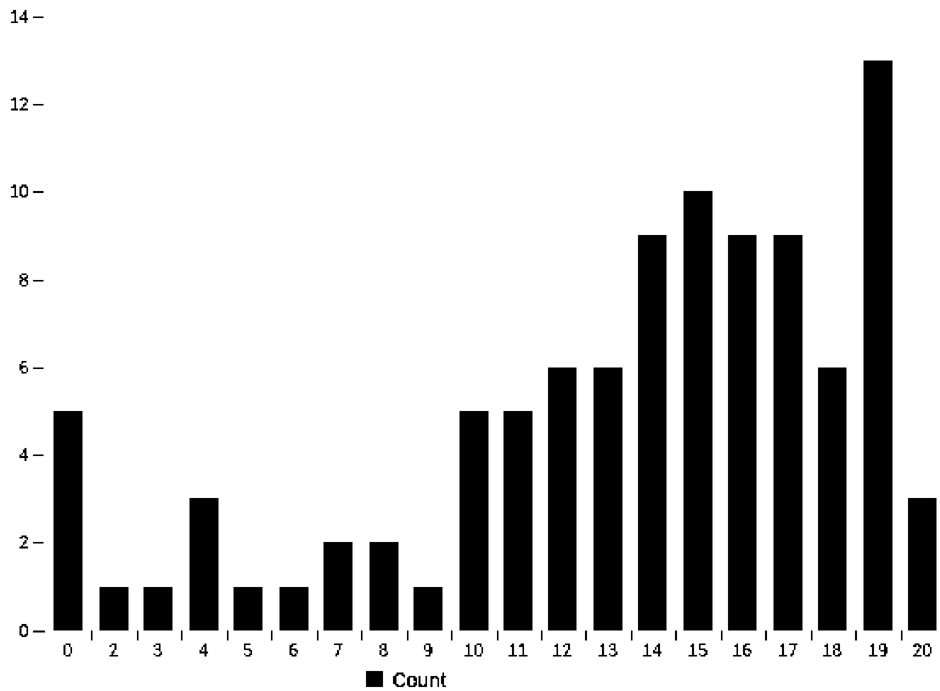


Figure 4 Total Post-Survey Score

The frequency graphs and tables for all questions in the QuASSR survey results, including all sub-branches, can be found in Appendix B.

Table 2 Mean pre-post scores +/- Confidence Interval for each QuASSR survey question across the Pre and Post responses at the 95% Confidence Level

Question	Time	Mean Score	CI +/-	SD	N
1	Pre	1.05	0.04	0.23	129
	Post	1.14	0.07	0.35	94
1N	Pre	2.00	0.39	0.53	7
	Post	2.17	0.39	0.69	12
1Y	Pre	2.07	0.13	0.71	122
	Post	1.93	0.13	0.60	81
2	Pre	1.84	0.06	0.36	129
	Post	1.85	0.07	0.36	93
2N	Pre	1.21	0.11	0.56	109
	Post	1.38	0.14	0.64	79
2Y	Pre	2.15	0.21	0.48	20
	Post	2.07	0.37	0.70	14
3	Pre	1.97	0.03	0.17	129
	Post	1.96	0.04	0.20	92
3L	Pre	2.50	0.85	0.87	4
	Post	1.75	0.81	0.83	4
3NL	Pre	1.06	0.02	0.11	125
	Post	1.07	0.07	0.33	88
4	Pre	1.92	0.05	0.27	129
	Post	1.98	0.03	0.15	90
4L	Pre	1.40	0.30	0.49	10
	Post	2.00	0.00	0.00	2
4NL	Pre	1.01	0.02	0.09	119
	Post	1.09	0.08	0.36	88
5	Pre	1.73	0.08	0.44	129
	Post	1.68	0.10	0.47	90
5Y	Pre	2.03	0.13	0.38	35
	Post	2.14	0.23	0.63	29
5N	Pre	2.21	0.24	1.18	94
	Post	2.02	0.26	1.04	60
6	Pre	1.12	0.06	0.33	129
	Post	1.08	0.06	0.27	89
7	Pre	1.97	0.03	0.17	129
	Post	1.98	0.03	0.15	88
7A	Pre	1.00	0.00	0.00	4
	Post	2.00	0.00	0.00	2
7NA	Pre	2.03	0.06	0.36	125
	Post	2.02	0.06	0.30	86
8	Pre	1.95	0.01	0.05	129
	Post	1.94	0.05	0.23	88

Table 2 Mean pre-post scores +/- Confidence Interval for each QuASSR survey question across the Pre and Post responses at the 95% Confidence Level (continued)

8WN	Pre	1.57	0.36	0.49	7
	Post	1.40	0.43	0.49	5
8W	Pre	2.25	0.16	0.92	122
	Post	2.25	0.20	0.93	83
9	Pre	1.87	0.06	0.34	129
	Post	1.80	0.08	0.40	88
9W	Pre	2.06	0.38	0.80	17
	Post	1.28	0.30	0.65	18
9WN	Pre	2.75	0.12	0.63	112
	Post	2.81	0.13	0.57	70
10	Pre	1.68	0.08	0.47	129
	Post	1.64	0.10	0.48	88
10S	Pre	2.00	0.29	0.94	41
	Post	1.44	0.27	0.79	32
10D	Pre	1.15	0.11	0.51	88
	Post	1.25	0.17	0.66	56
11	Pre	1.26	0.08	0.44	129
	Post	1.38	0.10	0.48	88
11WN	Pre	1.88	0.14	0.41	33
	Post	1.85	0.12	0.36	33
11W	Pre	1.77	0.12	0.60	96
	Post	1.96	0.18	0.69	55
TOTAL	**Pre**	**14.81**	**0.55**	**3.17**	**129**
	Post	**13.37**	**1.03**	**5.21**	**98**

Table 2 above summarizes the results seen in the individual frequency plots as well as the individual calculations of the mean score, standard deviation, and sample size (count = N) for each individual question, and the Total QuASSR scores, for pre and post surveys. In each case, the confidence interval (CI) was calculated using the standard formula below:

$$CI = Z \times SE$$

where the Z, the Z-Score, is 1.96 at the 95% confidence level, meaning that there is a 95% chance of the correct value appearing within ± 1.96 of the mean. SE is the Standard Error of the mean, where

$$SE = SD \div \sqrt{N}$$

where SD is the standard deviation and N is the sample or count size.

These calculations indicate that the overall QuASSR results show no significant difference between the pre and post administration of the instrument, i.e. the mean total values pre and post fall within the respective confidence intervals at the 95% confidence level. In addition, this is also true for each of the individual questions in the instrument, as displayed in Table 3 below, with the exception of two cases. However, in both those cases the standard deviation from the mean results was 0.0 and the sample size was between 2-4 students. Such a tiny sample does not allow drawing any conclusions from those questions.

Such low sample sizes are possible on individual questions because the QuASSR instrument has a branching design. In other words, the small sample number for the questions under consideration represent the fact that very few students selected the branches that led to those particular questions. As a result, those selections have a very minor effect on the overall scoring and offer little in the way of useful information for those topics.

As a result, it can be safely concluded that the QuASSR alone gives no indication of any student change in the dimensions of awareness, attitudes, and beliefs about socioscientific issues as a result of the SSI instructional intervention. The results are also broken out by their respective socioscientific reasoning (SSR) aspects – **C**omplexity, **P**erspective, **I**nquiry, **S**kepticism – in Table 3 below.

4.1.1 Pre/Post-Intervention Socioscientific Reasoning (SSR)

Table 3 Mean pre-post raw scale scores (0—2) +/- Confidence Interval for each SSR aspect at the 95% Confidence Level

Question	Time	Mean	CI +/-	SD	N	SSR
1	Pre	1.05	0.04	0.23	129	C
	Post	1.14	0.07	0.35	94	C
1N	Pre	2.00	0.39	0.53	7	C
	Post	2.17	0.39	0.69	12	C
1Y	Pre	2.07	0.13	0.71	122	C
	Post	1.93	0.13	0.60	81	C
2	Pre	1.84	0.06	0.36	129	C
	Post	1.85	0.07	0.36	93	C
2N	Pre	1.21	0.11	0.56	109	C
	Post	1.38	0.14	0.64	79	C
2Y	Pre	2.15	0.21	0.48	20	C
	Post	2.07	0.37	0.70	14	C
Complexity	Pre	1.72	0.16			
	Post	1.76	0.20			
3	Pre	1.97	0.03	0.17	129	P
	Post	1.96	0.04	0.20	92	P
3L	Pre	2.50	0.85	0.87	4	P
	Post	1.75	0.81	0.83	4	P
3NL	Pre	1.06	0.02	0.11	125	P
	Post	1.07	0.07	0.33	88	P
4	Pre	1.92	0.05	0.27	129	P
	Post	1.98	0.03	0.15	90	P
4L	Pre	1.40	0.30	0.49	10	P
	Post	2.00	0.00	0.00	2	P
4NL	Pre	1.01	0.02	0.09	119	P
	Post	1.09	0.08	0.36	88	P
Perspective	Pre	1.64	0.21			
	Post	1.64	0.17			
5	Pre	1.73	0.08	0.44	129	I
	Post	1.68	0.10	0.47	90	I
5Y	Pre	2.03	0.13	0.38	35	I
	Post	2.14	0.23	0.63	29	I
5N	Pre	2.21	0.24	1.18	94	I

Table 3 Mean pre-post raw scale scores (0—2) +/- Confidence Interval for each SSR aspect at the 95% Confidence Level (continued)

	Post	2.02	0.26	1.04	60	I
6	Pre	1.12	0.06	0.33	129	I
	Post	1.08	0.06	0.27	89	I
7	Pre	1.97	0.03	0.17	129	I
	Post	1.98	0.03	0.15	88	I
7A	Pre	1.00	0.00	0.00	4	I
	Post	2.00	0.00	0.00	2	I
7NA	Pre	2.03	0.06	0.36	125	I
	Post	2.02	0.06	0.30	86	I
8	Pre	1.95	0.01	0.05	129	I
	Post	1.94	0.05	0.23	88	I
8WN	Pre	1.57	0.36	0.49	7	I
	Post	1.40	0.43	0.49	5	I
8W	Pre	2.25	0.16	0.92	122	I
	Post	2.25	0.20	0.93	83	I
Inquiry	Pre	1.79	0.11			
	Post	1.85	0.14			
9	Pre	1.87	0.06	0.34	129	S
	Post	1.80	0.08	0.40	88	S
9W	Pre	2.06	0.38	0.80	17	S
	Post	1.28	0.30	0.65	18	S
9WN	Pre	2.75	0.12	0.63	112	S
	Post	2.81	0.13	0.57	70	S
10	Pre	1.68	0.08	0.47	129	S
	Post	1.64	0.10	0.48	88	S
10S	Pre	2.00	0.29	0.94	41	S
	Post	1.44	0.27	0.79	32	S
10D	Pre	1.15	0.11	0.51	88	S
	Post	1.25	0.17	0.66	56	S
11	Pre	1.26	0.08	0.44	129	S
	Post	1.38	0.10	0.48	88	S
11WN	Pre	1.88	0.14	0.41	33	S
	Post	1.85	0.12	0.36	33	S
11W	Pre	1.77	0.12	0.60	96	S
	Post	1.96	0.18	0.69	55	S
Skepticism	Pre	1.82	0.31			
	Post	1.71	0.16			

A calculation for each of the SSR aspect scores (Table 3), 6 questions for complexity, 6 questions for perspective taking, 10 questions for inquiry, and 9 for skepticism, show – as would be fully expected – that there was also no indication of any change, either positive or negative, for any of the students' awareness, attitudes, or beliefs, as they relate to the critical aspects of SSR as identified by Romine et al., (2017).

This null result across the board for the QuASSR survey will be discussed in detail in Chapter 5. However, it is worth noting at this point that this is in line with other published work. The developers of the instrument had similar results in a number of undergraduate settings (Romine, et al., 2017).

4.2 Discussion Posts Analysis

The discussion posts used in this study consisted of 900 total anonymous responses posted by 106 individual students, who represented 62.4% of the overall student sample. This tells us simply that a large number of students in the course participated in this voluntary activity and, with an average of 8.5 responses per student, most participants responded to most or all of the prompts offered.

The responses that make up the data set correspond to 9 total prompts that were divided into 3 sets of 3 prompts each. The three sets represent general questions about the Scientific Method module (SMQ1-3), the Climate Change Activity - I (A1Q1-3), and the TMT Activity – II (A2Q1-3). The actual prompts are listed in Table 1 on p. 40, as part of the Methods section above. These prompts were drawn directly from the module content and the activity worksheets. Posts were analyzed as a complete set, by each subdivided category (SMQ, A1Q, A2Q), and individually for the various analyses.

The responses were analyzed for two factors – word frequency and sentiment. The word frequency analysis was carried out using the free online Word Clouds text analysis software at www.wordclouds.com. For this part of the analysis I chose to limit the word lists to words with at least ten (10) total occurrences within the full set of responses. This resulted in individual prompt responses with word lists ranging from 29-87 words, with an average of 53 words per each of the 9 prompt responses. Tables 5-7 below show the words appearing in those prompt responses for the first question in each cluster, as well as the frequency with which each word occurred in the text. Then, for each word frequency table, a corresponding data visualization as a word cloud was generated. The remaining word tables and clouds appear in Appendix C.

Sentiment analysis is not available with the Word Cloud software. Instead, the sentiment analysis for the prompt responses on the anonymous discussion boards was done using the Displayr Analysis and Reporting software available at www.Displayr.com. This software is, in many ways, more sophisticated and versatile than Word Cloud and uses machine learning techniques integrated with the R statistical software packages. This software is not free; however it is possible to receive 10 free hours of analysis time as part of a trial period. This is how I accessed the software, and ten hours was ample time to learn the basics of operation and run the required analysis.

In order to rate the text for sentiment - defined as, the view or attitude toward a situation or event - that students may have demonstrated in their posts, the Displayr software uses a variety of well-known and respected English dictionaries (e.g. Oxford English Dictionary, The Merriam-Webster Dictionary, The American Heritage Dictionary, etc.) of positive and negative English-language words in order to generate a score for each response. Based on their most common definitions, words are coded as positive, negative, or neutral. Positive words in the text each add a score of +1, negative words add a score of -1, and neutral words add no score. The final score for any given post is obtained by summing all of the scores in a given response. The scoring heuristic used also is designed to identify when sentiment has been negated, so, for example, "not good" would generate a score of -1 instead of a score of +1, or 0. Using this scoring system, sentiment scores are limited only by the length and nature of the post. Across the 900 individual responses, the highest value (most positive) rating was +18, and the lowest value (most negative) rating was -19. However, the vast majority of post ratings were found to fall between the values -5 and +5.

Table 4 below displays the Mean Sentiment Score, and the sample size, for each of the significant division of the posted responses. This includes the three main clusters dealing with the Scientific Method module questions (SMQ), Activity I (A1Q), Activity II (A2Q), as well as the individual prompt posts, SMQ1-3, A1Q1-3, and A2Q1-3. Finally, the mean score for the entire sample of 900 responses is calculated at a positive score of +1.23. The data appears below, and the interpretation is presented in Chapter 5. The full data set with ratings for all 900 individual posts, as well as the full break out of all clusters and their component scores, can both be found in the appendix.

4.2.1 Prompts and Response Overview

In the data representations that follow, the word lists and word clouds provide a convenient means for looking at the individual items analyzed and allowing an understanding of word frequency, sentiment rating, and how these two factors may be related. For example, the Total

Overall Sentiment Mean Score was calculated to be +1.23, as shown in Table 4. This can be considered a slightly positive sentiment score. However, it is very close to the neutral value of zero. This is no surprise in the sense that most rating values are small single digit values. What is interesting is that the word frequency analysis begins to give some insight onto the reason for this. Many of the most frequently used words in the students' posts correspond to terms that appear repeatedly in almost all posts. These include words like science, information, knowledge, understanding, humans, people, temperature, etc. One thing that most of these words have in common is that they are generally words that the software would code as neutral and therefore assign a score of zero. This would seem to explain much of what is reflected in Table 4.

However, it does not explain a few scores that stand out. Specifically posts in cluster A1Q1 have a mean score of +2.90, and those in cluster A2Q1 come in with a mean score of +2.84. This is interesting, because both of these response clusters are for Activity Prompt 1 in each of the activities. These prompts deal with students staking out, and supporting, a claim based on the socioscientific issue scenario in each activity. The fact that these two clusters have larger positive values can be explored through the word frequency lists and word clouds to see if there is a significant difference in the type and frequency of the words used when students are in the position of staking a claim for or against social policies. The possible interpretation of these findings, and any implications, are explored in the discussion sections in Chapter 5.

Table 4 Sample size, and Mean Sentiment Score, for all Discussion Response Clusters

Cluster	Sample Size	Mean Sentiment Score
SMQ	326	+0.25
SMQ1	111	+1.31
SMQ2	109	-0.17
SMQ3	106	-0.50
A1Q	291	+1.95
A1Q1	98	+2.90
A1Q2	97	+0.93
A1Q3	96	+1.83
A2Q	283	+1.63
A2Q1	95	+2.82
A2Q2	94	+0.71
A2Q3	94	+1.39
TOTAL	900	+1.23

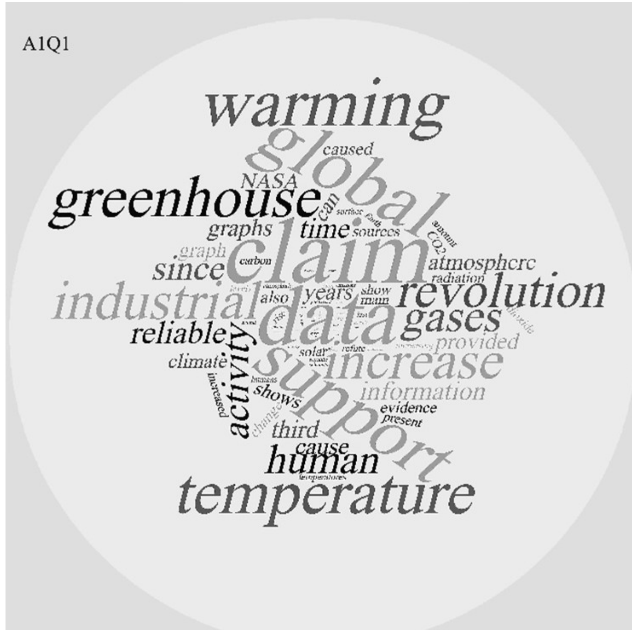
4.2.2 Word-Lists and Graphic Representations

In the data visualization samples that follow in Tables 5-7 and in Appendix C, simple circular word clouds were generated for each of the 9 individual prompt clusters in the discussion board data. In these representations, the size of the words corresponds to the frequency with which they appear in the relevant cluster of responses. Below each word cloud, a word frequency table lists the individual words which occur in that response group, along with the actual number of times that word appears. The word analysis is relatively course in that the software looks for exact matches and does not group closely related words. In addition, word frequency distribution for the different prompts varies considerably from a high of just 55 uses, to a high of 213 uses. I eliminated word frequencies below 10 in all cases, to avoid unnecessary clutter with entries of no value.

Table 5 SMQ1 Word Frequency

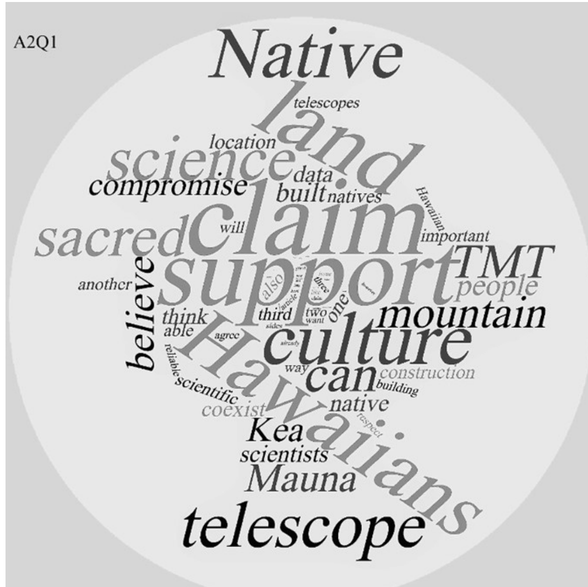
Frequency	Word	Frequency	Word
196	science	14	Lecture
62	change	14	new
54	ideas	13	much
35	information	13	never
35	scientific	13	say
26	works	12	just
24	really	12	things
24	think	12	view
22	method	11	found
20	idea	11	good
20	thought	11	taught
19	always	11	understand
18	changed	10	also
15	necessarily	10	axioms
15	something	10	can
15	understanding	10	gave
15	views	10	learned
15	way	10	nature
14	already	10	reinforced
14	interesting	10	two
14	knowledge	10	world

Table 6 A1Q1 Word Frequency



Frequency	Word	Frequency	Word	Frequency	Word
140	claim	35	can	20	levels
113	data	35	NASA	20	surface
101	global	34	graph	20	temperatures
95	support	33	climate	19	Earth
94	warming	32	shows	19	humans
84	temperature	31	caused	17	source
80	greenhouse	30	also	16	atmospheric
75	increase	28	evidence	16	clear
75	industrial	28	sources	15	emissions
73	revolution	27	change	15	first
69	gases	27	radiation	15	natural
60	human	26	main	15	scientific
56	activity	26	shows	14	scientists
51	since	26	solar	14	charts
49	reliable	25	CO2	14	clearly
43	time	25	present	14	Industrial
42	information	24	increased	13	occurred
38	cause	23	carbon	13	past
38	graphs	23	dioxide	12	reputable
38	third	22	amount	11	revolution
37	atmosphere	21	refute	11	government
37	provided	21	rise	10	changes
37	years	20	increasing	10	claims

Table 7 A2Q1 Word Frequency



Frequency	Word	Frequency	Word	Frequency	Word
117	claim	22	location	14	sides
89	support	22	one	13	already
78	land	21	construction	13	best
60	Hawaiians	21	natives	13	issue
56	culture	20	able	12	claims
54	Native	20	another	12	good
49	telescope	20	important	12	however
48	science	20	scientific	12	long
47	sacred	20	third	12	make
42	can	19	also	11	just
39	TMT	19	telescopes	11	moved
37	mountain	19	will	11	need
34	believe	18	two	11	seems
34	Mauna	18	way	11	trust
33	Kea	17	building	10	articles
32	compromise	17	Hawaiian	10	benefits
32	people	16	agree	10	clearly
30	built	16	reliable	10	decision
24	data	16	respect	10	enough
24	native	15	three	10	information
24	scientists	15	want	10	much
23	coexist	14	article	10	observatories
23	think	14	like	10	observatory

The remaining set of word cloud diagrams and word lists generated for each of the 9 prompts is printed in Appendix C.

The top twenty words used in each of clusters of prompt responses for A1Q1 and A2Q2 include, respectively: Claim, data, global, support, human, activity, reliable, information; and

Claim, support, Hawaiians, culture, native, sacred, can, believe, compromise, people, built.

It can be argued that these words are most often linked with the process of inquiry, social issues, and/or a positive sentiment. On the other hand, the majority of other words that appear in the word lists for these prompts are highly likely to be rated as neutral.

4.2.3 Correlation with SSR Aspects

The QuASSR instrument used earlier seeks to quantify four of the five SSR Aspects identified by the Socioscientific Issues model (Romine, et al., 2017). These four aspects are Complexity, Perspective, Inquiry, and Skepticism, as defined earlier. Limitations and Affordances of science is not measured. The results, as posted above in Table 3, showed no significant change in these parameters pre and post intervention. In order to determine if sentiment text analysis of the discussion posts at the SSR Aspect-level would provide any information that might add to the interpretation of the data, a new analysis model needed to be applied.

Unfortunately, the Displayr software package was not optimized for the creation of unique models of text analysis. The user interface was not designed for easy input of new aspect filters, at least within the total of 10 hours of processing time allowed. For this reason, a third software package was needed to accomplish the SSR Aspect-level analysis. A suitable package was identified from MonkeyLearn. MonkeyLearn is an artificial intelligence (AI) company associated with SurveyMonkey and the other SVMK, Inc. web-based survey and analysis tools.

MonkeyLearn's application, available at www.MonkeyLearn.com,[1] is an intelligent system for text and data analysis. It is specifically designed as a "no-code" program platform, so that the interface is far more accessible than that of Displayr. Aspect analysis and model creation are among the features offered for text-based data input. The model creation involves first inputting the desired aspects to be used as data filters. The same four SSR aspects as used by the QuASSR instrument were used. Then the model was created by training the system, which uses natural language processing and deep learning technologies. This was done through uploading the data sample, and then going through two steps. First, the system randomly selected a text sample – in this case, a set of complete responses from the 900 in the data file. The sample was then user coded by selecting, for each response, the SSR aspects that matched that response. One to four aspects could be identified for each sample (all that apply). 50 responses were manually coded in this way, using the definitions developed by Romine, et al. (2017). (The system required a minimum of four examples for each aspect – or, in this case, 16 coded responses.) Next, the system chose a new set of random examples from the data base. The text, as well as the associated SSRs chosen by the system based on its analysis, were then presented. Then SSR selections were either confirmed or corrected and confirmed for each selection presented. Once again, the system required at least four "tagged" or confirmed/corrected coding examples for each aspect in the model – 16 total examples. Once again, 50 confirmed coding examples were provided. At this point, the model was considered "trained" and batch analysis files could be run. In a batch file run, the system analysis output

[1] There are other possible packages to use, including one built into SAS and MeaningCloud (see www.meaningcloud.com). These came to my attention after doing the analyses with MonkeyLearn, which worked adequately for my needs. See https://sourceforge.net/software/product/MonkeyLearn/alternatives.

consists of each of the student prompt responses (900), followed by a list of 1-4 of the SSR aspects that are best demonstrated. Each aspect listed is delimited by a colon. This is then followed by a decimal percentage between 0.00-1.00 representing the system's confidence level in the aspect assignment. The confidence level is given in the same order as the assigned aspects, and they are also delimited by a colon. So, for example, An output of :

SMQ1	inquiry:perspective	1:0.899

indicates that a response to the SMQ1 prompt was coded as both "inquiry" and "perspective". The "inquiry" tag was assigned a confidence of 100% based on the AI model. Similarly the "perspective" tag received a confidence level assignment of 89.9%. The confidence levels for the coding ranged from 47.5% to 100%. However, the overwhelming majority of ratings were classified at 100%, and only a handful were under 70%. For this reason, all ratings were included in the analysis. In order to provide a check on these coding scores and their high confidence, I randomly selected several student responses from the total data set of 900. For each, I read the post and decided what aspects I believed were indicated by the response. I then compared my results to that of the AI algorithm. The samples and results are below:

SMQ1 - Post #68

The lecture did change my views on science, as someone who has a major outside of science and not had much experience in it other than in high school, I was unaware that the scientific process was less about a certain list of steps and that science is about the relationship among observations. Especially that scientific theories are based on consensus and not unanimous agreement, was something I had not fully appreciated until I heard it articulated in the lecture.

Among the four SSR Aspects rated, I marked this selection as demonstrating Perspective and Inquiry. The system rated it as Inquiry and Perspective, with a CI of 100% for each. I considered this a correct match.

A2Q1 - Post #689

I support claim two. The TMT is being built on stolen land without the consent of the native people. While the TMT is an important tool and should still be built, Mauna Kea is sacred and should not be further desecrated.

I rated this response as demonstrating Perspective only. The AI coded it as Perspective only. Another correct match.

A2Q1 - Post #864

I would like to believe the idea that science and culture should be able to coexist. I believe this ideal is attainable, however, not so much in this case. I support claim #2, as the Hawaiian people are justified in their lack of trust towards the scientists. Although there are scientists who have the Hawaiian peoples' interest at heart, wish to preserve the ecology of the sacred mountain, and pursue collective knowledge - it is difficult to restore this trust. Another location for TMT can be chosen.

I rated this response post as demonstrating Perspective and Skepticism. The AI algorithm also coded it as Perspective and Skepticism. In this case, with a confidence level of 100% and 80% respectively. I considered this to be another match, and even felt the confidence levels were a fair representation.

This simple cross-check of the AI allowed me to feel that the algorithm seemed to have been successfully trained to mirror the coding choices I would make.

The full print out of the batch-run analysis for all 900 student responses, showing the assigned SSR-Aspect codes and associated model confidence levels, is provided in Appendix D. The summarized results of that analysis, showing how often a specific SSR was demonstrated by students in each posted response cluster, appear in Table 8 below.

Table 8 Text Analysis by SSR Aspects for each Discussion Response Cluster

Cluster	Sample Size	Complexity	Perspective	Inquiry	Skepticism
SMQ	326	61 (19%)	312 (96%)	55 (17%)	12 (4%)
SMQ1	111	24 (22%)	99 (89%)	36 (32%)	7 (6%)
SMQ2	109	36 (33%)	109 (100%)	17 (16%)	1 (1%)
SMQ3	106	1 (1%)	104 (98%)	2 (2%)	4 (4%)
A1Q	291	4 (1%)	122 (42%)	273 (94%)	19 (7%)
A1Q1	98	2 (2%)	4 (4%)	96 (98%)	0 (0%)
A1Q2	97	1 (1%)	81 (89%)	88 (91%)	13 (13%)
A1Q3	96	1 (1%)	37 (39%)	89 (93%)	6 (6%)
A2Q	283	20 (7%)	236 (83%)	173 (61%)	98 (35%)
A2Q1	108	6 (6%)	108 (100%)	49 (45%)	85 (79%
A2Q2	88	8 (9%)	70(80%)	66 (75%)	9 (10%)
A2Q3	87	6 (7%)	58 (67%)	58 (67%)	4 (5%)
Total	900	85 (9%)	670 (74%)	501 (56%)	129 (14%)

5.0 Discussion

The focus of this Dissertation in Practice was to look at the impact of using a Socioscientific Issues (SSI) teaching approach in the environment of an undergraduate general education science classroom in the hope of determining if this instructional strategy could serve as a means to improve my own teaching practice, and the educational outcomes for my students. I was particularly interested in whether undergraduates would see an increase in Socioscientific Reasoning (SSR) that would help them deal with problems and decisions at the intersection of science and public policy. This was significant because, while SSI has been discussed and studied in the literature for two decades, almost all of that work has been aimed at middle school and high school instruction. Precious little research has been done on using SSI at the college level – with just 9 published papers in the last decade, and the majority of these by the same handful of researchers. In addition, only 2 of those publications dealt with using the QuASSR instrument.

This study was approached with mixed methods – deploying the QuASSR instrument that was specifically designed for use with undergraduate students, but also using text-based analysis to explore anonymous student discussion posts/responses to prompts focusing on questions aimed at key elements of the SSI instructional strategy. In both the QuASSR instrument, and text-analysis, the level of SSR engaged in by students was measured using the SSR-Aspects – complexity, perspective-taking, inquiry, and skepticism as defined by Romine, et al. (2017). The analysis of the quantitative survey data and the qualitative discussion post data yielded very different, and interesting, results.

5.1 Correlation of Findings with the Literature

First, as detailed in Chapter 4, the overall QuASSR results show no significant difference between the pre and post intervention administration of the instrument, i.e. the mean total values pre and post fall within the respective confidence intervals at the 95% confidence level. In addition, the QuASSR results give no indication of any student change in the categories of socioscientific reasoning (SSR) aspects – complexity, perspective-taking, inquiry, and skepticism. So, again, no statistically significant change between pre and post intervention surveying emerges. This aligns well with the results of the only two published studies that deployed the QuASSR in an undergraduate science course, Romine, et.al, (2017), and Romine, et al.(2020). Note that these studies are both carried out by the same research team, who are also the developers of the QuASSR instrument.

In both the 2017 and 2020 papers, the authors provided evidence for the validity of the QuASSR instrument as a measure of SSR when using SSI instructional techniques (Romine, et al., 2017, 2020). However, in the 2017 study they reported no statistically significant difference between pre and post QuASSR scores around the SSI instruction deployed. (Romine, et al., 2017) This was true for total scores and individual SSR clusters.

In the 2020 study, however, students' mean SSR item score was measured at 0.38 with SD = 0.58 on the pre-survey, and 0.45 with SD = 0.69 on the post-survey. This gain in SSR reported over the course of the SSI instruction was statistically significant (0.071, SD = 0.59), and just within the 95% confidence level. However, they also calculated effect size using Cohen's D at D= 0.12. The effect size is then, very low. These results show the ability of the QuASSR instrument to detect changes in SSR in the context of SSI-based instruction, but the low effect size leads the team to then conclude that they do not have evidence that a higher QuASSR score indicates students are more likely to engage in SSR by demonstrating the SSR aspects (Romine, et al., 2020). Obviously, three limited studies do not rule out the QuASSR as an effective and reliable tool in investigating the impact of an SSI teaching strategy for undergraduates, however, it does indicate that more work needs to be done on the development and deployment of the instrument, and that no meaningful conclusions can be drawn from the QuASSR survey results in this study. The text-based analysis, however, tells a different story.

The texted-based analysis conducted in this study also parallels some of the conceptual and empirical work done in exploring the SSI instructional model (Kahn, 2016, 2017; Zeidler, 2019). SSI research has become important in science education because SSI has a central role in promoting scientific literacy (Sadler, 2009; Zeidler and Keefer, 2003). The science education community has documented ways in which SSI-based instruction supports a range of important learning outcomes including science content understandings and scientific practices such as argumentation and reasoning (Topçu, et.al, 2018). Zeidler, et al., (2019) maintain that SSR aspect research has been particularly helpful in this role, and that it has "demonstrated the primacy" of perspective and the closely linked process of inquiry. They maintain that this flows naturally from the SSI Teaching and Learning Model (Sadler, et al., 2017). This model, on which this study's activities are based, seeks to create student engagement in, and understanding of, science that connects to social issues through reasoning and argumentation (SSR) about the inquiry process and societal perspectives. The result of this process should be a synthesis of ideas and practices that prioritize perspective-taking and inquiry in combination with the other SSR aspects. (Zeidler, et al., 2019, Sadler, et al., 2017). Specifically, these aspects are:

- Recognizing the complexity of social and political issues involving science, and therefore not jumping to conclusions

- Understanding that SSI are subject to ongoing inquiry and being able evaluate credible information, and to identify information that is required but missing

- Analyzing SSI from multiple perspectives, and not just your own, and appreciating the unique concerns of all the stakeholders

- Exhibiting reflective skepticism in the processing and analysis of information about SSI from potentially biased sources and identifying and addressing your own potential bias (Romine, et. al, 2020).

The qualitative results in this study, which are drawn from text-based sentiment analysis both at the basic level of positive vs. negative sentiment, and at the more complicated SSR aspect level, show an alignment with this model. Specifically, Table 3 in chapter 4 indicates that at the level of positive and negative sentiment, most results are very close to the neutral result of 0.0. However, there are two scores that stand out. Posts in cluster A1Q1 have a mean score of +2.90, and those in cluster A2Q1 come in with a mean score of +2.84. These two high positive score results are interesting because both of these response clusters come from the Activity prompt 1 in both of the activities. These prompts deal with students staking out, and supporting, a claim based on the socioscientific issue scenario in each activity:

" Which claim from the Activity Sheet do you support or refute (base your position solely on the data provided)? Justify your position by explaining why the information best supports/refutes this claim over the others. Discuss why the data is, or is not, reliable."

As reported in Chapter 4, the high positive scores seem to be driven by a number of words used in each set of cluster responses for A1Q1 and A2Q2 that not only have the likelihood of the requisite positive ratings, i.e.. *claim, data, global, support, human, activity, reliable, information, Hawaiians, culture, native, sacred, can, believe, compromise, people, built*, but are often linked with the process of inquiry, as well as social perspective.

While the general sentiment analysis and word frequency analysis provide some interesting clues to what is going on as the students engage with SSI, it is the SSR aspect-level analysis that I believe allows a deeper insight into the dynamics. Table 8 in Chapter 4, shows that when an SSR aspect level text analysis is run for all student discussion responses, the perspective and inquiry aspects of student reasoning were identified 670 and 501 times, respectively. This compares to only total occurrences of 85 and 129 times, respectively for the complexity and skepticism aspects of student reasoning. Based on an assumption of accurate training of the AI algorithm using the SSR definitions developed by Romine, et al., (2017), these results correlate well with the existing literature, and demonstrate what Zeidler, et al., (2019) would refer to the 'primacy of perspective' and the closely related process of inquiry that arise in students engaging with SSI.

Unfortunately, what is not addressed by the text analysis in this study, nor by the observational work done by other researchers, (Topçu, et.al, 2018; Zeidler, et al., 2019), is whether students already entered the course with a high level of SSR reasoning ability, and whether it specifically emphasized the ability for perspective-taking and inquiry. This is a well-founded concern in that QuASSR results indicate that the 129 students in the pre-survey sample, and 98 students in the post-survey sample had mean pre/post scores for individual SSR items of 1.74/1.74 (on a scale of 0-2). Compare this with the results reported by Romine et al., (2017) where the pre/post mean for individual SSR items was 1.06/1.02, for a pre/post sample size of 57 students.

In the 2020 study, the pre and post mean scores for each SSR item were 0.38/0.45 (Romine, et al., 2020). The undergraduates participating in the Pitt study seem to have had significant SSR skills prior to entering the course.

5.2 Insights and Issues

A variety of significant insights and issues arise from the reported results, and their comparison to the existing literature – as small as that may be. First, the QuASSR was designed to create an instrument that could assign a quantitative score for SSR reasoning in classes using and SSI teaching approach. It is the first, and only, validated instrument of this type to date. The hope was that it would allow for a relatively simple, easily scored, and easily reproducible, deployment with potentially large sample sizes often found in undergraduate college general science courses. The research team that developed this tool has demonstrated its ability to measure *changes* in SSR (Romine et al., 2017; Topçu, et.al, 2018; Zeidler, et al., 2019). However, as they freely admit, the results of QuASSR based per and post instruction surveys still leave questions about whether you can accurately measure SSR skills to begin with – as you are dealing with highly complex issues driven by many factors – by using a narrow, forced choice survey system. As the team in 2020 reported themselves (Romine, et al., 2020), based on QuASSR studies so far, they must conclude that they do not have a meaningful benchmark for SSR levels using QuASSR. This means that while they can measure an SSR change, it cannot be said that a higher QuASSR score indicates students are more likely to engage in SSR aspects (Romine, et al., 2020). My experience parallels the experience of others deploying this instrument and, accordingly, I cannot draw any conclusions for application to my practice, or that of other undergraduate science instructors, from the QuASSR data. Ironically, the use of QuASSR was meant, in part, to increase the generalizability of results measuring the impact of SSI instruction. However, in this case, nothing is still nothing. This unfortunate insight is offset by some of the insights gleaned from the text analysis that focused on the thought process of students tackling SSI style problems.

As reported above, the text analysis, and especially the SSR aspect level analysis in this study, show that perspective-taking and the inquiry process emerge as the key factors as students engage with meaningful SSI issues. To be clear, perspective-taking is about students' ability to recognize and express their own perspective, as well as be able to understand and see an issue through the perspective of others. This is not the same as position, which is simply where you stand on a given issue. Instead, it speaks to how one perceives and interprets an issue (Zeidler, et al., 2019). In the jargon of science communication this could be described as understanding the framing of an issue. How do you frame the problem, and how do others frame it (Jamieson, et al., 2017)? Perspective-taking, then, is a critical component of successfully avoiding the types of cultural cognition divide that arises in identity issue and feeds the contention nature of SSI based problems in today's political and social climate (Kahan, 2017, 2011). This supports the main contention of SSI, that learning science content and practices is not enough to substantively impact the ways in which learners negotiate SSI (Romine et al.,2017; Sadler et al., 2011).

The inquiry process is closely aligned with perspective in SSR in that it is often the mechanism by which students gain that critical insight into the perspective of other stakeholders in an SSI scenario. Both the scientific method module taught during the 1-week instructional period, and the two SSI activities are designed to stress the role of evidence, reliable sources, and critical thinking in supporting the fundamental goal of perspective-taking and decision making (Sadler, et al., 2011). The discussion post prompts specifically ask students to make and support claims regarding SSI scenarios where they are asked to provide the supporting evidence for their position. They are also prompted to respond to the perspectives of the various stakeholders associated with the SSI scenarios. All of this engagement with the inquiry process demonstrates the dynamic interplay between inquiry and perspective-taking, explaining the two aspect peaks that appear in the data. It is important to keep in mind that SSI uses a variety of techniques such as scientific argumentation, debate, and discussion, and to engage thinking and reasoning processes, and to attempt to simulate the dynamics at play in real life problems related to sociocultural and policy issues that involve science. Instructors engaging in SSI methods try to provide a forum where characteristics such as tolerance, mutual respect, and moral sensitivity play a key role. For this to happen, perspective-taking and inquiry are vital to supporting much of SSR framework (Zeidler, et al., 2019).

While this analysis is supported by the three elements of the data described earlier – general sentiment analysis, word frequency analysis, and aspect-level text analysis – it still does not resolve one of the data issues inherent in this and other SSI studies. Specifically, because of a lack of pre-instruction discussion data, it cannot be said that the inquiry and perspective-taking aspects of SSR effectively demonstrated by students is a direct result of the SSI instructional module and student activities (Romine, et al., 2020). This is an issue that can be addressed in future study design. However, the SSR framework, as presented in the literature, and that highlights perspective-taking and using inquiry to guide issue resolution also fails to address another key element.

Among the many social lessons of 2020, it hard to miss the fact that perspective-taking in social and public policy issues of all kinds – including SSI – must address the perspectives of marginalized groups. Time and time again, we have seen that it is the marginalized groups –

whether by race, socio-economic status, gender identity, etc.- who most often pay the price for policy decisions that are based in a poor understanding of science and its intersection with society. I attempted to address this to some extent by including the TMT activity which provided students with the opportunity to explore the perspective of Native populations. I think this is especially important for a predominantly white institution (PWI) such as Pitt. If SSI instruction is to live up to its potential and its stated goal of fostering tolerance, mutual respect, and moral sensitivity in the resolution of SSI-based problems (Zeidler, et al., 2020), instructors will need to be intentional about including the perspectives of marginalized groups in their scenario selection. As stated earlier, guidelines for selecting SSI scenarios are already in short supply. This issue serves to add urgency to remedying that situation.

Another element that must be discussed relative to SSI instruction for undergraduates is exactly how this change in focus will be viewed and embraced or rejected by instructors. Learning science content and developing the competencies for scientific practices has long been thought to prepare learners for dealing with complex issues in society that have a science component (Zeidler et.al, 2019; Bybee, 2014, Bauer, 2009)). The SSI model seeks to contextualize this science content in real-world applications through the use of SSR (Zeidler, et al., 2019). But, in doing so it also flips the order of priority.

The SSIs drive the desire and need for students to learn science content and processes. In short, SSIs are not always about the debate over scientific findings. SSIs are often driven, in large part, by the sociocultural factors, including identity issues. This means content is no longer king – or at least, no longer in the driver's seat. While a large amount of literature points to the deployment of the SSI model in middle-school and high-school instruction (Zeidler et al., 2019; Zeidler and Kahn, 2014; Zeidler, 2003), the dearth of research on the use of SSI for undergraduate instruction is likely, at least in large part, to be a result of the fact that university instructors are steeped in content driven curricula where real-world problem selection and solving is driven by the need to cover content rather than the needs of society. For many university faculty, then, adoption of SSI strategies requires a major realignment of instructional priorities. Unfortunately, the structure and culture of many higher education STEM departments does not make such paradigm shifts easy (or even likely) to accomplish. If SSI instructional benefits for undergraduate students are clearly established, this issue will need to be addressed.

5.3 Limitations

There are several key limitations that have impacted this study. Some arose from the need to respond to the COVID-19 Pandemic and the resultant shift to a fully online, and asynchronous, delivery of both the intervention and data gathering. For example, the asynchronous video delivery of the Scientific Method Module on the nature and process of science precluded a direct back and forth of questions or comments between students and between students and the instructor. While students were invited to post questions online, this did not occur. In addition, while the Canvas analytics made it possible to know that the vast majority of the students accessed the videos, there was no way to tell if they actually watched them. The system can only indicate that the videos were played, nothing more. So, the actual nature of the participation in the content is unconfirmed. A student could start a video, and then not actually watch it.

Next, the instructor of record graciously allowed the full integration of the Module and Activities in their course syllabus. However, at the same time, it was necessary to stress participation was completely voluntary. This meant the study would likely suffer from the fact that some (or many) students would choose to opt out of participation. Happily, from the 170 students enrolled in the course, 129 and 98 participated in the pre and post QuASSR surveys, respectively. In addition 106 students participated in the online discussion boards. I tend to ascribe this high participation rate to several potential causes – integration of the material in the course, clear communication with students about the nature of the study, and good rapport with students from respectfully asking for participation and thanking them at each step of the process. The drop off from 129 to 98 is likely due to the fact that the pre survey and discussion boards occurred during the actual week assigned for that Module. However, the post survey, by its nature, occurred after the Module was ended and they were moving on to other material. Therefore the decay of the participation rate was actually 129 → 106 → 98. In that context, the mortality seems quite understandable and expected.

The next study concern was the need to preserve anonymity in the context of the QuASSR surveys. As a result of this factor, the pre and post surveys were not matched pairs – i.e. the pre surveys could not be connected with the post surveys for the same students. This prevented the use of various statistical methods for analysis – such as T-test – that might normally be applied in such a case. This left the analysis to be solely on the individual and mean scores directly. While this is still an acceptable approach, in future research, developing a planned approach for pairing participant surveys would greatly improve the reliability of the results. Analysis of unmatched pairs means it is not possible to know if all 98 post survey participants actually completed the pre surveys, and thus potentially skews the results.

In addition, as discussed above, the students in this survey seemed to enter the course with a very high SSR aspect rating, at least in comparison to the two other published studies that used the QuASSR instrument. As a result, several concerns are raised for the results. In starting with such a high score, is the ability to generate a measurable increase still possible with the QuASSR? In addition, in terms of the text-analysis, do the results simply indicate SSR abilities already in place without any increase due to the instruction and activities? Both of these concerns might be addressed by a redesign of the study. Instead of viewing the artifact analysis of the discussion boards as a tool to add depth to QuASSR results, SSR pretesting analysis could be accomplished by moving to a pre/post format with the discussion prompts. While this would require some minor adjustments to the prompts, it is certainly possible and something to be explored in future work.

Finally, there is one key element, and potential limitation, that underlies all the work in this study that should be mentioned. As a problem of practice, it was natural to apply SSI to my own undergraduate courses. However, as already discussed, the literature for undergraduate SSI instruction is exceptionally thin. More than this, the work is all done by the same small group of researchers. While this opens the door to doing work that has the potential to be helpful to the field – my much larger samples per se – it's also true that there isn't much of a foundation to build on. However, the issue is even a bit deeper than this. In doing the literature review, and even in my doctoral course work, I couldn't help but notice that the contextualization of science learning, and the subfields of education exploring the understanding of STEM teaching and learning, - e.g. SSI, NOS, STE(A)M, STS, etc. – seem to be largely driven by small in-groups, with 2-3 researchers being the only people consistently working in a given area. I don't think I am naive, because I realize that in most fields the intense focus on a given topic can produce a very small number of individuals who are conversant, let alone expert, in that topic. But, in the case of science education, this seems quite an extreme situation with the potential to limit the ideas being explored and the voices being heard. As a scholar-practitioner, that makes action research – and my job in general – a little harder.

5.4 Implications for Practice

The action research done for my Dissertation in Practice provides a number of implications for application in, and improvement of, my own teaching practice. First, while the QuASSR survey results raise as many questions as they answer, the text analysis results are extremely encouraging. The discussion boards indicate that the students did, in fact, seem to demonstrate many of the key factors in SSR:

1. Students demonstrating conceptual scientific understanding.
2. Students relating science content to the real world.
3. Students considering NOS themes associated with the issue.
4. Students focusing on, and assessing, the risks and benefits of the issue.
5. Students focusing on social dimensions of the issue (e.g. political/economic).
6. Students engaging in higher order practices.
7. Students negotiating social dimensions of the issue.
8. Students collecting and/or analyzing scientific data related to the issue.

This study supports the demonstration of factors 2, 4, 5, 7 and 8. In particular**,** there is clear indication of students' ability to think critically through use of inquiry and the ability to hold the perspectives of other stakeholders in addition to their own. Also, they are successful at making real-world connections to content by contextualizing the content with socio-cultural issues and public policy. Even more than that, there is some indication of what Zeidler , et al. (2019) identify as the additional benefits of the SSI instructional model - tolerance, mutual respect, and moral sensitivity. These various positive outcomes can be seen in some direct quotes from the discussion boards. It is especially clear that the aspects of inquiry and perspective-taking are present. Here are some important examples:

"It is definitely clearer to me how nonlinear the "scientific method" can be. Hearing it described as a 'human endeavor' did a lot for my understanding of how science- astronomy in particular- is fueled by man's innate curiosity."

"The [Lecture 2 Module] really opened my eyes to why society rejects science so often. The [Lecture] video didn't necessarily change my perspective of science but the way that society views science. This foundation is key for everybody to have."

"[The Module] didn't change my ideas of how science works, but elevated them by providing interesting supplemental viewpoints from historical figures as well as many great points about how identity and predisposition can impact someone's belief in scientific conclusions (a relevant example would be how many are ignoring/minimizing the gravity of COVID-19 due to personal beliefs and, most likely, a subconscious fear of what scientists are telling them)."

"This lecture was super informative for me about what science is. I am also not a big science person but it was really interesting to come back to the key aspects of what science is. Seeing it explained the way it was throughout the lectures allowed me to understand the bigger picture."

"I support the second claim for a few reasons. First off, exploitation of Natives has been something America has been doing for way too long and it needs to be put to a stop whenever it can, and this is one of those times. Another reason is because one of the big supporters of the TMT

(India) said that another location in the Canary Islands, would work fine. There would be no opposition to the move here which is a huge benefit."

"Although I appreciate the importance of exploration, I feel claim 2 is the best moral decision. I know if a land sacred to me was completely disrespected and left unprotected, I would want someone to help me. Claim 2 is the best way to avoid serious conflict. Although claim 3 is a hopeful compromise, I do not believe it is honestly realistic. There is no way for both groups to get exactly what they want so I feel it is better to respect the Native Hawaiians."

"Science and culture should be able to coexist. There are Native Hawaiians, acting in good faith, on both sides of the issue. They should try to negotiate a compromise that allows construction to move forward under strict environmental guidelines for all of the Mauna Kea Observatories." I lean more towards it being the native's land, but if there is any compromise that would keep the native people happy then I believe it should be fine."

These types of responses from my students are greatly encouraging to me and lead me to believe that the time spent on the nature of science instruction and SSI activities is well worth it even with the possibility that some SSR knowledge and skill is already present. In fact, many students do specifically state that they had been exposed to many of these ideas before, but still saw the SSI instruction as providing "greater depth", "an important refresher", or "deeper understanding" of the issues. In addition, the students themselves clearly identify these lectures and activities as fun, interesting, eye-opening, and helpful – among many other positive words used in their discussion posts.

Another relevant element of the results of this work with regard to my teaching practice centers around overall student engagement. Educational research supports the idea that increased levels of student interest, activity, and engagement all correspond with increased benefits across educational outcomes (Fischoff, 2013; Macissac, 2011; Applebaum, et.al., 2010; Bauer, 2008). Therefore, striving to connect with student interest is a high impact teaching practice. The data from the text analysis of discussions supports, both directly and indirectly, the idea that student engagement and interest was elevated. First, a case can be made that interest and engagement are inherent in the inquiry aspect. In training the DisplayR intelligent system on the SSR aspect of inquiry, statements such as "I'd want to know", "we need to find out", and "we should look at" etc. were tagged as demonstrating the presence of the SSR inquiry aspect according to the definitions by Romine, et al. (2017). It could certainly be argued that these also correspond to sentiments of curiosity and interest, and therefore engagement with the material. In other words, a high level of SSR inquiry, by its very nature, should correspond with engagement and help to improve overall outcomes.

It can also be argued that the overall student response rates for completely voluntary discussion activities is also a strong indication of student interest. Despite receiving no positive incentives, or negative outcomes, for their decision to participate or not, 106 students chose to engage on the discussion board with posts. Further, with 900 total responses, the indication is the vast majority of those students either engaged with all posts or posted additional responses to a given prompt or responded to a fellow student's post. That indicates a fair amount of effort by students to engage with the material. As a result, I would conclude that SSI activities elicit engagement from students and that increasing the number of SSI based activities in the instruction would be a logical way to continue to improve my students' overall interest in course content.

This is not to say that I would necessarily walk away from the QuASSR instrument. The fact that this instrument has been put out into the STEM community as a validated instrument, capable of measuring changes in SSR and that its developers are interested in other researchers using it (Romine et al., 2020; Zeidler, et al., 2019) surely creates a disconnect when it has been unable to confirm a statistically significant result (change in SSR) and/or a reasonable effect size in three studies. This raises several possibilities that must be considered.

1. The QuASSR is not actually capable of measuring meaningful changes in SSR.
2. The QuASSR is not sensitive enough.
3. The studies involved have been either too small, or had too short an intervention, for SSI teaching to create a meaningful change in SSR.
4. SSI teaching strategies do not impact SSR.

While all of these explanations are certainly possible, this study had an element that the others did not, i.e. an alternative data source for exploring the use of SSR in the form of student artifact analysis. The text analysis, and especially the AI-based SSR Aspect-level analysis would certainly seem to indicate that *something* positive is taking place in terms of student SSR, without answering the "what" and "why" questions. However, that fact seems to indicate that, as a starting position at least, it would be wise to focus first on possibilities 1-3 above, before jumping ahead to deciding SSI is a failed strategy at the undergraduate level (keeping in mind, also, that it has a much more robust track record in K-12 research). I will address this more fully in Section 5.5 below.

In light of the apparent success of the use of SSI instruction in both developing SSR and potentially increasing overall student interest and engagement, I will continue to use and refine the nature of science module that was deployed in this study, as well as review all of my course syllabi for opportunities where content lends itself to SSI issues that can be presented as student activities. This will allow me to thread SSI throughout my courses, rather than in a single short-term intervention. In addition, I will give more attention to student participation in both face-to-face and online discussions (as appropriate for university operating conditions going forward).

In addition to adjusting, and expanding, my use of SSI instructional strategies, I will also continue to explore and refine the use of text analysis on student artifacts generated through SSI based activities. The text analysis methods used in this study – especially those associated with the use of AI for higher level sentiment analysis – have been shown to have great potential as a tool for investigating how students engage with science that impacts social issues. I believe this is a natural complement to the work done on SSI, and it maty be found to be a more sensitive or accurate way to measure SSR as well as to gain a deeper understanding of the actual dynamics of student engagement. For these reasons, I would like to explore ways to turn the text analysis into a pre/post model. As it stands, I used text analysis as a secondary data source. In actuality, it would be potentially fruitful to investigate this as a primary tool. For that to be meaningful, I would need to look at the pre intervention SSR aspect levels of students. I believe that this would be fairly easy to do, in much the same way that the QuASSR is designed. Specific topic prompts could be administered both before and after the instructional intervention.

This also leads to another aspect of my personal practice that can and will be enhanced by this work. My teaching practice includes not only teaching undergraduates but teaching faculty through the University Center for Teaching & Learning (UCTL) at Pitt. In my role as an education consultant, I have the opportunity to deliver workshops and seminars, review and design courses, and provide one-to-one consultations for large numbers of faculty, especially in the STEM fields. This means that I also have the opportunity to share my own work with them, and potentially to recruit them in further investigations of SSI. Even more than this, the AI text analysis may have other valuable applications in the work of UCTL. The high-level sentiment analysis could be used in any investigation of open-ended written responses. This means that it may have utility in the analysis of student evaluation of teaching – an area sorely in need of additional analysis tools. It could also be used to analyze faculty surveys with open ended questions used as needs assessments, or in faculty evaluation of UCTL offerings and services. This application of the groundwork in this study allows for impact far beyond my immediate classroom, accruing benefits to a large segment of the Pitt community.

5.5 Implications and Directions for Future Research

I have already alluded to several clear implications and potential directions for future research concerning SSI teaching strategies. I will elaborate on those potential avenues as well as discuss several others as well.

One of the most promising and interesting areas for further investigation is the use of sentiment-based text analysis, especially AI driven higher level sentiment analysis focusing on SSR aspects demonstrated by students. As mentioned earlier, this data source was considered as a secondary method to the QuASSR survey and was meant to add depth and context to the QuASSR results. Not only that, but this method was chosen initially as "backup" approach meant to replace the more traditional face-to-face discussions and observer coding. This change was required because of disruptions due to the COVID-19 pandemic. Because of the pandemic, Pitt transferred all instruction to remote delivery methods. In addition, many instructors decided to deliver their courses in an asynchronous online mode. This was a very sound decision in many cases. However, the decision of the instructor of record for Astronomy 0088 to use this approach precluded my ability to have live student interactions and discussions around the content. This led to my decision to use online asynchronous discussion boards as a replacement strategy. This in turn led to investigating the use of online tools to handle all the students artifacts in the form of online postings. Ultimately, such an approach was a good decision in light of the fact that students produced 900 individual responses and some 47,700 words for analysis. But, of course, what really made this a good choice was that it was the AI driven text analysis that provided the most interesting results and insights in the study. For this reason, further research concerning high-level text analysis with regard to SSR aspects is at the top of the list of areas to explore. It may also be possible to take speech to text conversions of classroom discourse, which would help in applying the techniques used in this study back in post-pandemic face-to-face classrooms where the discussions are live. Such intriguing "discussion tracker" applications have already been tried at the secondary level (Olshefski, et.al., 2020). In addition, it has implications not only for SSI research, but for a wide range of educational situations where large numbers of open-ended responses are being evaluated. This includes, as mentioned earlier, student evaluation of teaching, faculty program and service evaluation, and more.

There was much useful information to be gained from this technique, but it did suffer from a study design flaw as detailed above. Because of the way the study had evolved, there was no allowance for a pre analysis of student discussion, and it would have been difficult to arrange this under the constraints of our COVID protocols. However, with enough planning, study design could be adjusted to gather this bench-marking data and improve the reliability of the results by addressing the question of how much SSR knowledge and skill students have prior to the instructional intervention.

As intrigued by the text analysis results as I am, again, I still think that there is ample justification for further investigation of the QuASSR instrument. Toward that end the logical points to address are the following. First, increase the sample sizes in future studies. My sample size was considerably larger than that used by either of the other published studies, and that is problematic. Next, extend the length and number of instructional treatments. In all the studies at the undergraduate level to date, the intervention was a 1-week week period for all learning activities, including no more than 1-3 class meetings (depending on the course schedule). This would be important and potentially valuable step in seeing the actual value of SSI. In addition, this much larger instructional period might "move the needle" on QuASSR results. Finally, my last issue to address in revisiting QuASSR is to create a study design that allows the use of anonymous IDs so that the pre and post surveys can be matched for individuals without identifying information. This is possible with Qualtrics, but my understanding is that there is some risk of non-unique IDs being generated. In any case, this is worth further investigation, because it provides the benefit of more rigorous statistical analysis such as paired sample t-tests, which can be used to determine whether there is statistical evidence that the mean difference between paired observations is significantly different from zero.

Another area to be looked at is one that becomes possible because of the AI text-analysis. It would be of value to me, and potentially many other instructors, to investigate the relationship between "soft" course Learning Objectives and the SSI instruction directly. This falls under what would be possible with high-level sentiment analysis. Many undergraduate (and graduate) programs are beginning to build professional interaction or "soft skills" into course learning objectives. These can include things such as communication, teamwork, attitude, leadership and more. It is easy to see how AI systems could be trained to identify these additional general aspects.

Along these same lines, as mentioned earlier, the flexibility of AI text analysis opens up a wide-range of related areas that can be explorer, and that tie directly to my practice and the work of the UCTL. Specifically, there are two key areas where the utility of text analysis has great promise. First, in my own teaching and faculty development work. In this case, text analysis can be expanded to multiple courses in my own practice, I can partner with other faculty to expand data samples by involving their courses and students and ultimately, perhaps expanding the circle to include other interested STEM faculty at other institutions. There are some current and upcoming projects involving broad teaching coalitions that might be ideal for such explorations. For example, Process Oriented Guided Inquiry Learning (POGIL) (Simpson, 2019) is a long-standing project that has been heavily focused on secondary science education but, in the last few years, has been increasing in application at the undergraduate level. Since SSI is an inquiry-based teaching model, there is some natural synergy with this group and might be interest in conducting SSI research. Another example is SEISMIC, a much newer undergraduate initiative among ten large research universities, including Pitt (https://www.seismicproject.org/about/overview/). There is potential synergy here as well, in that SEISMIC is focused on achieving equity in STEM education. This is also a key element of my doctoral program that I discuss in more detail below. The natural alignment, and the potential ability of this text analysis to be easily scalable, makes these types of partnerships something to be explored.

The other area that could benefit greatly from scaling the text analysis applied in this study is the field of student evaluation of teaching. In both the SSI research, and the research into student evaluation of teaching, what is most needed is to hear the voices of the students. The AI text analysis has been demonstrated here to have the potential to open up a new and powerful means to collect the information in those voices and make the kinds of adjustments needed to advance

SSI teaching, and frankly, teaching in general. For example, I can envision broad open-ended questions becoming a staple of student teaching surveys, rather than the heavily reliance on Likert-scale type responses. The AI text analysis could actually solve the problem of the time-intensive work currently needed to distill information from student responses. Reliable AI sentiment coding would allow the gathering and analysis of large amounts of student opinion data on a very high level. This is most definitely an exciting are to explore.

Obviously, the instructional environment (online vs. face-to-face) had significant implications for this study, many that could not be avoided. However, it is also true that the COVID-19 pandemic is likely to leave a deep mark on college education. I believe that it is clear that moving forward we will see more remote learning offerings and more hybrid offerings (combining remote and face-to-face experiences). For this reason, it will be essential to continue to explore SSI instructions in both modalities, in an attempt to identify the differences and, more importantly, the potential strength and weaknesses of each approach to see if SSI will be able to become a valuable tool in the kit of college-level STEM instructors.

I think another area of exploration, or rather a missing piece of the puzzle for undergraduate teaching is looking at the link between improved outcomes for student content knowledge and SSI. There is a lot of research on SSI in the K-12 environment that shows clear evidence of improved content knowledge being driven by SSI strategies (Zeidler, et al., 2003; Zeidler and Kahn, 20014; Zeidler, 2014). However, the work at the undergraduate level does not directly address this issue. This is obviously significant because content is the key driver of course design in college level STEM. Demonstrating the link at this level would be necessary in convincing most STEM faculty to consider SSI as a useful tool for their courses. It can certainly be argued that the ability to understand content knowledge and apply it is essential to solving SSI scenarios. This has been discussed and demonstrated repeatedly (Sadler, et al., 2007; Topçu, et al., 2018, Zeidler, 2014). I am not disputing this. However, it has not been done at the undergraduate level. I am simply advocating for research that demonstrates this connection as an essential element of the work needed to advance SSI instruction in the college classroom.

Finally, I would like to briefly mention another important discussion to be had around future SSI research and applications. We have seen that SSI has the potential to have a significant impact on the aspect of perspective-taking. In fact, perspective-taking has emerged in this study as one of the most important elements in developing student SSR. Many of the SSI activities that I have seen address important sociocultural issues such as climate change, fracking, vaccination, etc. (Zeidler, 2019). In doing so, they often show the clear perspectives of opposing sides in the debates. Interestingly, however, I have not noticed many SSI scenarios that investigate the perspectives of those whose perspective is most often missing in public policy debate.

One other important outcomes of the annus horribilis that we have all just lived through, is the elevation of issues of social justice, diversity, equity, and inclusion. But where are the underrepresented populations in SSI? They are largely absent. Making sure that they were included in some fashion was one of the drivers behind my developing the Thirty Meter Telescope (TMT) Activity for this study. I believe that the analysis of student responses showed that they included the unique perspective of the Native Hawaiians in their use of SSR. But one example is hardly enough.

One of the most important aspects of Pitt's EdD program is instilling the vision, and providing the tools, so that each scholar-practitioner can transform the field of education through striving for equity and justice in education. We each will seek to do this in our own area of concentration and within our own practice. I feel strongly that to be true to this goal, I can help to investigate the use of SSI in such a way as to highlight how underrepresented populations are so often simply not at the table when issue of science and public policy collide, even though they are much more likely to suffer when poor decisions are made around SSI situations. They deserve to be there and need to be heard. "Nothing About Us Without Us!", is the way this need is often communicated as a slogan. (Its origins trace back to the Polish-Lithuanian Commonwealth in the 16th century, Wagner, 1992.) It speaks to the understanding that no issue should ever be resolved without the full participation of those who are directly involved. Recognizing this fact is true perspective-taking at the highest level. Since this perspective seems to be lacking in the investigation of SSI at the college level, I believe that it is vital, as a graduate of this program, that I try to further the integration of DEI issues and perspectives into SSI teaching strategies.

Appendix A: Scripts and Instruments

Draft Recruitment Script

Surveys:

Thank you for considering participation in this short survey about the social impact of a science-based issues! Specifically, I am interested in how students think about these types of problems. The survey is completely voluntary and anonymous. The choice to participate or not will not impact how you do in this class in any way. You may decide to stop participation at any time.

You will be asked to complete the survey again later in the course.

This survey is for the sole purpose of a study at the University of Pittsburgh. This study will be used to help complete my doctoral studies. Information obtained will be kept confidential and used only for purposes of the study. If you have any comments, questions, or concerns, please contact me directly.

Instruments and Protocols

QuASSR Pre/Post Sample:

FRACKING IN PAVILION WYOMING

Pavilion is a town in Wyoming located in the west central part of the state. Pavilion has a population of 240 people and is situated near a site where hydraulic fracturing (or "fracking") of natural gas takes place. In fracking, pressurized water mixed with chemicals and particles like sand are forced into layers of shale (a rock composed of sheets of hard mud which lay on top of each other like the pages in a book), opening fractures which allow large amounts of natural gas to be extracted. After cracking the rocks, the liquid then returns to the surface where it is stored in a sealed container or pond, and the sand remains in the cracks to keep them open. Proponents of fracking consider it a breakthrough in the energy industry. Fracking allows extraction of much larger quantities of natural gas than traditional natural gas extraction methods and allows us to tap into reserves that were previously impossible to reach. The oil and gas industry is an important part of Wyoming's economy, bringing billions of dollars into the state. Recently, however, the aquifer from which the residents of Pavilion get their water has been found to be contaminated with high levels of dissolved organic gases like methane, ethane, and propane, which has rendered the water unsafe. Residents of the area, as well as scientists from the Environmental Protection Agency (EPA) and the United States Geology Survey (USGS) who collected the data, point out that fracking in the area is possibly to blame. The data from these tests go against claims by the drilling industry, which reports that injecting water, sand, and chemicals underground has never led to groundwater contamination. The company denies that the pollution in the aquifer is related to its operations. They cite a similar incident that took place in the Marcellus Shale region of Pennsylvania; similar water contamination there was found to be a result of a gas reserve near the resident's water well, and not due to nearby fracking activities. What should be done about this situation?

SSR Aspect: Complexity

1. Is the issue of fracking a complex issue? YES/NO

NO: Select the response below that best explains why the fracking issue is a fairly straightforward issue.

a. The world needs energy, and fracking provides access to new sources of relatively clean energy. Therefore, fracking is a positive development for our society. – 0 pts
b. Fracking contaminates fresh water supplies with toxic chemicals. Therefore, fracking should not be used to extract natural gas. – 0 pts
c. Fracking may generate controversies, but science and technology can be used to overcome these potential problems. – 0 pts

YES: Select the response below that best explains why the fracking issue is complex.

a. The fracking issue is complex because it deals with complicated dimensions of geology and economics. – 1 pt.
b. The fracking issue is complex because it presents multiple tradeoffs related to supply of energy and the environment. – 2 pts
c. The fracking issue is complex because we do not know all the consequences (positive and/or negative) of the process. – 1 pt.

2. Is the case of fracking in Pavilion, WY easy to resolve?

YES/NO

NO: Why is the Pavilion fracking case difficult to resolve?

a. Because it involves balancing environmental concerns, demands for energy, and the economy. – 2 pts

b. Because topics like the environment, the availability of energy and the economy are complicated topics. – 1 pt.

c. Because the description of the case offers limited information. If more details were available, the issue would be easier to resolve. – 1 pt.

YES: Why is the Pavilion fracking case easy to resolve?

a. It is clear that fracking will provide access to energy and be beneficial for the local economy; therefore, fracking should continue to be used in Pavilion. – 0 pts

b. It is clear that fracking will lead to environmental problems; therefore, fracking should be discontinued in Pavilion. – 0 pts

c. Once scientists are able to analyze the complete case, they will be able to create a solution that is fair for all interested parties. – 0 pts

SSR Aspect: Perspective-taking

3. How likely is it that the residents of Pavilion and representatives of the gas company would endorse the same solution to the Pavilion fracking case?

It is **very likely** that the residents of Pavilion and gas company representatives would endorse the same solution.

It is **NOT very likely** that the residents of Pavilion and gas company representatives would endorse the same solution.

Why is it **very likely** that the residents of Pavilion and the gas company representatives would endorse the same solution?

a. The two groups will likely collaborate and reach a shared solution. – 0 pts

b. If both groups work toward a solution they will end up with the same basic plan. – 0 pts

c. An independent panel of experts could be called in to develop a solution that meets the needs of all interested parties. – 0 pts

Why is it **not very likely** that the residents of Pavilion and the gas company representatives would endorse the same solution?

a. The gas company representatives and the residents of Pavilion residents have different priorities. – 2 pts

b. The gas company representatives and the residents of Pavilion have access to different pieces of information. – 1 pt.

c. They gas company representatives and the residents of Pavilion have not had enough time to reach consensus. – 0 pts

4. How likely is it that an environmental advocacy group and representatives of the gas company would endorse the same solution to the Pavilion fracking case?

It is **very likely** that the environmental advocacy group and gas company representatives would endorse the same solution.

It is **NOT very likely** that the environmental advocacy group and gas company representatives would endorse the same solution.

Why is it **very likely** that the environmental advocacy group and the gas company representatives would endorse the same solution?

a. The two groups will likely collaborate and reach a shared solution. – 0 pts
b. If both groups work toward a solution they will end up with the same basic plan. – 0 pts
c. An independent panel of experts could be called in to develop a solution that meets the needs of all interested parties. – 0 pts

Why is it **not very likely** that the residents of Pavilion and the gas company representatives would endorse the same solution?

a. The gas company representatives and the environmental advocacy group have different priorities. – 2 pts
b. The gas company representatives and the environmental advocacy group have access to different pieces of information. – 1 pts
c. They gas company representatives and the environmental advocacy group have not had enough time to reach consensus. – 0 pts

SSR Aspect: Inquiry

5. If you were asked to make a decision on whether to stop or continue fracking in Pavilion, do you feel as though you have enough information to make a decision?

I **feel I have sufficient information** to make a decision about whether to stop or continue fracking.

I **do not feel I have sufficient information** to make a decision about whether to stop or continue fracking.

Why is there **sufficient information** to make a decision about whether to stop or continue fracking?

a. The benefits of fracking outweigh the risks. Fracking brings money into the local economy and provides cheap energy, both of which are important for living a comfortable life.—0 pts
b. The risks of fracking outweigh the potential benefits. Fracking causes pollution in Pavilion which will negatively impact the quality of life for Pavilion residents.—0 pts
c. Since research was done independently by the Environmental Protection Agency (EPA) and the United States Geological Survey (USGS), the effects of fracking are clear.—0 pts

Why is there **not sufficient information** to make a decision about whether to stop or continue fracking?

a. Everyone has different data. If the gas company, the residents of Pavilion, the United States Geologic Survey (USGS) and Environmental Protection Agency (EPA) agree on the proper data, and then collect it in a nonbiased way, then there will be sufficient information to make a decision.—0 pts
b. I am not sure about the economic and scientific details behind fracking, and thus should do more reading before I can make a decision.—1 pt.
c. The long-term risks and benefits of fracking are unclear and need more study before a decision can be made. –2 pts

d. It is still unclear whether or not fracking is causing the water contamination in Pavilion. This needs to be confirmed before a decision can be made.—2 pts

6. If you were forced to make a decision whether to stop or continue fracking based on the information in the article, what decision would you make?
   a. Stop Fracking
   b. Continue Fracking

7. Do you think the residents of Pavilion, the gas company, the United States Geologic Survey (USGS), and a local environmental advocacy group would agree with your decision?

   I feel all parties **would agree** with my decision.

   I feel one or more of the parties **would not agree** with my decision.

   Why would all parties agree with your decision?
   a. If all parties looked at the issue without bias, then it is clear that fracking is causing more harm than good.—0 pts
   b. If all parties looked at the issue without bias, then it is clear that the benefits of fracking outweigh the potential harmful effects. –0 pts

   Why would one or more parties likely not agree with your decision?
   a. Certain parties will disagree because they don't have proper understanding of the risks and benefits of fracking.—0 pts
   b. It is unlikely that I could get all parties to agree with my decision because their agreement depends on whether or not they are benefitting from fracking.—2 pts

c. It is unlikely that all parties would agree at first due to their different perspectives. However, they would eventually come to a common agreement about the best course of action to take.—1 pt.

8. If the decision you made on whether to stop or continue fracking were put into action, would you recommend that additional funds and resources be used to continue studying the effect of fracking on Pavilion's water supply?

I **would not recommend** continuing to study the effect of fracking on Pavilion's water supply.

I **would recommend** continuing to study the effect of fracking on Pavilion's water supply.

Why would you not recommend continuing to study the effect of fracking on Pavilion's water supply?

a. Since a decision has already been made, it is a dead issue so no need to continue collecting data.—0 pts
b. That a decision has already been made implies that there was sufficient information to make that decision. So, no more study is needed.—0 pts

Why would you recommend continuing to study the effect of fracking on Pavilion's water supply?

a. Collecting additional data would help address and defray criticisms from groups that disagree with my decision.—1 pt.
b. Collecting additional data will likely lead to a common agreement.—0 pts
c. Collecting additional data will help people continue discussing and re-evaluating my decision.—2pts

SSR Aspect: Skepticism

9. At a town meeting, a group of scientists employed by the gas company and another group of scientists employed by the United States Geological Survey (USGS) provided expert opinions on the fracking issue. Would you expect their opinions to be similar?

Expert opinions offered by the scientists employed by the USGS and the gas company **will likely** be similar.

Expert opinions offered by the scientists employed by the USGS and the gas company **will likely not** be similar.

Why would the opinions of both groups of scientists likely be similar?

a. Science is an objective process based on data, so the opinions of both groups of scientists should be similar.—0 pts
b. While the data from both groups of scientists may be different initially, they will likely come to agreement after they share data with each other.—0 pts
c. Scientists are typically unconcerned with subjective opinions and are more concerned with reaching a result based on actual findings. So, the opinions of both parties will be similar.—0 pts

Why would the opinions of both groups not likely be similar?

a. The details behind the fracking issue are multifaceted and difficult to understand, so the scientists will likely have different opinions on the issue.—1pt
b. While the data from both groups of scientists may be different initially, they will likely come to agreement after they share data with each other.—0 pts

c. The gas company and USGS will hire scientists who have opinions consistent with the groups' goals, so the different scientists will offer different opinions. –2pts

10. In response to the criticism about the questionable effects of fracking on Pavilion's water supply, the gas company has suggested using part of its profits to hire a team of scientists dedicated to collecting data on water quality in the area and giving regular reports to the local community. The residents of Pavilion decide to hire a different group of scientists to also conduct water monitoring. Would you expect the findings of these two groups of scientists be similar or different?

I **would expect** the findings of the two groups of scientists to be the **same**.

I **would expect** the findings of the two groups of scientists to be **different**.

Why would you expect the findings of both groups of scientists to be the **same**?

a. Findings would be the same if the science was done correctly since science is an objective process.—0 pts
b. The scientists may have different findings at first but would eventually come to agreement after talking it out.—0 pts
c. Both groups of scientists will be studying the same polluted water supply, so should get similar results.—0 pts

Why would you expect the findings of the two groups of scientists to be **different**?

a. The two groups of scientists will be collecting data to support different perspectives, so findings will likely be different.—2 pts

b. The gas company has the money to pay for better scientists, and so their data will likely be more trustworthy.—0 pts

c. Findings may be different because each group of scientists may use different methods.—1 pt.

11. A geologist at a prestigious university publishes an article in a top-ranked journal confirming that the chemicals contaminating Pavilion's water supply are many of the same chemicals that are associated with the nearby fracking operation. Do you think this will change the fracking debate?

I **would expect** the new findings to change the fracking debate.

I **would not expect** the new findings to change the fracking debate.

Why would you **not expect** this to change the fracking debate?

a. The study is unnecessary since these findings have already been confirmed by the USGS and EPA.—0 pts

b. The opposing parties are already set in their beliefs, and so are unlikely to consider additional data which may change their opinions.—2 pts

c. The geologists publishing this article are outsiders not directly involved in the debate, and so the parties involved are unlikely to consider the findings.—1 pt.

Why would you **expect** this to change the fracking debate?

a. After considering these new findings, both parties are likely to agree that fracking is the cause of Pavilion's water contamination and will take action to correct the situation.—0 pts

b. The parties opposing fracking will use these findings to strengthen their position and influence overall opinion on the debate.—2 pts

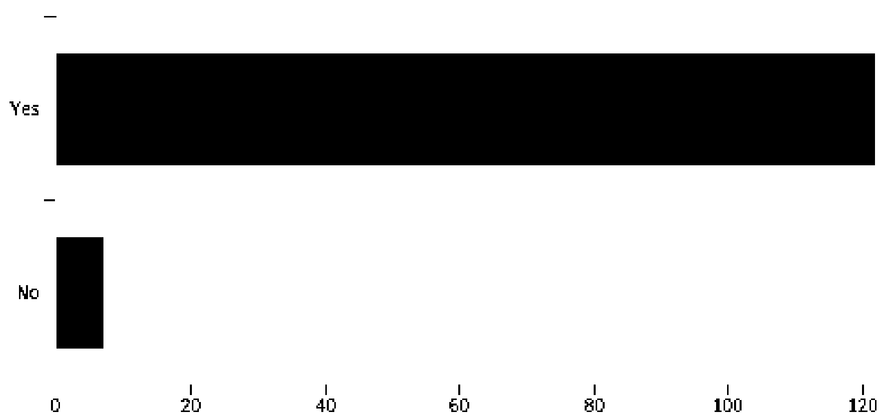
c. The opposing parties will likely interpret the report differently which may drive the debate further from reaching a solution.—1 pt.

Romine, W. L., Sadler, T. D., & Kinslow, A. T. (2017). Assessment of scientific literacy: Development and validation of the Quantitative Assessment of Socio-Scientific Reasoning (QuASSR). *Journal of Research in Science Teaching*, *54*(2), 274–295. https://doi.org/10.1002/tea.21368

Appendix B: QuASSR Results

Q1 Pre/Post - Is the issue of fracking a complex issue?

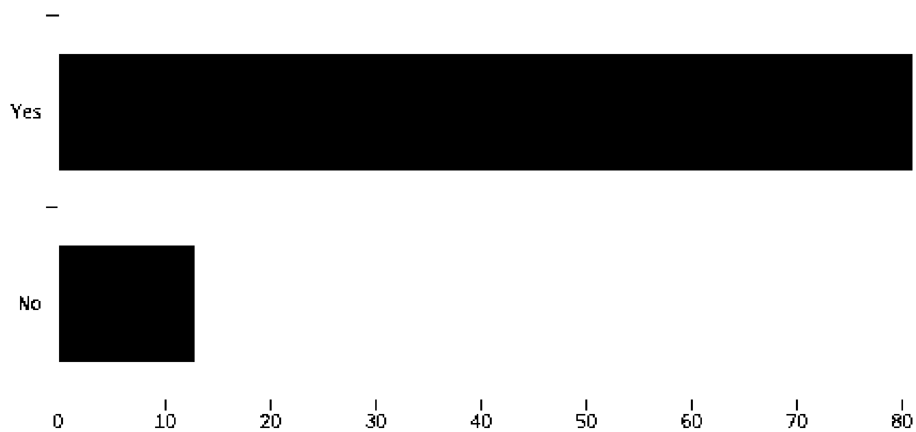
Pre



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is the issue of fracking a complex issue?	1.00	2.00	1.05	0.23	0.05	129

#	Answer	%	Count
1	Yes	94.57%	122
2	No	5.43%	7
	Total	100%	129

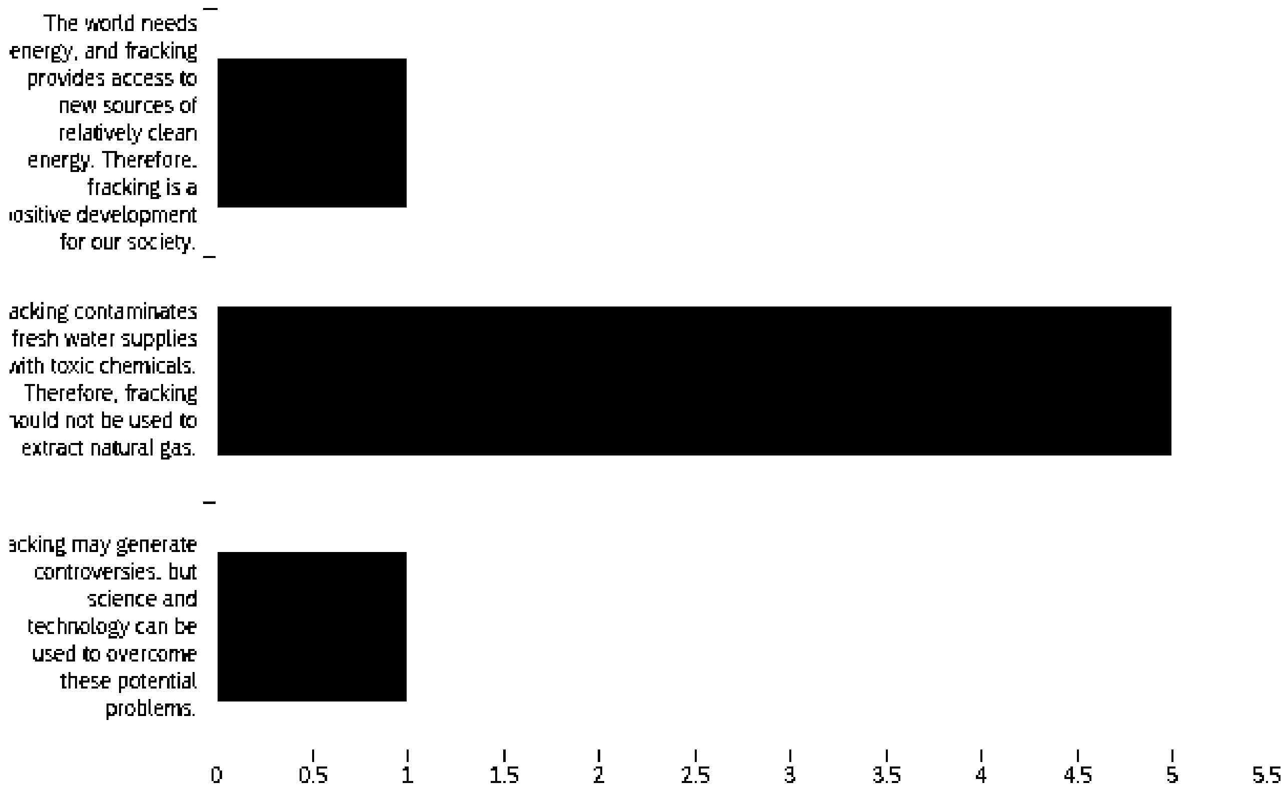
Post



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is the issue of fracking a complex issue?	1.00	2.00	1.14	0.35	0.12	94

#	Answer	%	Count
1	Yes	86.17%	81
2	No	13.83%	13
	Total	100%	94

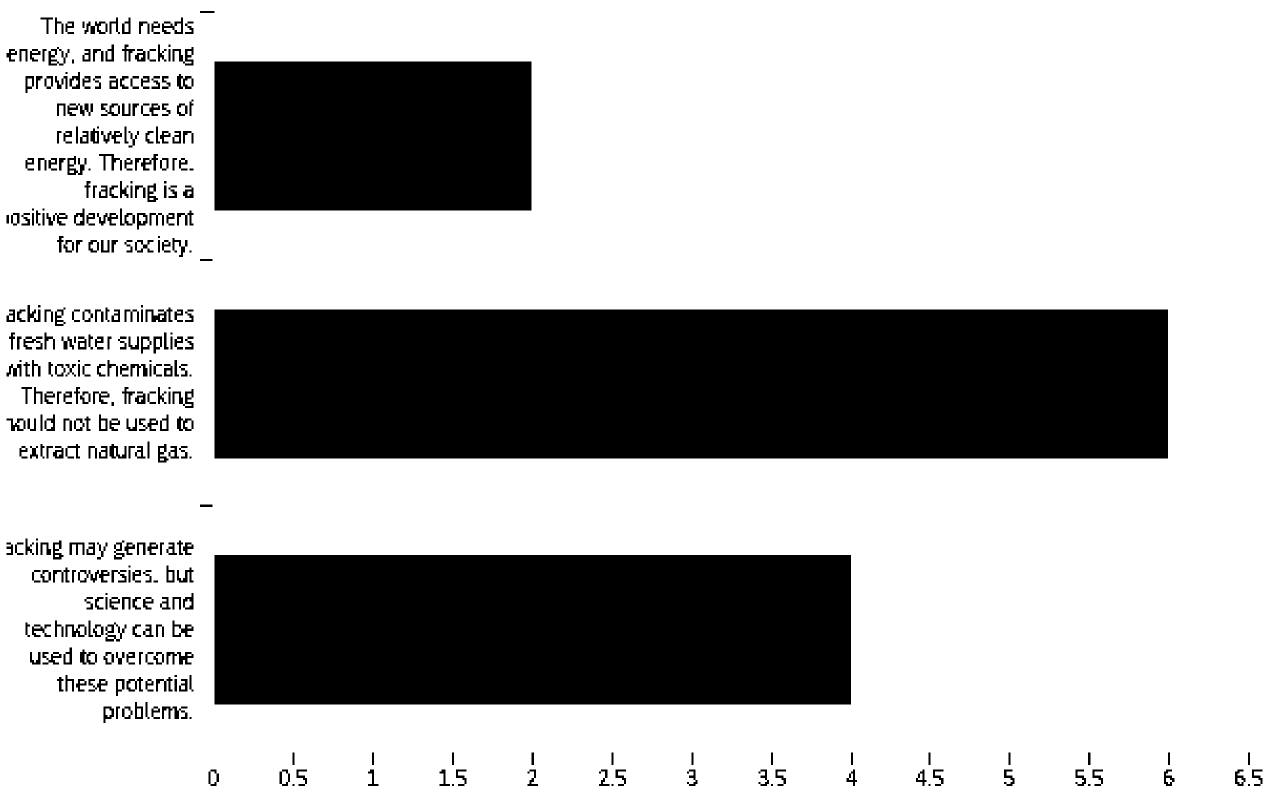
Q1N Pre - Select the response below that best explains why the fracking issue is a fairly straightforward issue.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Select the response below that best explains why the fracking issue is a fairly straightforward issue.	1.00	3.00	2.00	0.53	0.29	7

#	Answer	%	Count
1	The world needs energy, and fracking provides access to new sources of relatively clean energy. Therefore, fracking is a positive development for our society.	14.29%	1
2	Fracking contaminates fresh water supplies with toxic chemicals. Therefore, fracking should not be used to extract natural gas.	71.43%	5
3	Fracking may generate controversies, but science and technology can be used to overcome these potential problems.	14.29%	1
	Total	100%	7

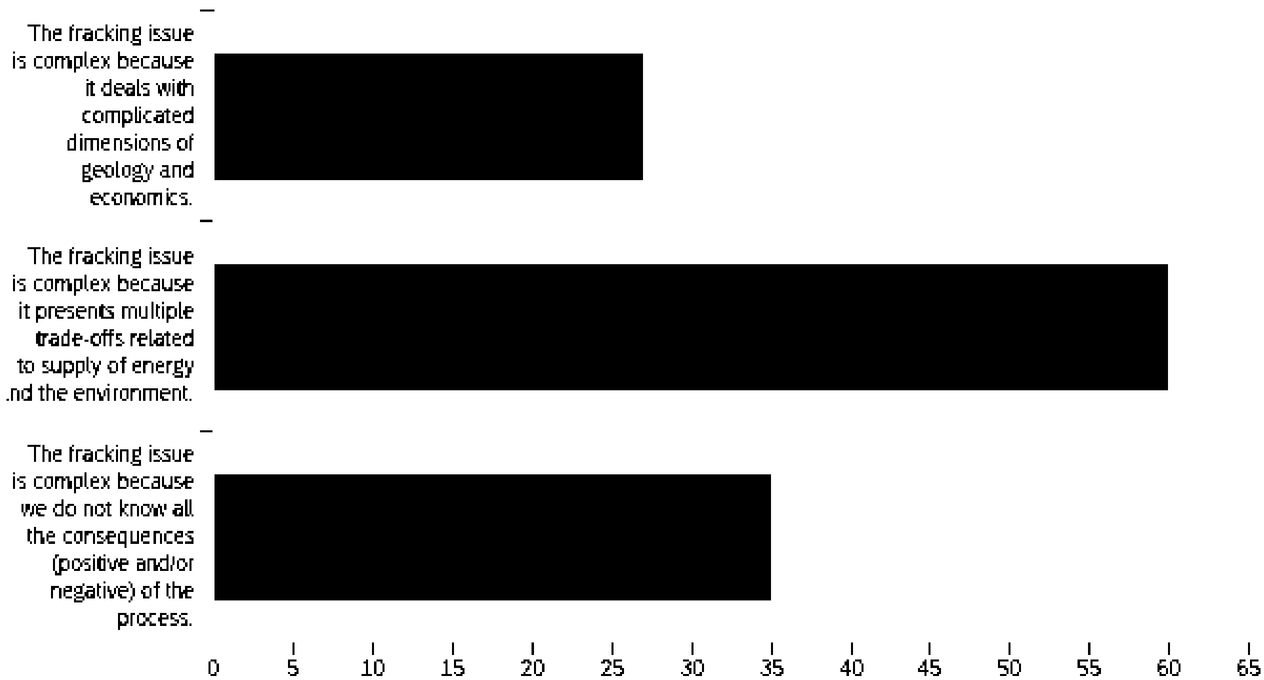
Q1N Post - Select the response below that best explains why the fracking issue is a fairly straightforward issue.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Select the response below that best explains why the fracking issue is a fairly straightforward issue.	1.00	3.00	2.17	0.69	0.47	12

#	Answer	%	Count
1	The world needs energy, and fracking provides access to new sources of relatively clean energy. Therefore, fracking is a positive development for our society.	16.67%	2
2	Fracking contaminates fresh water supplies with toxic chemicals. Therefore, fracking should not be used to extract natural gas.	50.00%	6
3	Fracking may generate controversies, but science and technology can be used to overcome these potential problems.	33.33%	4
	Total	100%	12

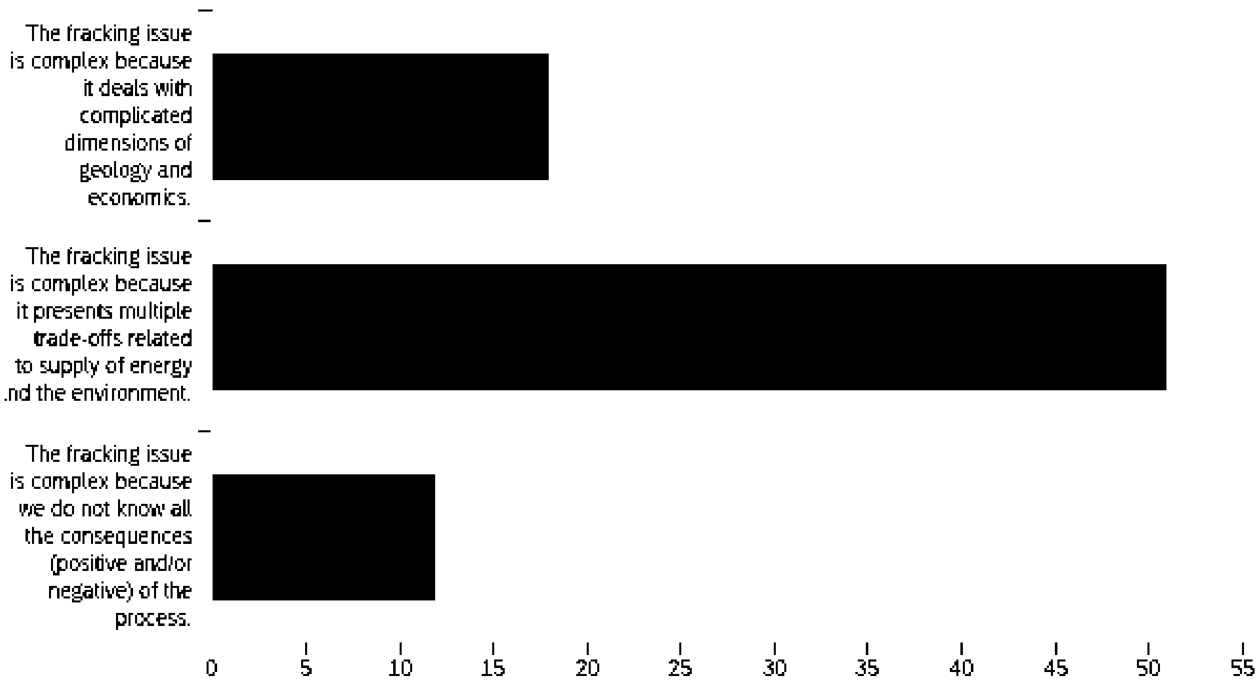
Q1Y Pre - Select the response below that best explains why the fracking issue is complex.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Select the response below that best explains why the fracking issue is complex.	1.00	3.00	2.07	0.71	0.50	122

#	Answer	%	Count
1	The fracking issue is complex because it deals with complicated dimensions of geology and economics.	22.13%	27
2	The fracking issue is complex because it presents multiple trade-offs related to supply of energy and the environment.	49.18%	60
3	The fracking issue is complex because we do not know all the consequences (positive and/or negative) of the process.	28.69%	35
	Total	100%	122

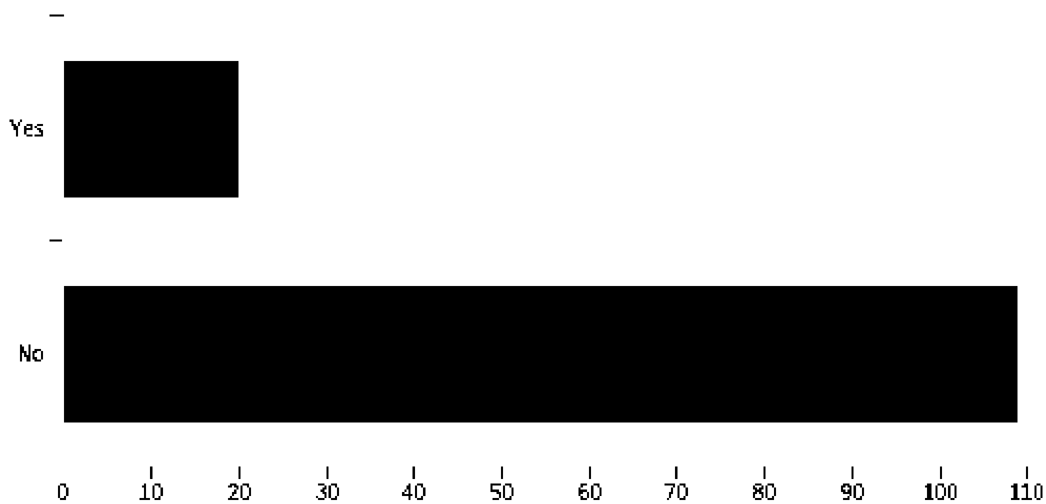
Q1Y Post - Select the response below that best explains why the fracking issue is complex.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Select the response below that best explains why the fracking issue is complex.	1.00	3.00	1.93	0.60	0.36	81

#	Answer	%	Count
1	The fracking issue is complex because it deals with complicated dimensions of geology and economics.	22.22%	18
2	The fracking issue is complex because it presents multiple trade-offs related to supply of energy and the environment.	62.96%	51
3	The fracking issue is complex because we do not know all the consequences (positive and/or negative) of the process.	14.81%	12
	Total	100%	81

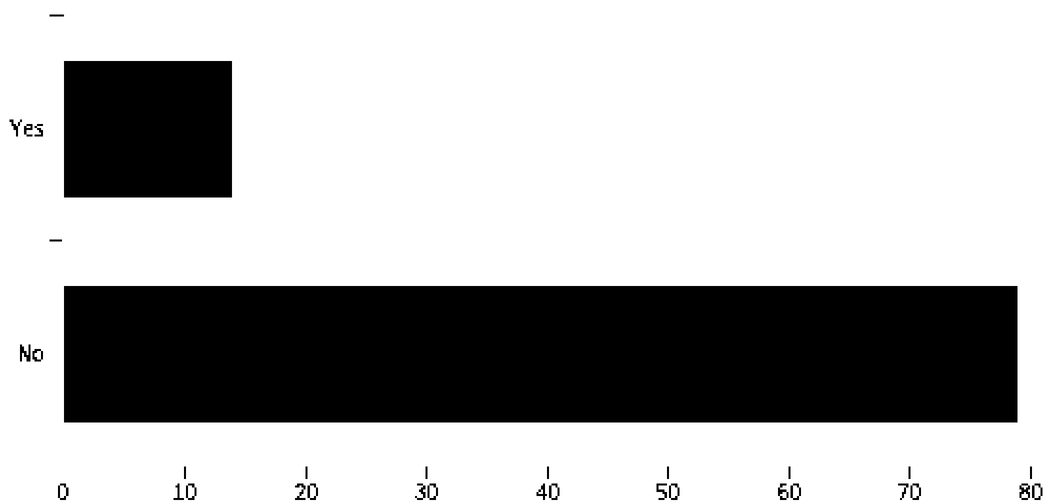
Q2 Pre - Is the case of fracking in Pavilion, WY easy to resolve?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is the case of fracking in Pavilion, WY easy to resolve?	1.00	2.00	1.84	0.36	0.13	129

#	Answer	%	Count
1	Yes	15.50%	20
2	No	84.50%	109
	Total	100%	129

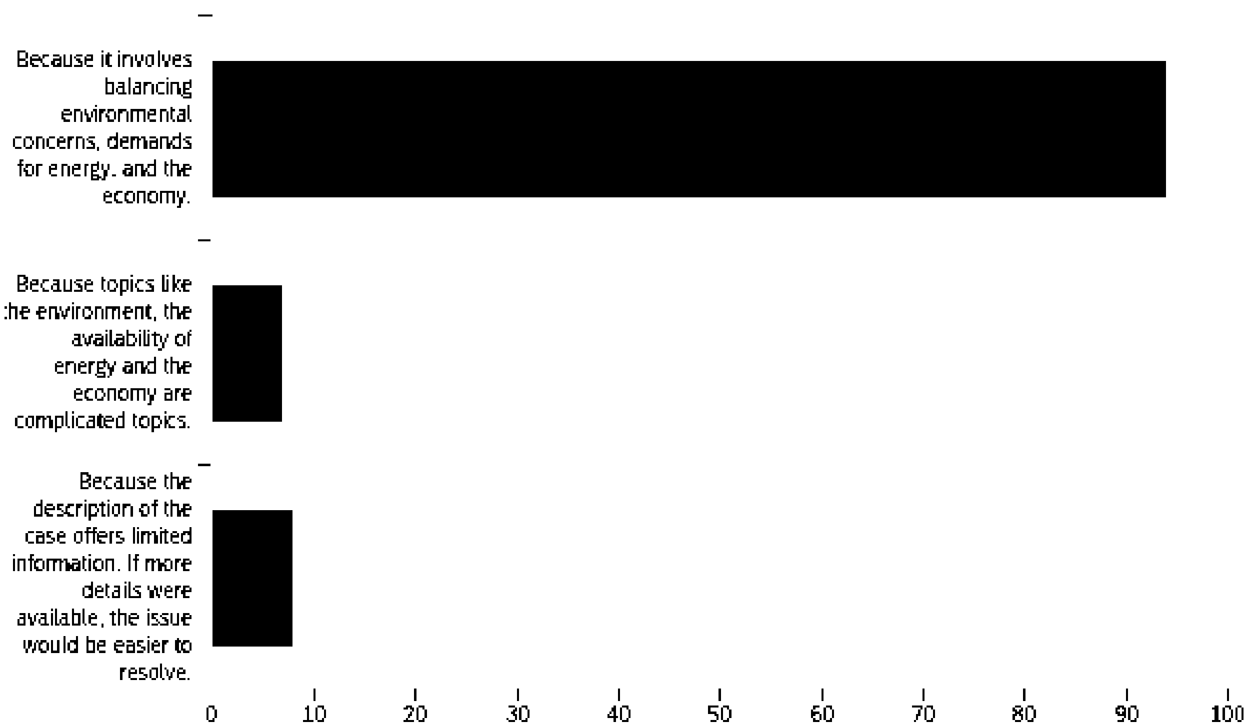
Q2 Post - Is the case of fracking in Pavilion, WY easy to resolve?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Is the case of fracking in Pavilion, WY easy to resolve?	1.00	2.00	1.85	0.36	0.13	93

#	Answer	%	Count
1	Yes	15.05%	14
2	No	84.95%	79
	Total	100%	93

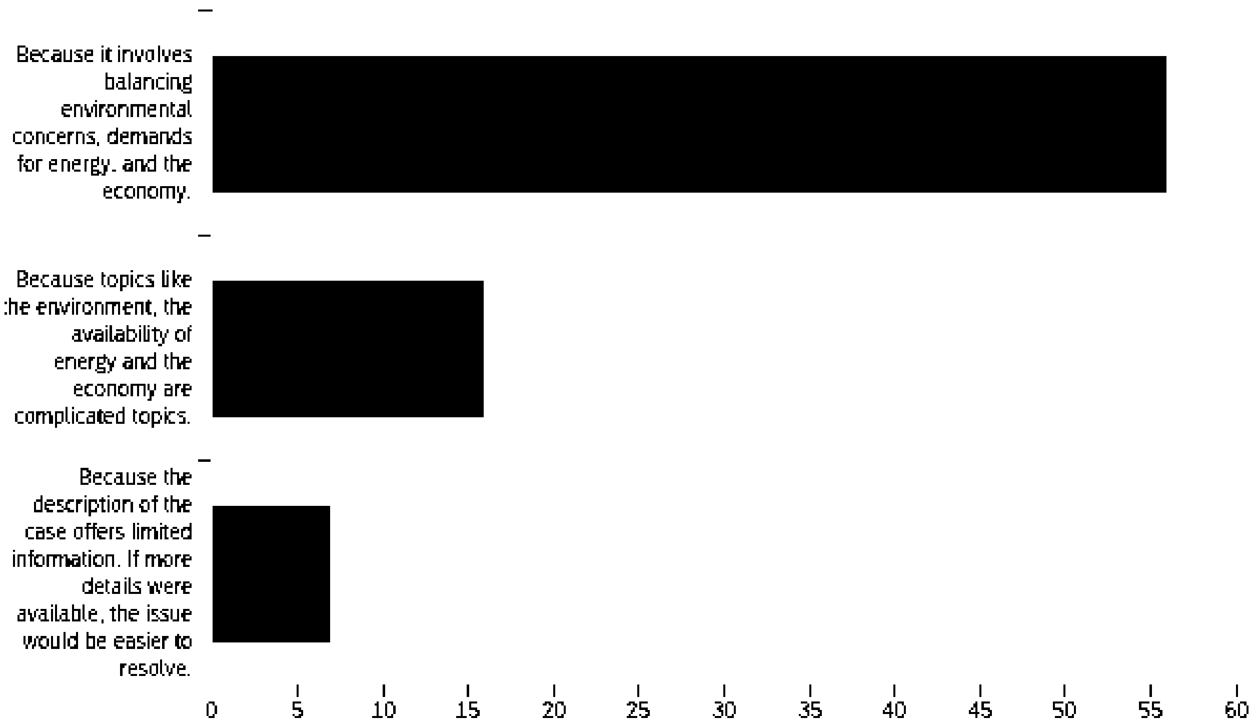
Q2N Pre - Why is the Pavilion fracking case difficult to resolve?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is the Pavilion fracking case difficult to resolve?	1.00	3.00	1.21	0.56	0.31	109

#	Answer	%	Count
1	Because it involves balancing environmental concerns, demands for energy, and the economy.	86.24%	94
2	Because topics like the environment, the availability of energy and the economy are complicated topics.	6.42%	7
3	Because the description of the case offers limited information. If more details were available, the issue would be easier to resolve.	7.34%	8
	Total	100%	109

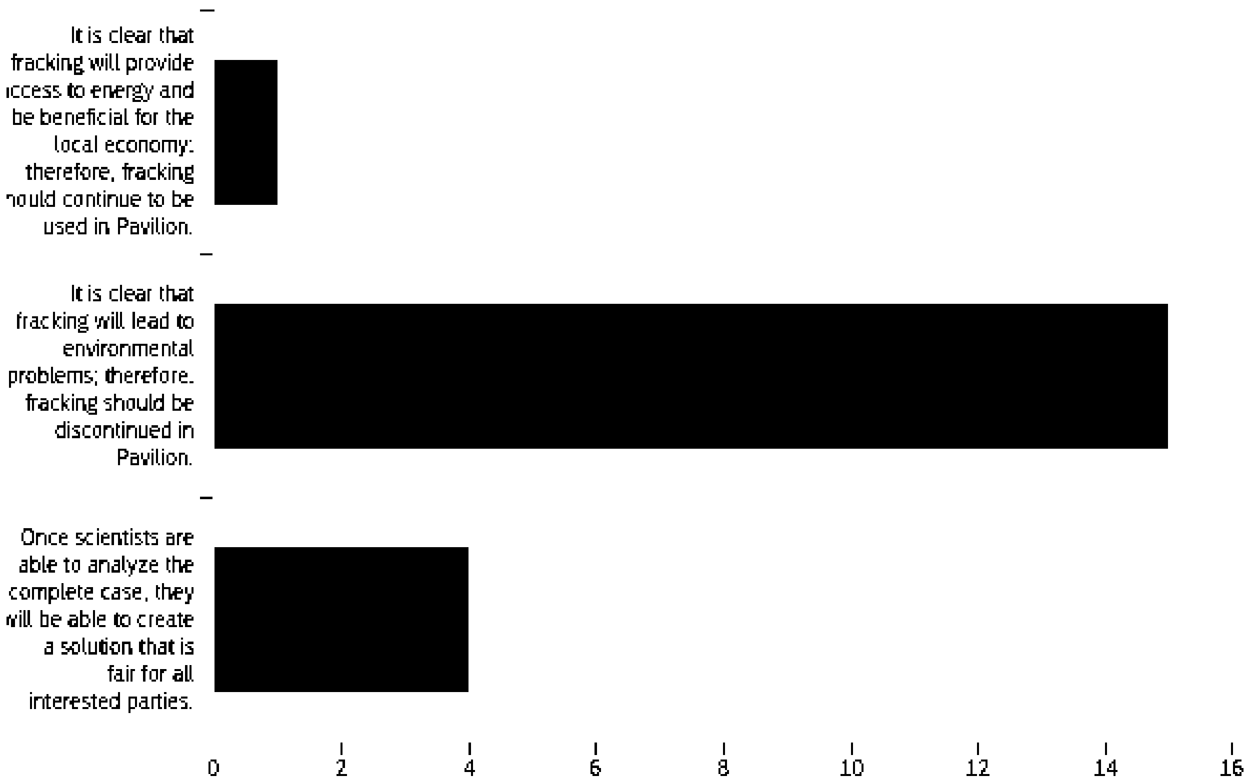
Q2N Post - Why is the Pavilion fracking case difficult to resolve?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is the Pavilion fracking case difficult to resolve?	1.00	3.00	1.38	0.64	0.41	79

#	Answer	%	Count
1	Because it involves balancing environmental concerns, demands for energy, and the economy.	70.89%	56
2	Because topics like the environment, the availability of energy and the economy are complicated topics.	20.25%	16
3	Because the description of the case offers limited information. If more details were available, the issue would be easier to resolve.	8.86%	7
	Total	100%	79

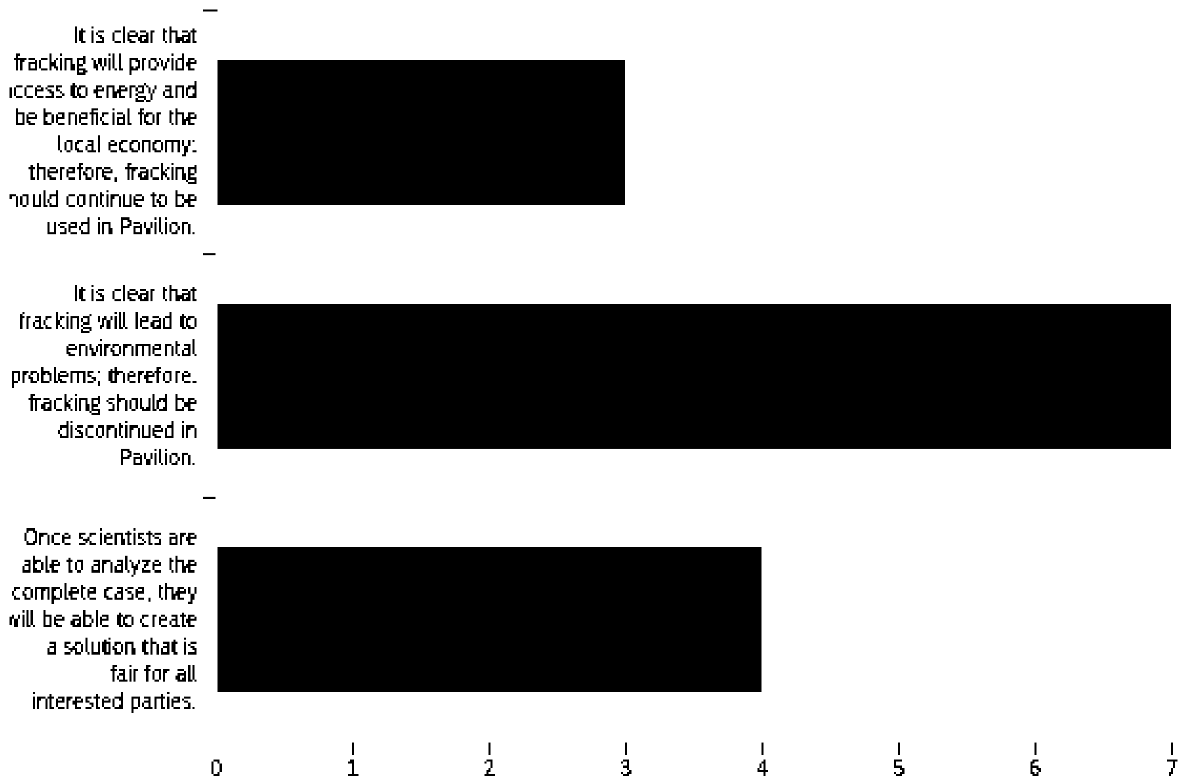
Q2Y Pre - Why is the Pavilion fracking case easy to resolve?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is the Pavilion fracking case easy to resolve?	1.00	3.00	2.15	0.48	0.23	20

#	Answer	%	Count
1	It is clear that fracking will provide access to energy and be beneficial for the local economy; therefore, fracking should continue to be used in Pavilion.	5.00%	1
2	It is clear that fracking will lead to environmental problems; therefore, fracking should be discontinued in Pavilion.	75.00%	15
3	Once scientists are able to analyze the complete case, they will be able to create a solution that is fair for all interested parties.	20.00%	4
	Total	100%	20

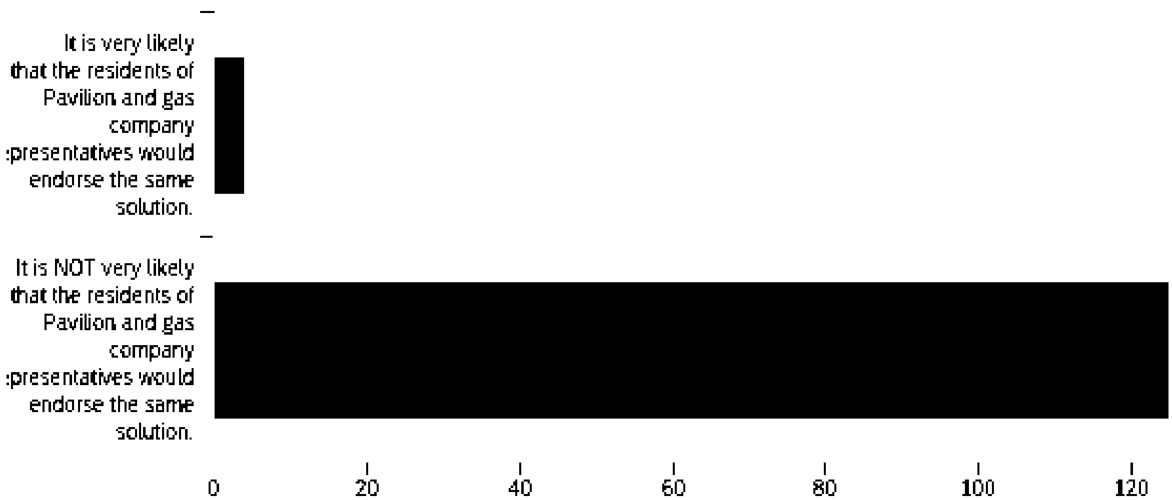
Q2Y Post - Why is the Pavilion fracking case easy to resolve?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is the Pavilion fracking case easy to resolve?	1.00	3.00	2.07	0.70	0.49	14

#	Answer	%	Count
1	It is clear that fracking will provide access to energy and be beneficial for the local economy; therefore, fracking should continue to be used in Pavilion.	21.43%	3
2	It is clear that fracking will lead to environmental problems; therefore, fracking should be discontinued in Pavilion.	50.00%	7
3	Once scientists are able to analyze the complete case, they will be able to create a solution that is fair for all interested parties.	28.57%	4
	Total	100%	14

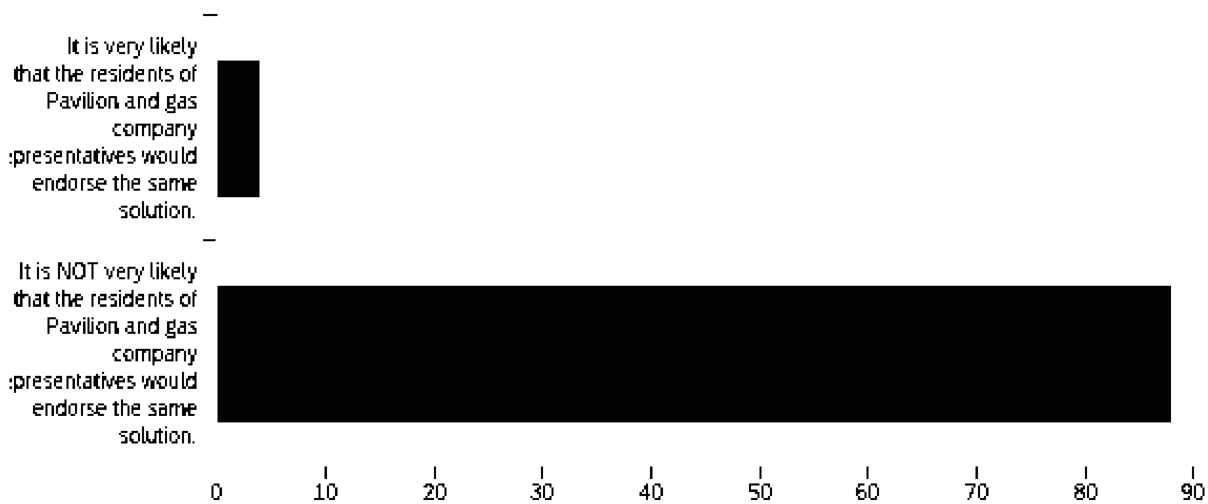
Q3 Pre - How likely is it that the residents of Pavilion and representatives of the gas company would endorse the same solution to the Pavilion fracking case?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How likely is it that the residents of Pavilion and representatives of the gas company would endorse the same solution to the Pavilion fracking case?	1.00	2.00	1.97	0.17	0.03	129

#	Answer	%	Count
1	It is very likely that the residents of Pavilion and gas company representatives would endorse the same solution.	3.10%	4
2	It is NOT very likely that the residents of Pavilion and gas company representatives would endorse the same solution.	96.90%	125
	Total	100%	129

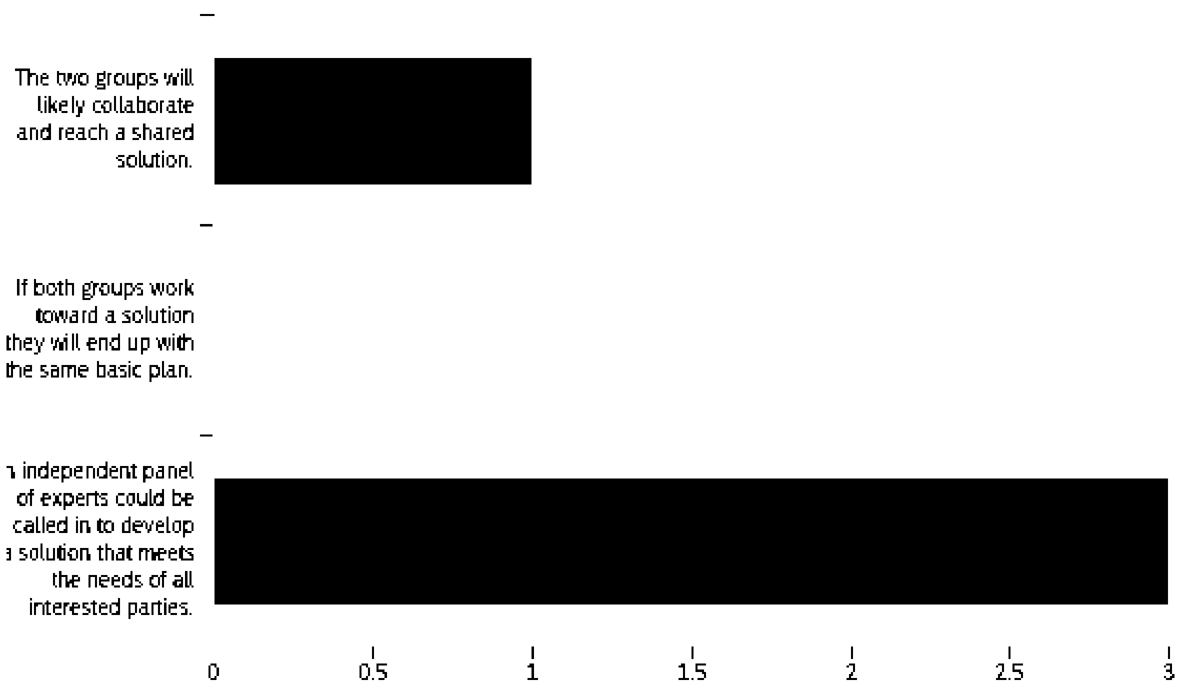
Q3 Post - How likely is it that the residents of Pavilion and representatives of the gas company would endorse the same solution to the Pavilion fracking case?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How likely is it that the residents of Pavilion and representatives of the gas company would endorse the same solution to the Pavilion fracking case?	1.00	2.00	1.96	0.20	0.04	92

#	Answer	%	Count
1	It is very likely that the residents of Pavilion and gas company representatives would endorse the same solution.	4.35%	4
2	It is NOT very likely that the residents of Pavilion and gas company representatives would endorse the same solution.	95.65%	88
	Total	100%	92

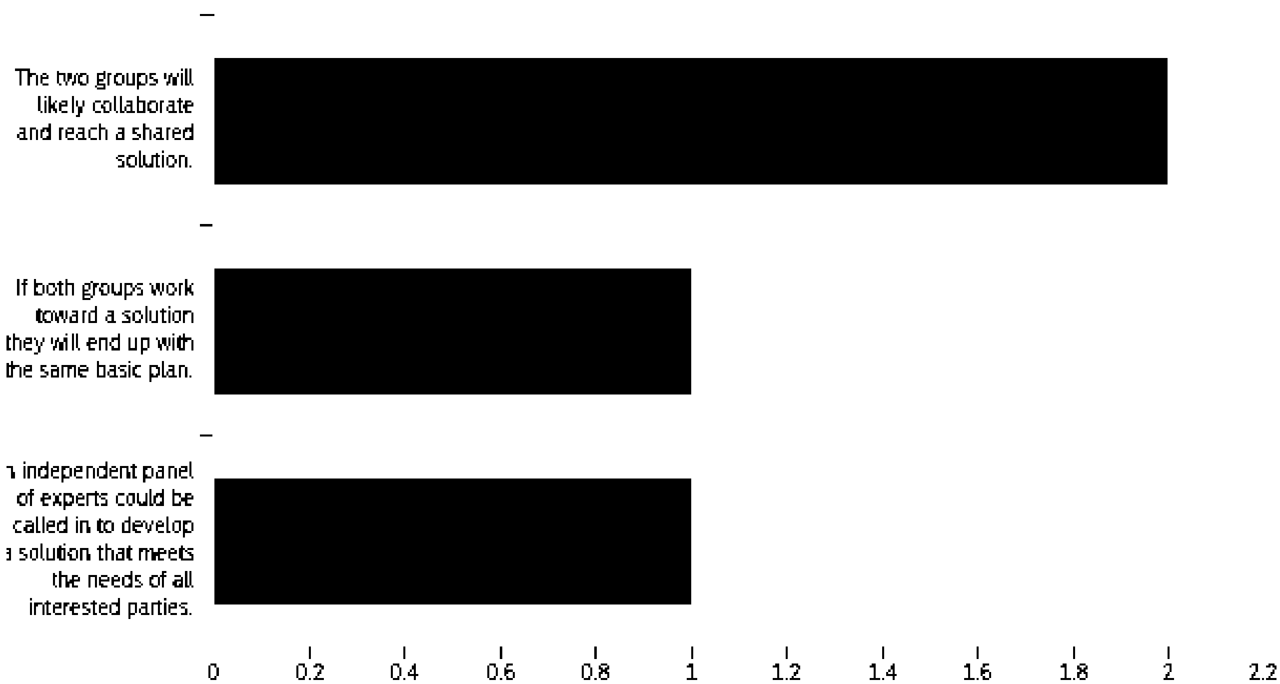
Q3L Pre - Why is it very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?	1.00	3.00	2.50	0.87	0.75	4

#	Answer	%	Count
1	The two groups will likely collaborate and reach a shared solution.	25.00%	1
2	If both groups work toward a solution they will end up with the same basic plan.	0.00%	0
3	An independent panel of experts could be called in to develop a solution that meets the needs of all interested parties.	75.00%	3
	Total	100%	4

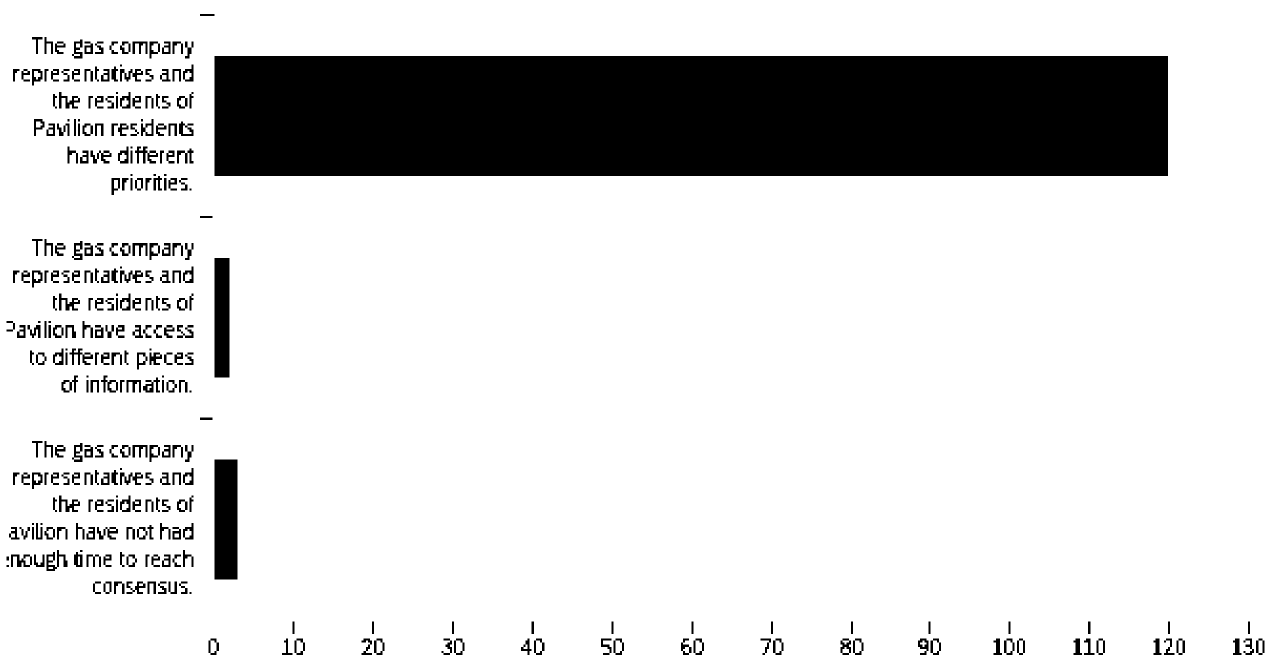
Q3L Post - Why is it very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?	1.00	3.00	1.75	0.83	0.69	4

#	Answer	%	Count
1	The two groups will likely collaborate and reach a shared solution.	50.00%	2
2	If both groups work toward a solution they will end up with the same basic plan.	25.00%	1
3	An independent panel of experts could be called in to develop a solution that meets the needs of all interested parties.	25.00%	1
	Total	100%	4

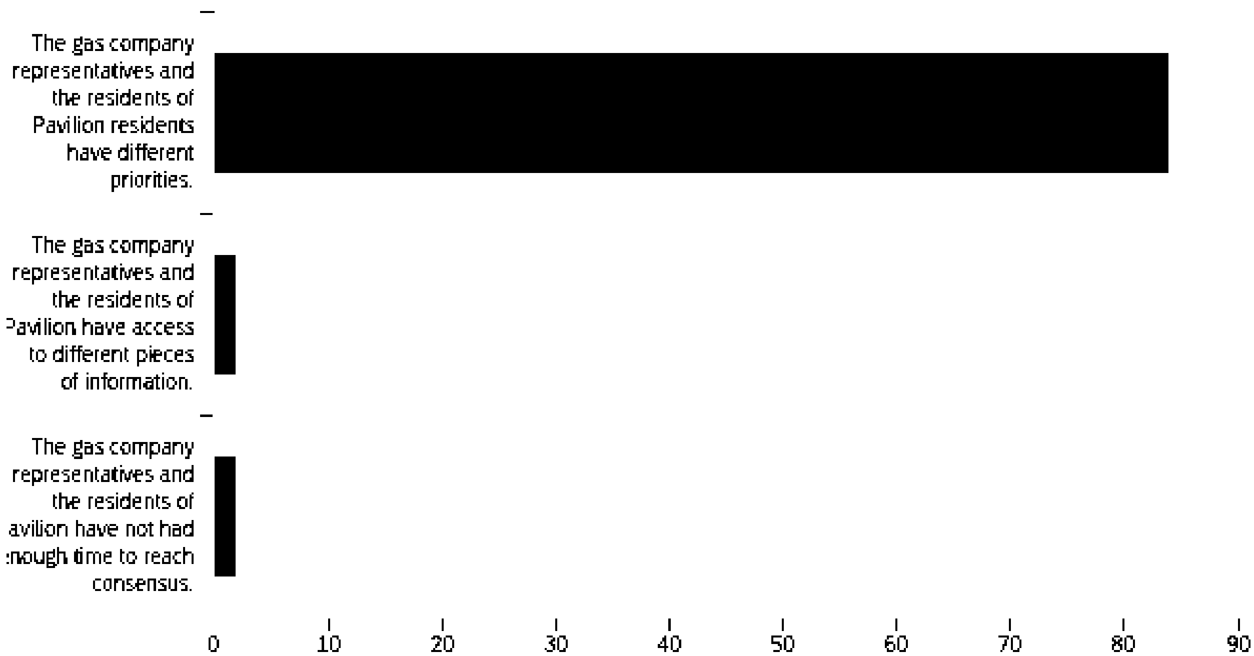
Q3NL Pre - Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?	1.00	3.00	1.06	0.33	0.11	125

#	Answer	%	Count
1	The gas company representatives and the residents of Pavilion residents have different priorities.	96.00%	120
2	The gas company representatives and the residents of Pavilion have access to different pieces of information.	1.60%	2
3	The gas company representatives and the residents of Pavilion have not had enough time to reach consensus.	2.40%	3
	Total	100%	125

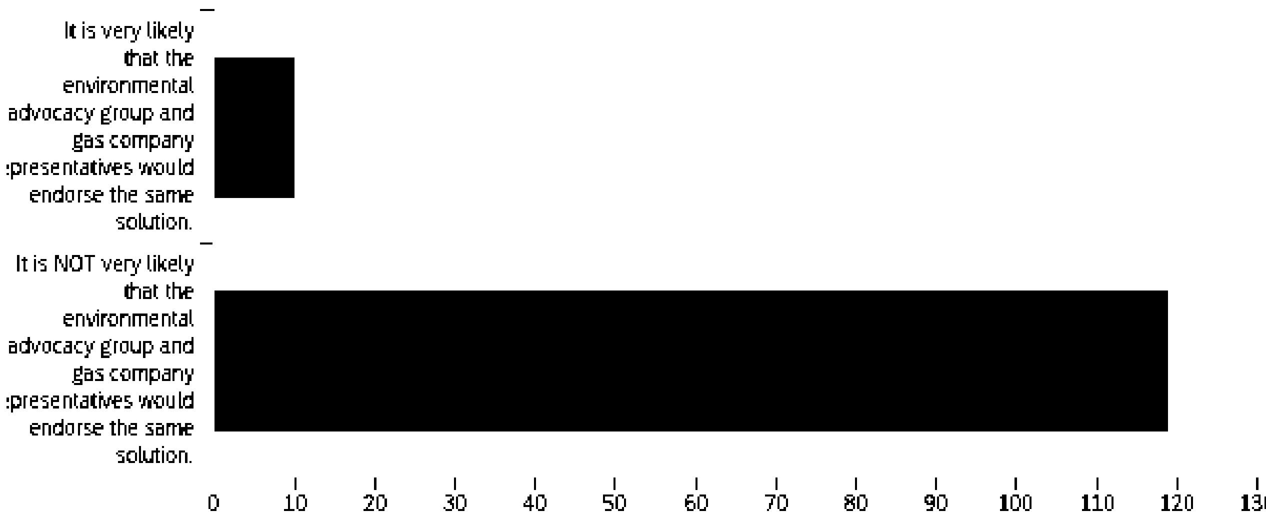
Q3NL Post - Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?	1.00	3.00	1.07	0.33	0.11	88

#	Answer	%	Count
1	The gas company representatives and the residents of Pavilion residents have different priorities.	95.45%	84
2	The gas company representatives and the residents of Pavilion have access to different pieces of information.	2.27%	2
3	The gas company representatives and the residents of Pavilion have not had enough time to reach consensus.	2.27%	2
	Total	100%	88

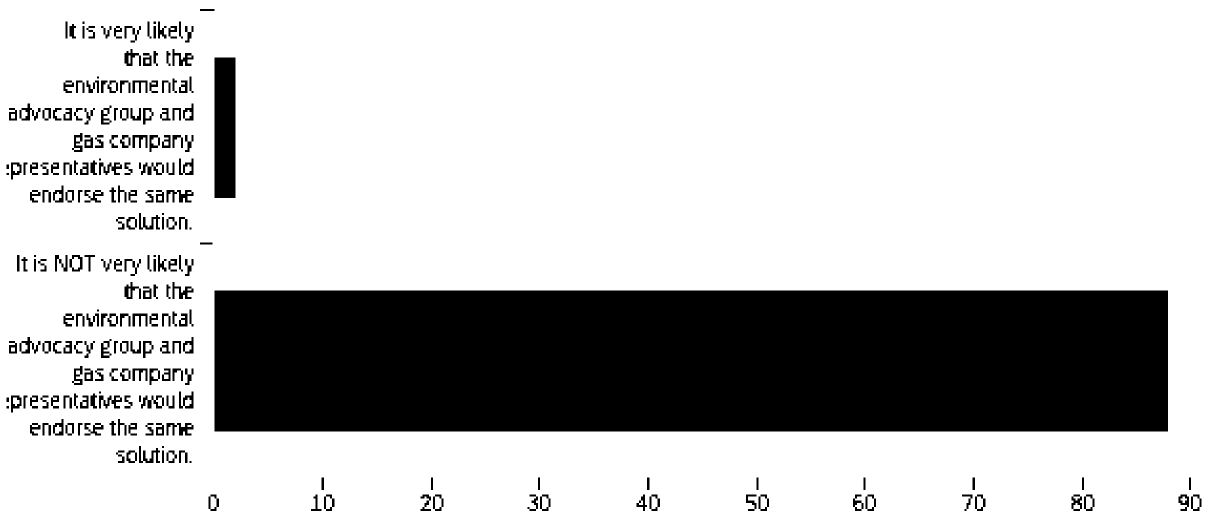
Q4 Pre - How likely is it that an environmental advocacy group and representatives of the gas company would endorse the same solution to the Pavilion fracking case?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How likely is it that an environmental advocacy group and representatives of the gas company would endorse the same solution to the Pavilion fracking case?	1.00	2.00	1.92	0.27	0.07	129

#	Answer	%	Count
1	It is very likely that the environmental advocacy group and gas company representatives would endorse the same solution.	7.75%	10
2	It is NOT very likely that the environmental advocacy group and gas company representatives would endorse the same solution.	92.25%	119
	Total	100%	129

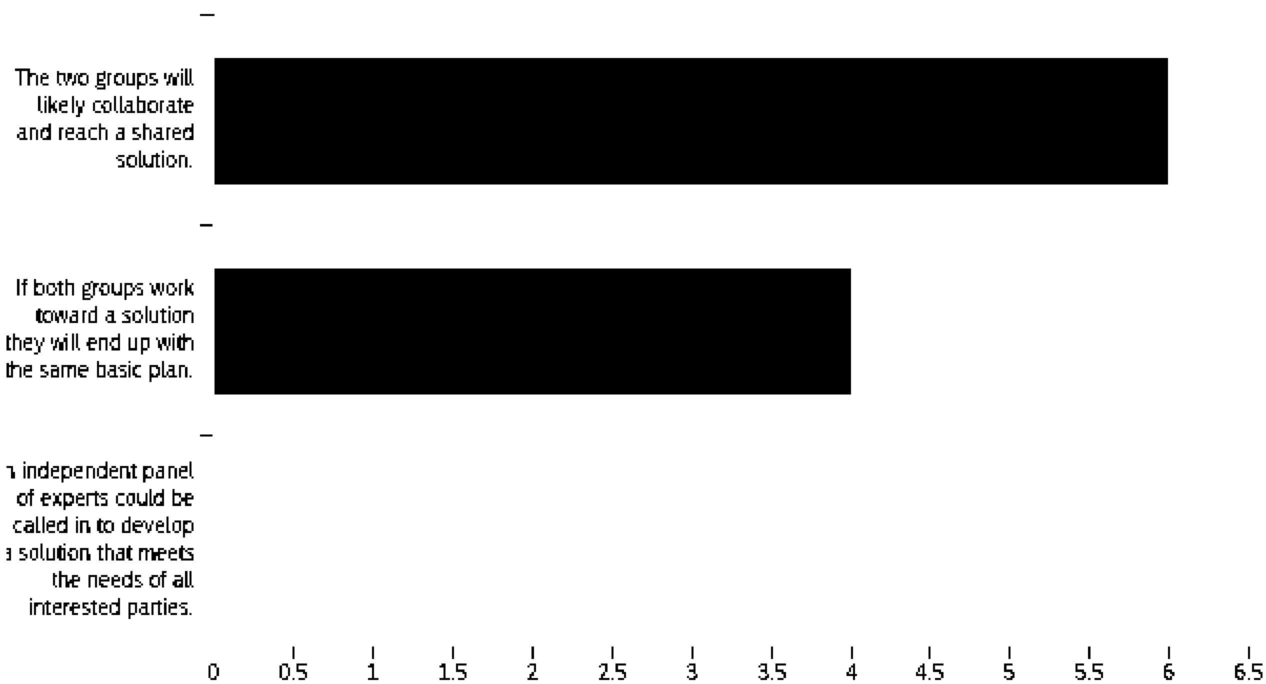
Q4 Post - How likely is it that an environmental advocacy group and representatives of the gas company would endorse the same solution to the Pavilion fracking case?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How likely is it that an environmental advocacy group and representatives of the gas company would endorse the same solution to the Pavilion fracking case?	1.00	2.00	1.98	0.15	0.02	90

#	Answer	%	Count
1	It is very likely that the environmental advocacy group and gas company representatives would endorse the same solution.	2.22%	2
2	It is NOT very likely that the environmental advocacy group and gas company representatives would endorse the same solution.	97.78%	88
	Total	100%	90

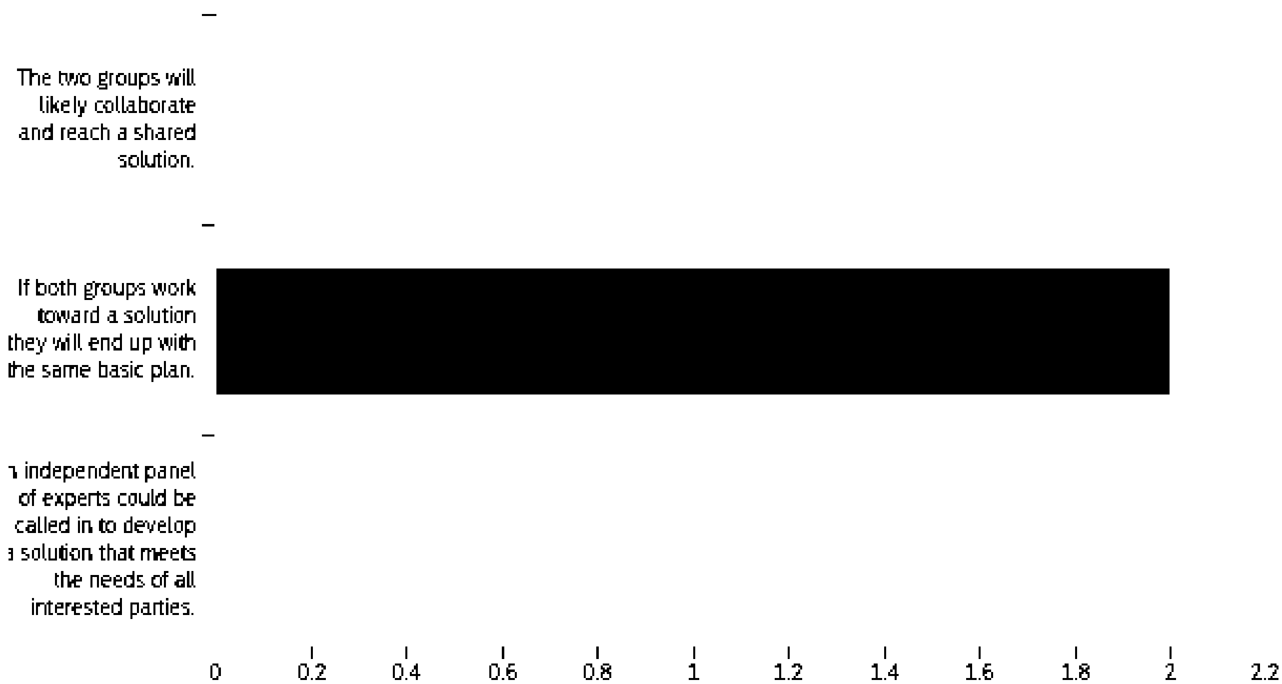
Q4L Pre - Why is it very likely that the environmental advocacy group and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it very likely that the environmental advocacy group and the gas company representatives would endorse the same solution?	1.00	2.00	1.40	0.49	0.24	10

#	Answer	%	Count
1	The two groups will likely collaborate and reach a shared solution.	60.00%	6
2	If both groups work toward a solution they will end up with the same basic plan.	40.00%	4
3	An independent panel of experts could be called in to develop a solution that meets the needs of all interested parties.	0.00%	0
	Total	100%	10

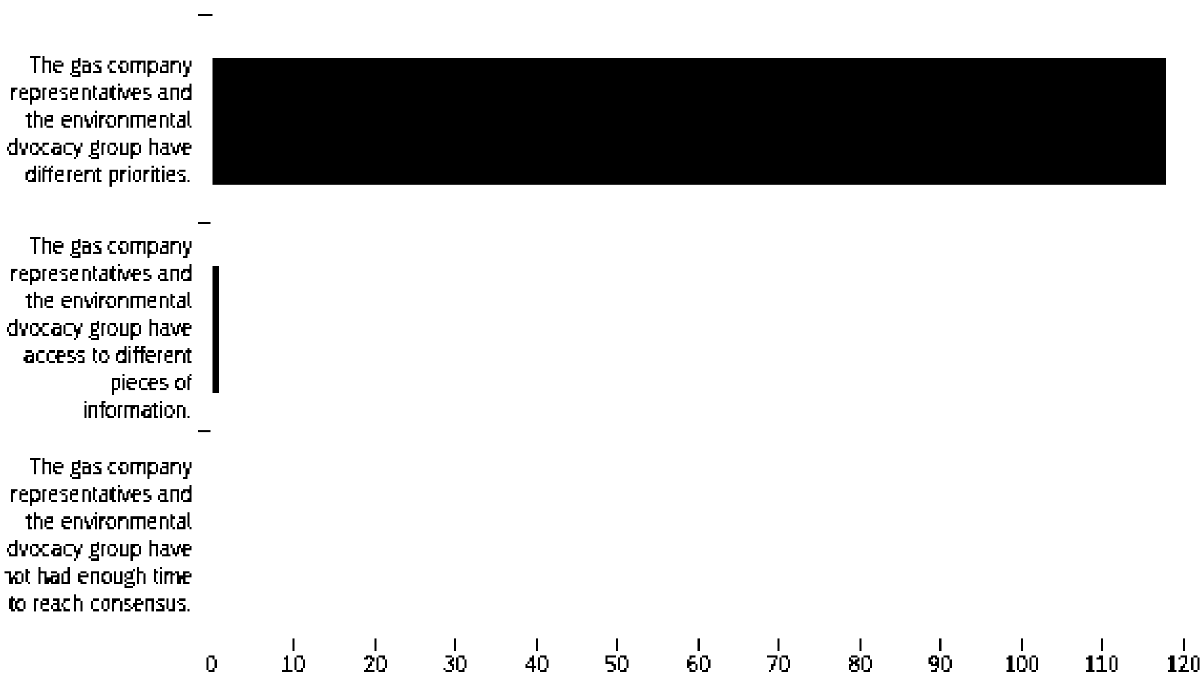
Q4L Post - Why is it very likely that the environmental advocacy group and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it very likely that the environmental advocacy group and the gas company representatives would endorse the same solution?	2.00	2.00	2.00	0.00	0.00	2

#	Answer	%	Count
1	The two groups will likely collaborate and reach a shared solution.	0.00%	0
2	If both groups work toward a solution they will end up with the same basic plan.	100.00%	2
3	An independent panel of experts could be called in to develop a solution that meets the needs of all interested parties.	0.00%	0
	Total	100%	2

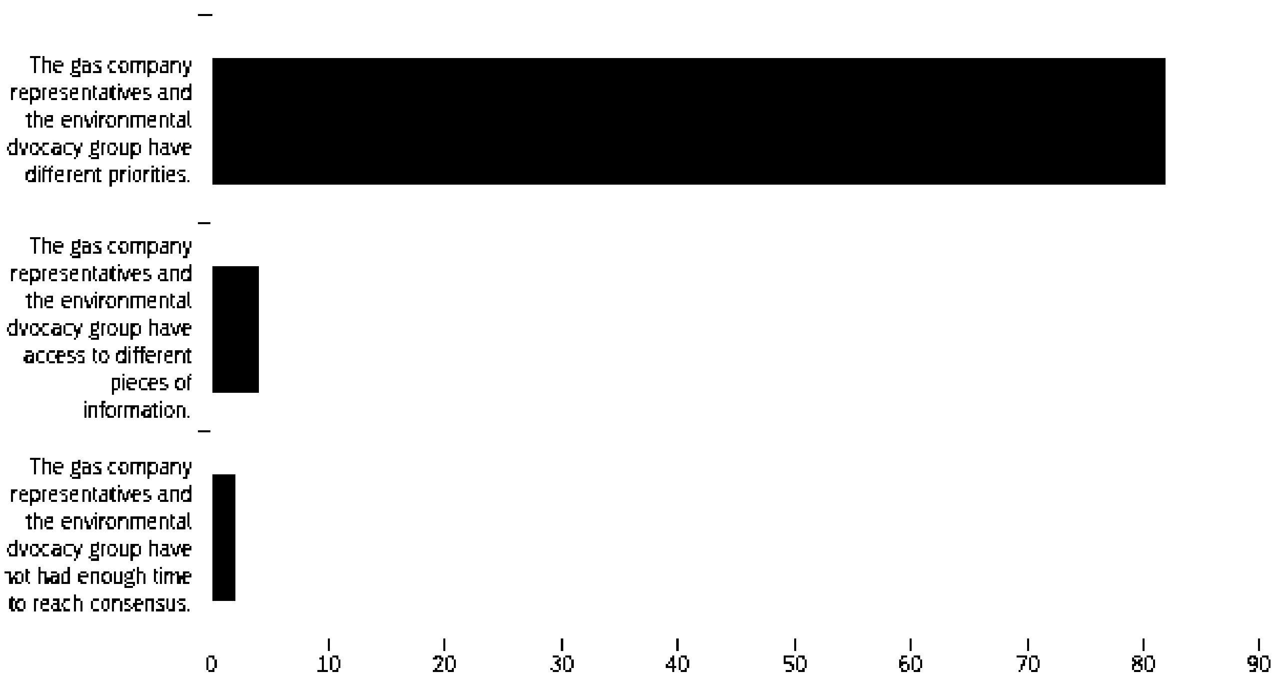
Q4NL Pre - Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?	1.00	2.00	1.01	0.09	0.01	119

#	Answer	%	Count
1	The gas company representatives and the environmental advocacy group have different priorities.	99.16%	118
2	The gas company representatives and the environmental advocacy group have access to different pieces of information.	0.84%	1
3	The gas company representatives and the environmental advocacy group have not had enough time to reach consensus.	0.00%	0
	Total	100%	119

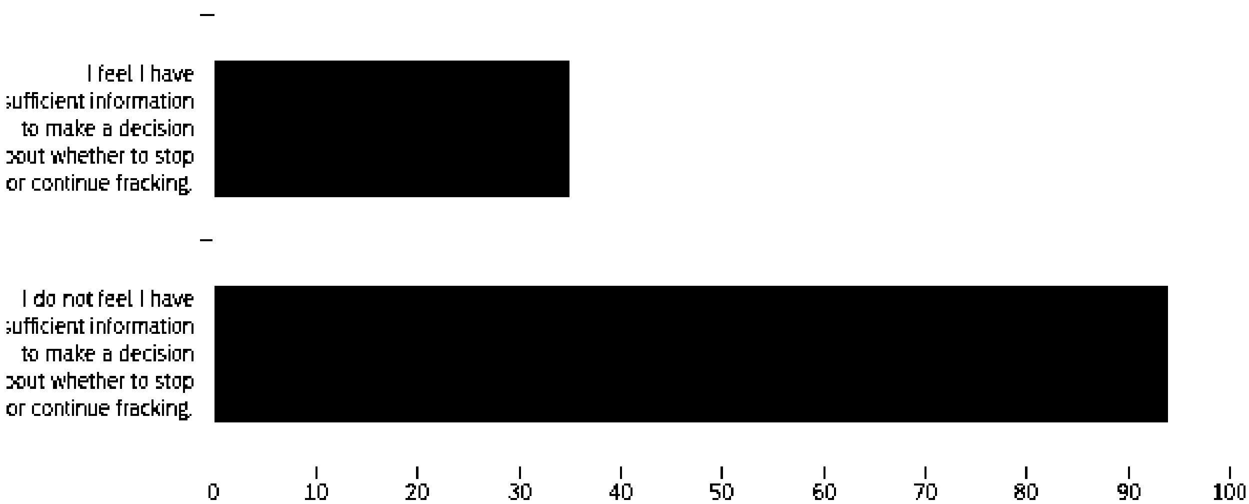
Q4NL Post - Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is it not very likely that the residents of Pavilion and the gas company representatives would endorse the same solution?	1.00	3.00	1.09	0.36	0.13	88

#	Answer	%	Count
1	The gas company representatives and the environmental advocacy group have different priorities.	93.18%	82
2	The gas company representatives and the environmental advocacy group have access to different pieces of information.	4.55%	4
3	The gas company representatives and the environmental advocacy group have not had enough time to reach consensus.	2.27%	2
	Total	100%	88

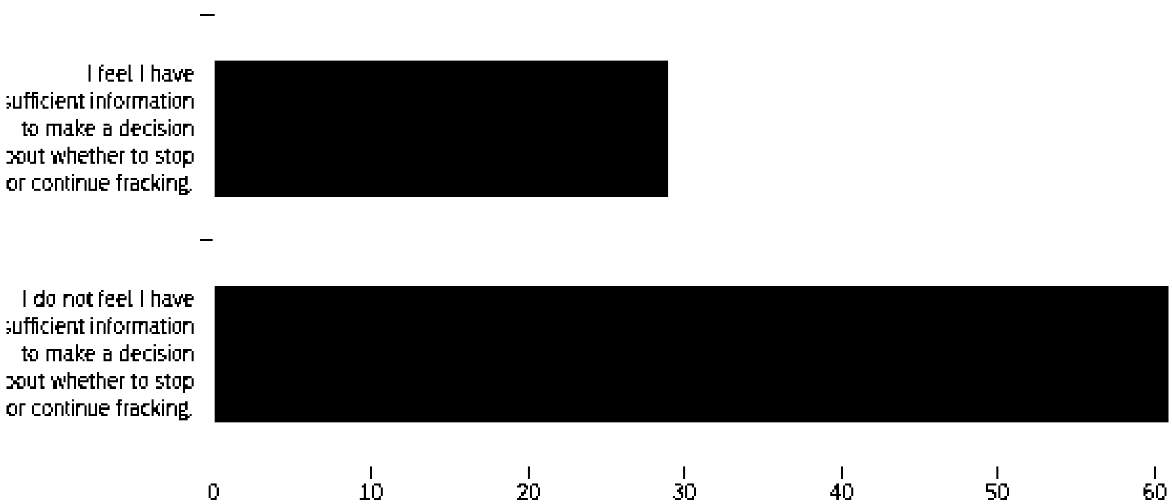
Q5 Pre - If you were asked to make a decision on whether to stop or continue fracking in Pavilion, do you feel as though you have enough information to make a decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If you were asked to make a decision on whether to stop or continue fracking in Pavilion, do you feel as though you have enough information to make a decision?	1.00	2.00	1.73	0.44	0.20	129

#	Answer	%	Count
1	I feel I have sufficient information to make a decision about whether to stop or continue fracking.	27.13%	35
2	I do not feel I have sufficient information to make a decision about whether to stop or continue fracking.	72.87%	94
	Total	100%	129

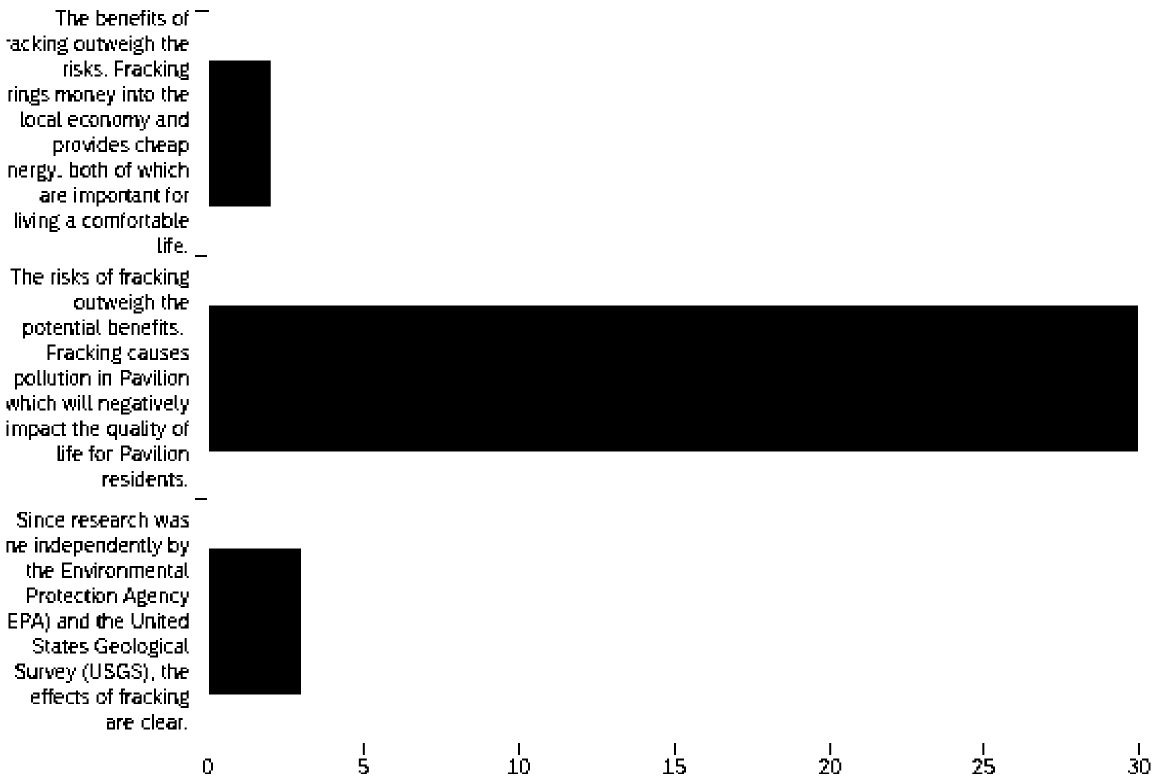
Q5 Post - If you were asked to make a decision on whether to stop or continue fracking in Pavilion, do you feel as though you have enough information to make a decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If you were asked to make a decision on whether to stop or continue fracking in Pavilion, do you feel as though you have enough information to make a decision?	1.00	2.00	1.68	0.47	0.22	90

#	Answer	%	Count
1	I feel I have sufficient information to make a decision about whether to stop or continue fracking.	32.22%	29
2	I do not feel I have sufficient information to make a decision about whether to stop or continue fracking.	67.78%	61
	Total	100%	90

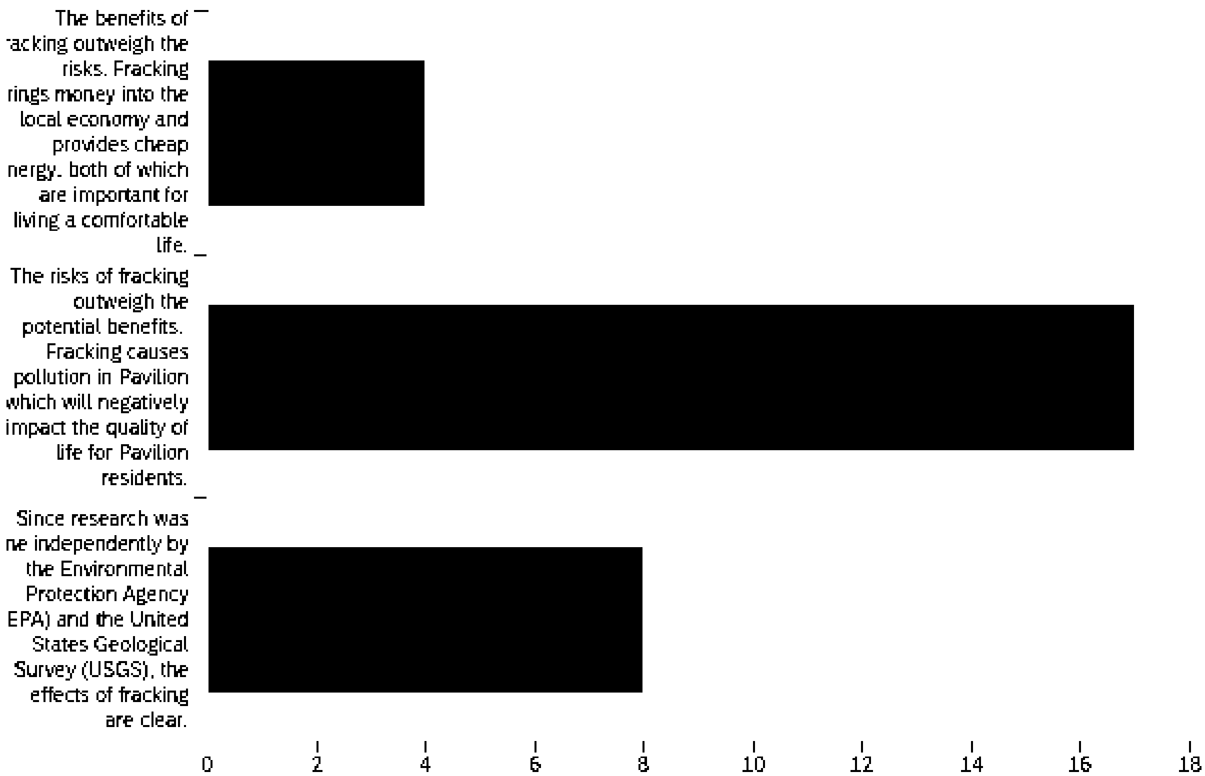
Q5Y Pre - Why is there sufficient information to make a decision about whether to stop or continue fracking?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is there sufficient information to make a decision about whether to stop or continue fracking?	1.00	3.00	2.03	0.38	0.14	35

#	Answer	%	Count
1	The benefits of fracking outweigh the risks. Fracking brings money into the local economy and provides cheap energy, both of which are important for living a comfortable life.	5.71%	2
2	The risks of fracking outweigh the potential benefits. Fracking causes pollution in Pavilion which will negatively impact the quality of life for Pavilion residents.	85.71%	30
3	Since research was done independently by the Environmental Protection Agency (EPA) and the United States Geological Survey (USGS), the effects of fracking are clear.	8.57%	3
	Total	100%	35

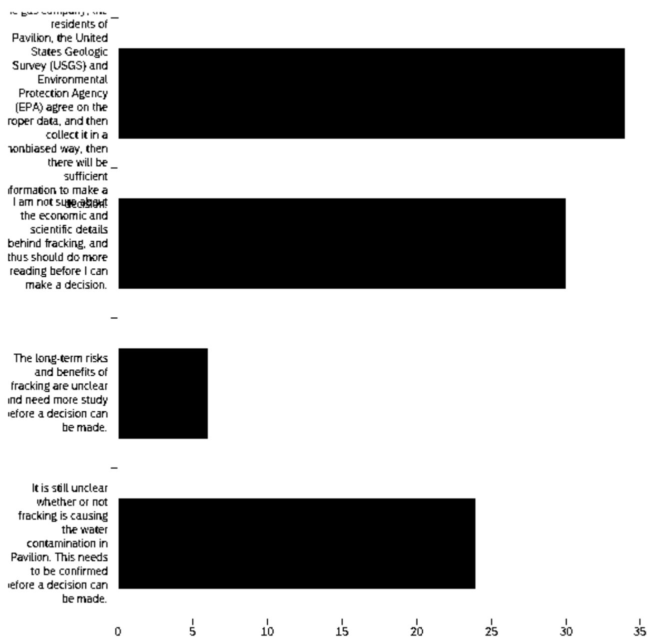
Q5Y Post - Why is there sufficient information to make a decision about whether to stop or continue fracking?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is there sufficient information to make a decision about whether to stop or continue fracking?	1.00	3.00	2.14	0.63	0.39	29

#	Answer	%	Count
1	The benefits of fracking outweigh the risks. Fracking brings money into the local economy and provides cheap energy, both of which are important for living a comfortable life.	13.79%	4
2	The risks of fracking outweigh the potential benefits. Fracking causes pollution in Pavilion which will negatively impact the quality of life for Pavilion residents.	58.62%	17
3	Since research was done independently by the Environmental Protection Agency (EPA) and the United States Geological Survey (USGS), the effects of fracking are clear.	27.59%	8
	Total	100%	29

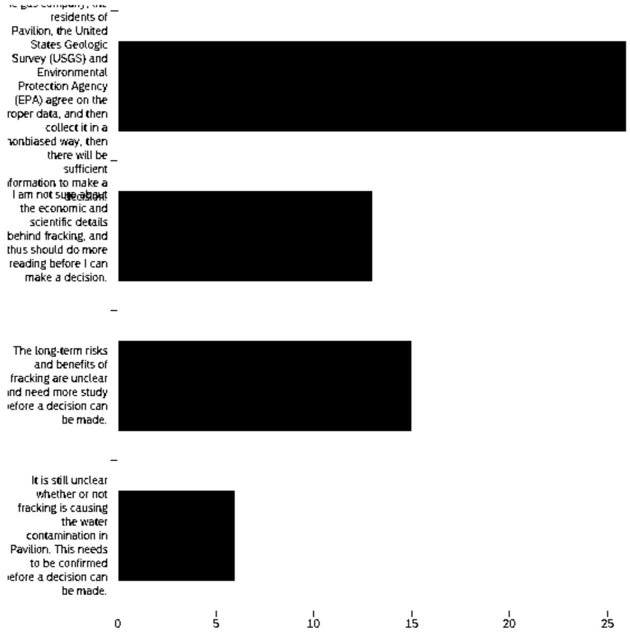
Q5N Pre - Why is there not sufficient information to make a decision about whether to stop or continue fracking?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is there not sufficient information to make a decision about whether to stop or continue fracking?	1.00	4.00	2.21	1.18	1.40	94

#	Answer	%	Count
1	Everyone has different data. If the gas company, the residents of Pavilion, the United States Geologic Survey (USGS) and Environmental Protection Agency (EPA) agree on the proper data, and then collect it in a nonbiased way, then there will be sufficient information to make a decision.	36.17%	34
2	I am not sure about the economic and scientific details behind fracking, and thus should do more reading before I can make a decision.	31.91%	30
3	The long-term risks and benefits of fracking are unclear and need more study before a decision can be made.	6.38%	6
4	It is still unclear whether or not fracking is causing the water contamination in Pavilion. This needs to be confirmed before a decision can be made.	25.53%	24
	Total	100%	94

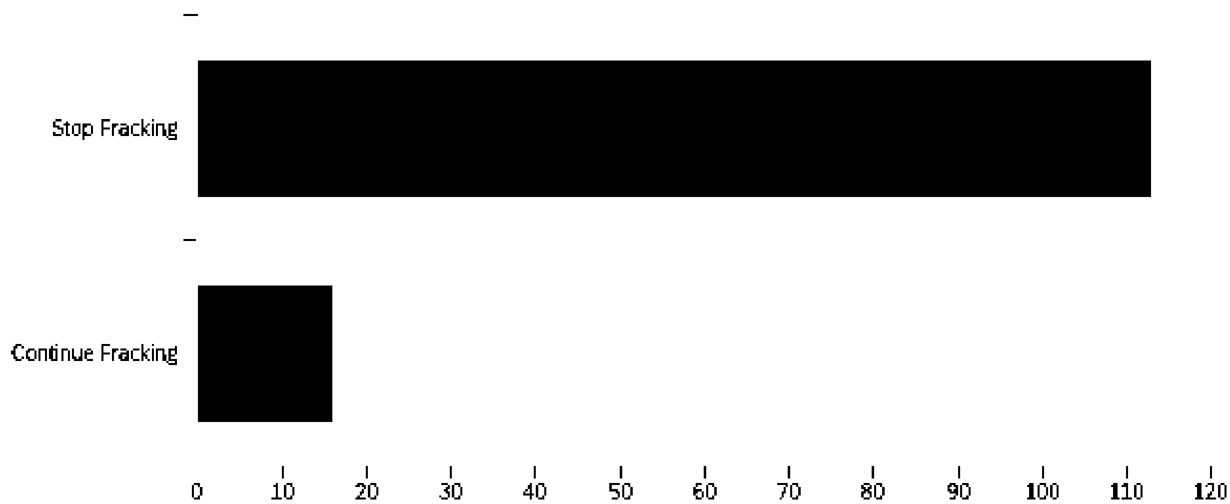
Q5N Post - Why is there not sufficient information to make a decision about whether to stop or continue fracking?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why is there not sufficient information to make a decision about whether to stop or continue fracking?	1.00	4.00	2.02	1.04	1.08	60

#	Answer	%	Count
1	Everyone has different data. If the gas company, the residents of Pavilion, the United States Geologic Survey (USGS) and Environmental Protection Agency (EPA) agree on the proper data, and then collect it in a nonbiased way, then there will be sufficient information to make a decision.	43.33%	26
2	I am not sure about the economic and scientific details behind fracking, and thus should do more reading before I can make a decision.	21.67%	13
3	The long-term risks and benefits of fracking are unclear and need more study before a decision can be made.	25.00%	15
4	It is still unclear whether or not fracking is causing the water contamination in Pavilion. This needs to be confirmed before a decision can be made.	10.00%	6
	Total	100%	60

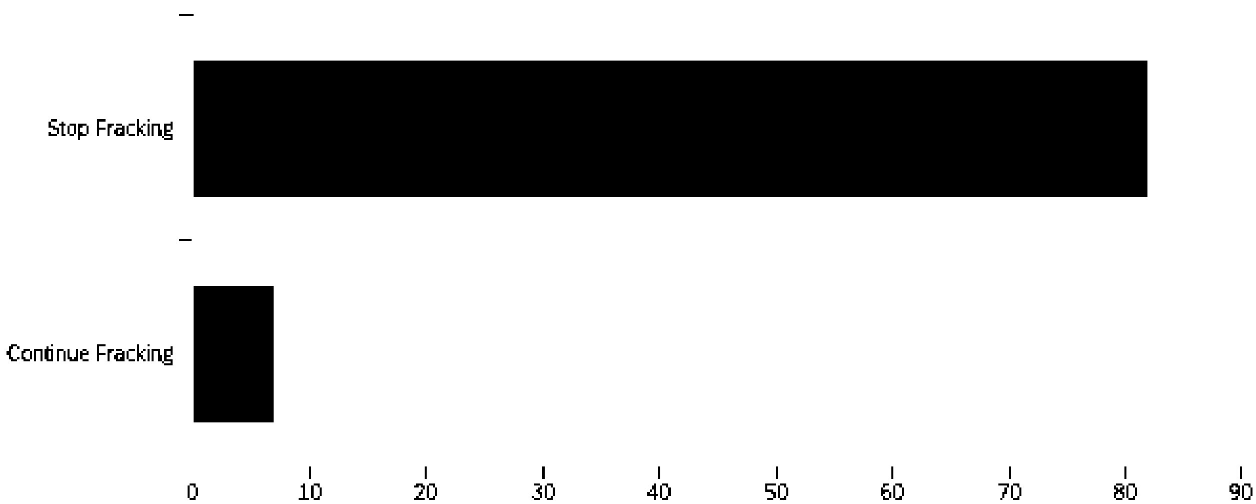
Q6 Pre - If you were forced to make a decision whether to stop or continue fracking based on the information in the article, what decision would you make?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If you were forced to make a decision whether to stop or continue fracking based on the information in the article, what decision would you make?	1.00	2.00	1.12	0.33	0.11	129

#	Answer	%	Count
1	Stop Fracking	87.60%	113
2	Continue Fracking	12.40%	16
	Total	100%	129

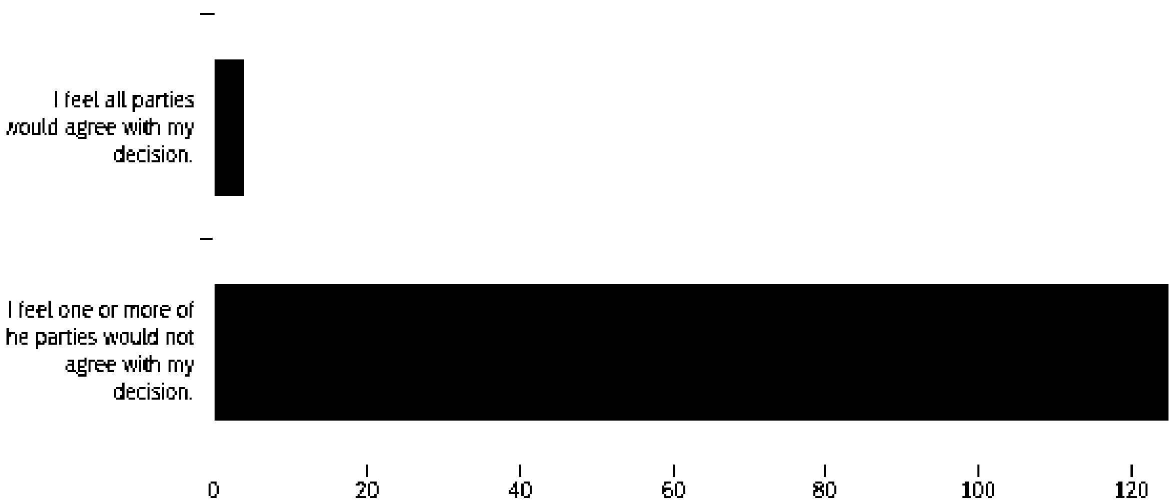
Q6 Post - If you were forced to make a decision whether to stop or continue fracking based on the information in the article, what decision would you make?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If you were forced to make a decision whether to stop or continue fracking based on the information in the article, what decision would you make?	1.00	2.00	1.08	0.27	0.07	89

#	Answer	%	Count
1	Stop Fracking	92.13%	82
2	Continue Fracking	7.87%	7
	Total	100%	89

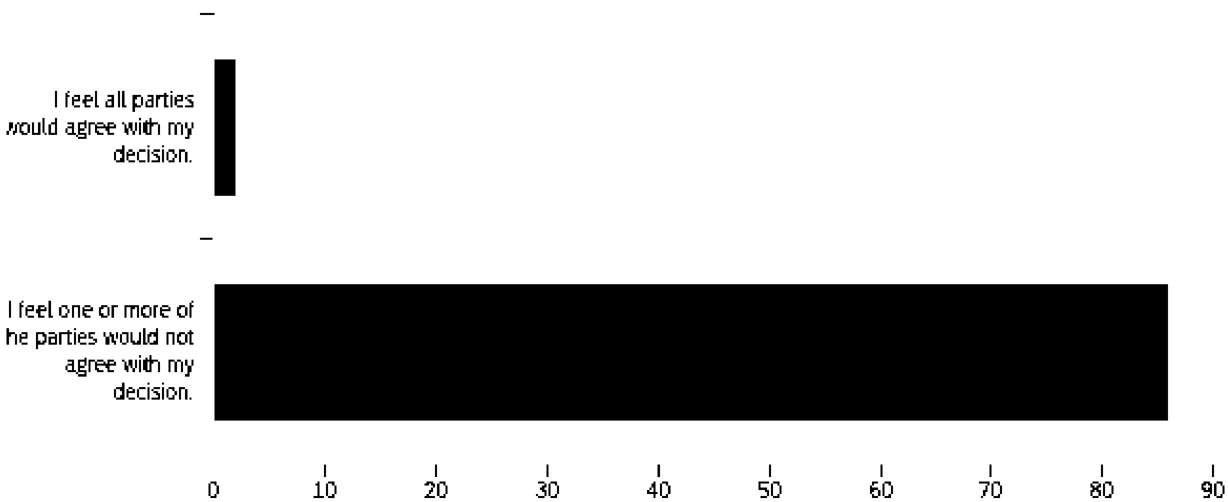
Q7 Pre - Do you think the residents of Pavilion, the gas company, the United States Geologic Survey (USGS), and a local environmental advocacy group would agree with your decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do you think the residents of Pavilion, the gas company, the United States Geologic Survey (USGS), and a local environmental advocacy group would agree with your decision?	1.00	2.00	1.97	0.17	0.03	129

#	Answer	%	Count
1	I feel all parties would agree with my decision.	3.10%	4
2	I feel one or more of the parties would not agree with my decision.	96.90%	125
	Total	100%	129

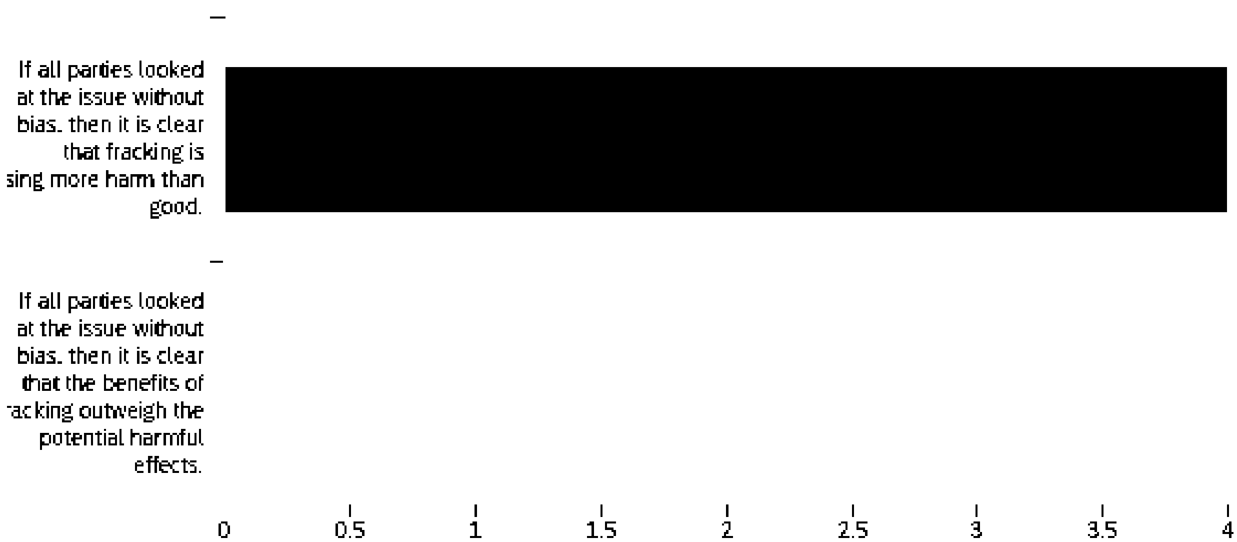
Q7 Post - Do you think the residents of Pavilion, the gas company, the United States Geologic Survey (USGS), and a local environmental advocacy group would agree with your decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do you think the residents of Pavilion, the gas company, the United States Geologic Survey (USGS), and a local environmental advocacy group would agree with your decision?	1.00	2.00	1.98	0.15	0.02	88

#	Answer	%	Count
1	I feel all parties would agree with my decision.	2.27%	2
2	I feel one or more of the parties would not agree with my decision.	97.73%	86
	Total	100%	88

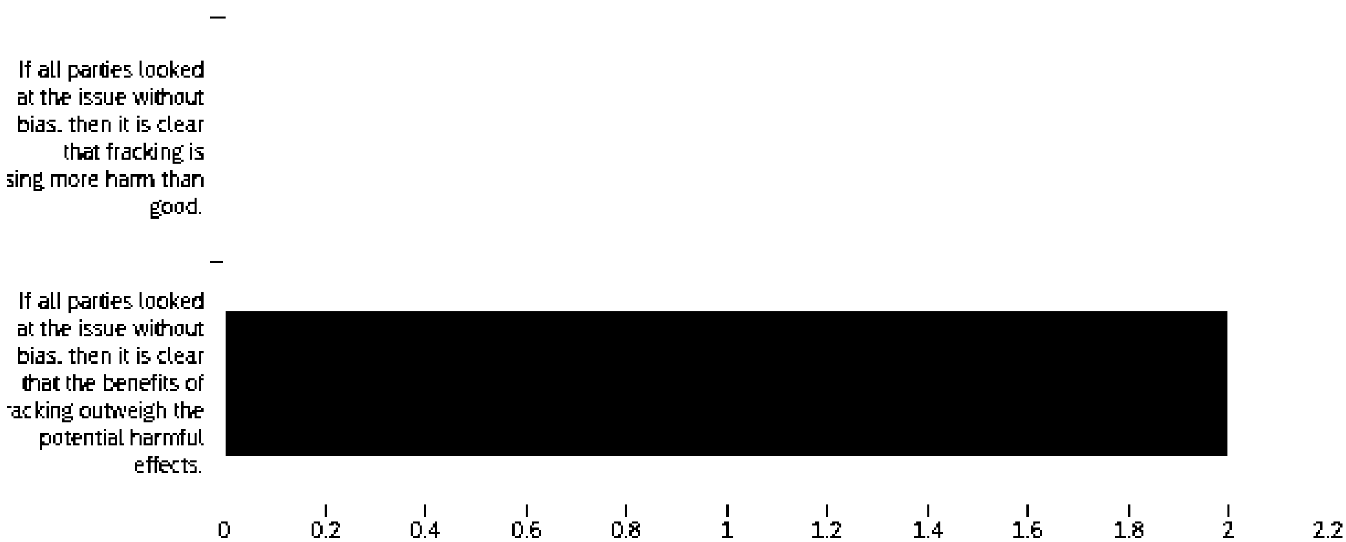
Q7A Pre - Why would all parties agree with your decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would all parties agree with your decision?	1.00	1.00	1.00	0.00	0.00	4

#	Answer	%	Count
1	If all parties looked at the issue without bias, then it is clear that fracking is causing more harm than good.	100.00%	4
2	If all parties looked at the issue without bias, then it is clear that the benefits of fracking outweigh the potential harmful effects.	0.00%	0
	Total	100%	4

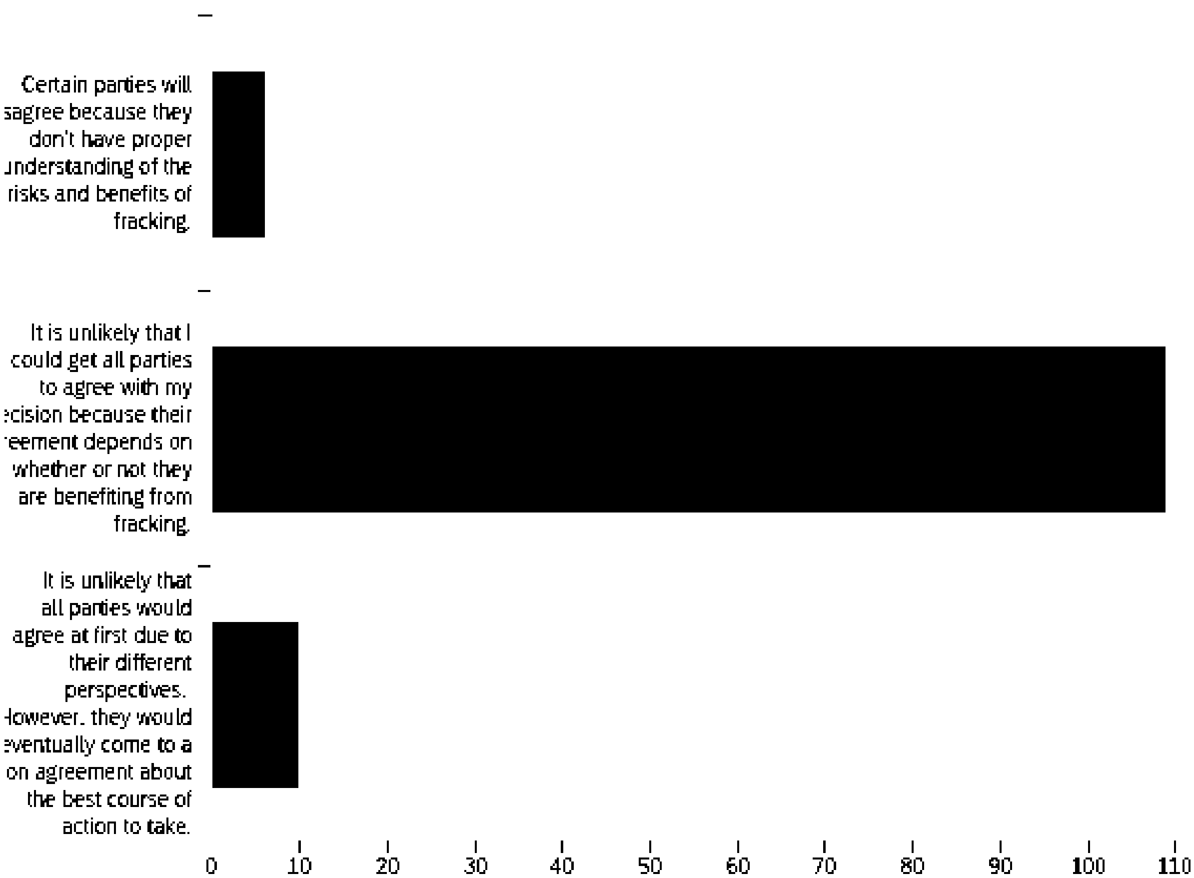
Q7A Post - Why would all parties agree with your decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would all parties agree with your decision?	2.00	2.00	2.00	0.00	0.00	2

#	Answer	%	Count
1	If all parties looked at the issue without bias, then it is clear that fracking is causing more harm than good.	0.00%	0
2	If all parties looked at the issue without bias, then it is clear that the benefits of fracking outweigh the potential harmful effects.	100.00%	2
	Total	100%	2

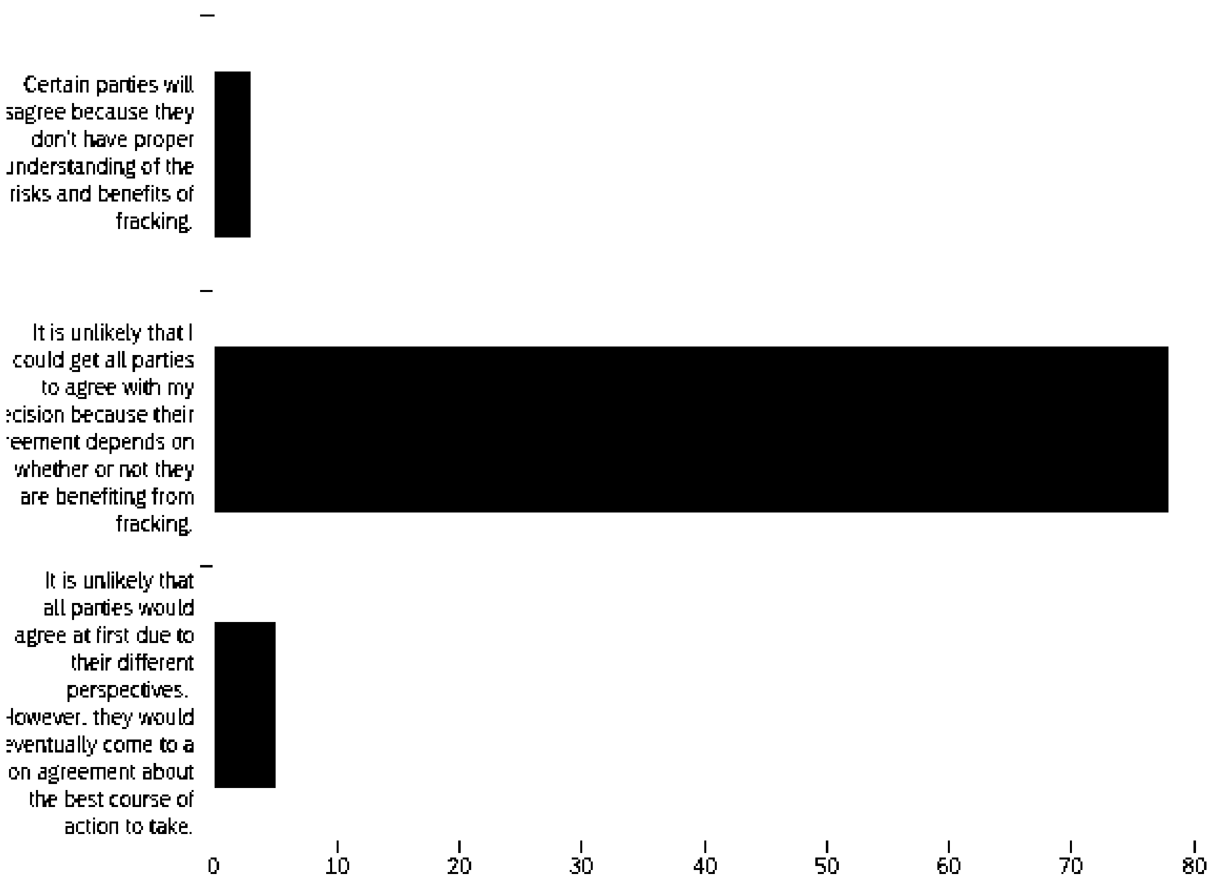
Q7NA Pre - Why would one or more parties likely not agree with your decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would one or more parties likely not agree with your decision?	1.00	3.00	2.03	0.36	0.13	125

#	Answer	%	Count
1	Certain parties will disagree because they don't have proper understanding of the risks and benefits of fracking.	4.80%	6
2	It is unlikely that I could get all parties to agree with my decision because their agreement depends on whether or not they are benefiting from fracking.	87.20%	109
3	It is unlikely that all parties would agree at first due to their different perspectives. However, they would eventually come to a common agreement about the best course of action to take.	8.00%	10
	Total	100%	125

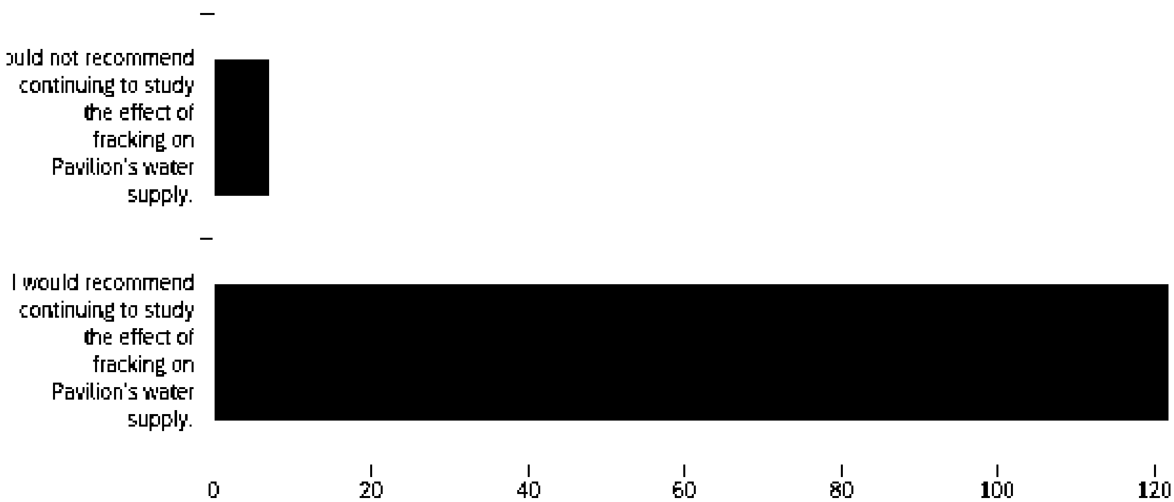
Q7NA Post - Why would one or more parties likely not agree with your decision?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would one or more parties likely not agree with your decision?	1.00	3.00	2.02	0.30	0.09	86

#	Answer	%	Count
1	Certain parties will disagree because they don't have proper understanding of the risks and benefits of fracking.	3.49%	3
2	It is unlikely that I could get all parties to agree with my decision because their agreement depends on whether or not they are benefiting from fracking.	90.70%	78
3	It is unlikely that all parties would agree at first due to their different perspectives. However, they would eventually come to a common agreement about the best course of action to take.	5.81%	5
	Total	100%	86

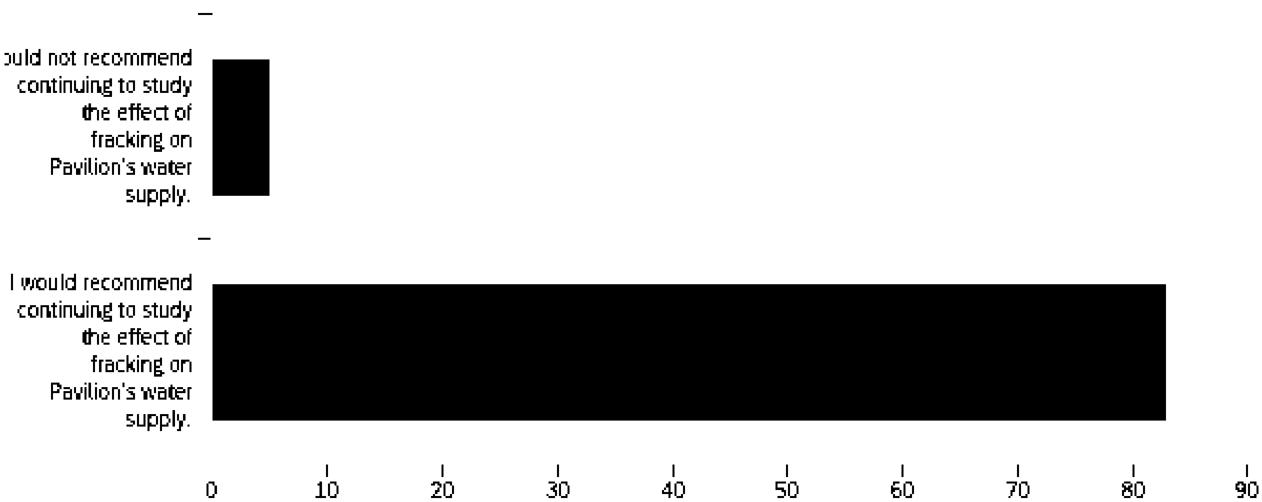
Q8 Pre - If the decision you made on whether to stop or continue fracking were put into action, would you recommend that additional funds and resources be used to continue studying the effect of fracking on Pavilion's water supply?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If the decision you made on whether to stop or continue fracking were put into action, would you recommend that additional funds and resources be used to continue studying the effect of fracking on Pavilion's water supply?	1.00	2.00	1.95	0.23	0.05	129

#	Answer	%	Count
1	I would not recommend continuing to study the effect of fracking on Pavilion's water supply.	5.43%	7
2	I would recommend continuing to study the effect of fracking on Pavilion's water supply.	94.57%	122
	Total	100%	129

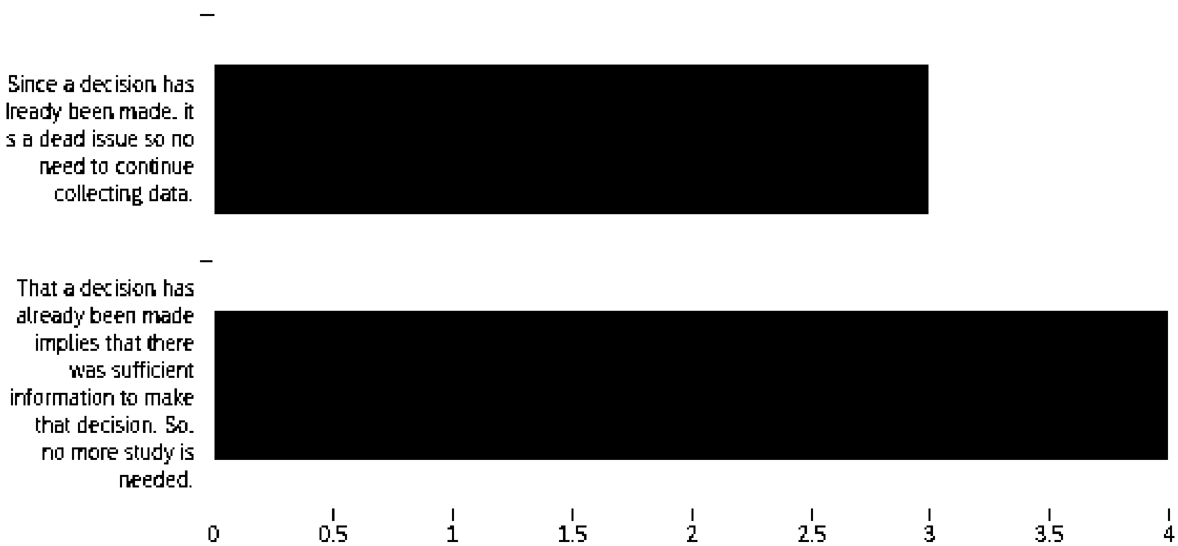
Q8 Post - If the decision you made on whether to stop or continue fracking were put into action, would you recommend that additional funds and resources be used to continue studying the effect of fracking on Pavilion's water supply?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If the decision you made on whether to stop or continue fracking were put into action, would you recommend that additional funds and resources be used to continue studying the effect of fracking on Pavilion's water supply?	1.00	2.00	1.94	0.23	0.05	88

#	Answer	%	Count
1	I would not recommend continuing to study the effect of fracking on Pavilion's water supply.	5.68%	5
2	I would recommend continuing to study the effect of fracking on Pavilion's water supply.	94.32%	83
	Total	100%	88

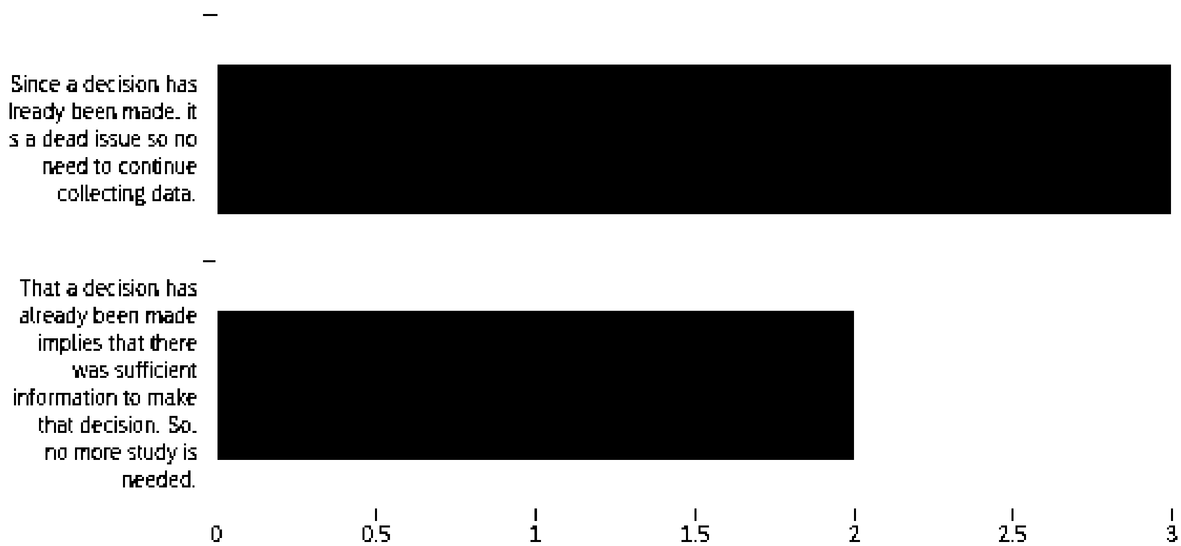
Q8WN Pre - Why would you not recommend continuing to study the effect of fracking on Pavilion's water supply?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you not recommend continuing to study the effect of fracking on Pavilion's water supply?	1.00	2.00	1.57	0.49	0.24	7

#	Answer	%	Count
1	Since a decision has already been made, it is a dead issue so no need to continue collecting data.	42.86%	3
2	That a decision has already been made implies that there was sufficient information to make that decision. So, no more study is needed.	57.14%	4
	Total	100%	7

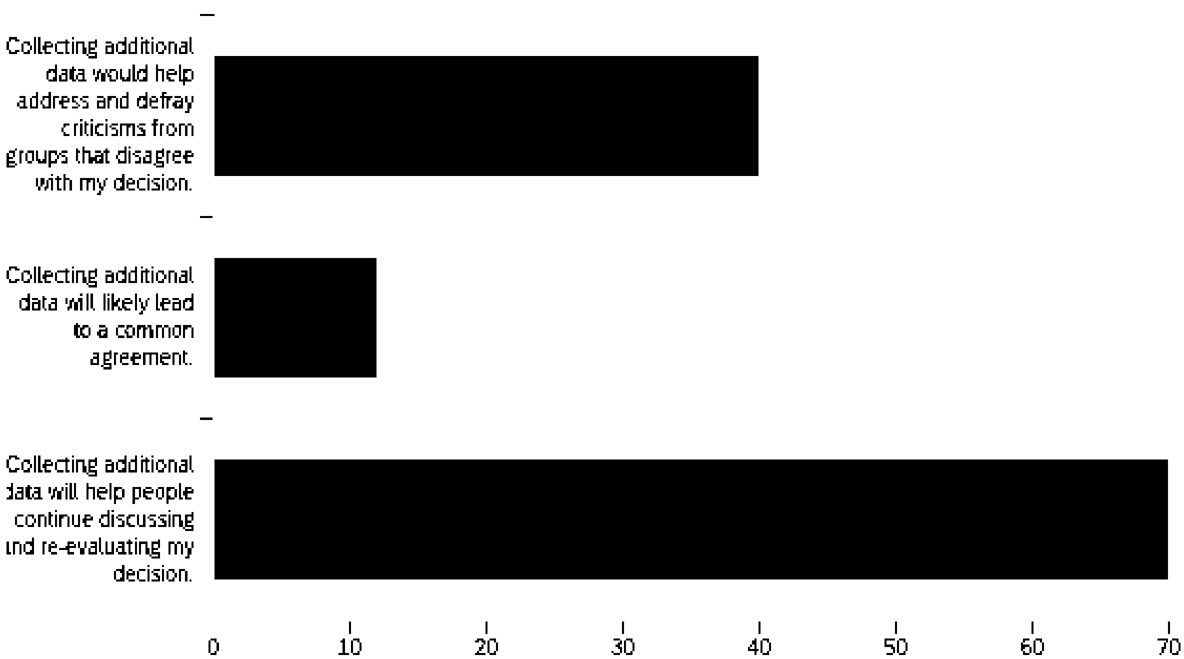
Q8WN Post - Why would you not recommend continuing to study the effect of fracking on Pavilion's water supply?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you not recommend continuing to study the effect of fracking on Pavilion's water supply?	1.00	2.00	1.40	0.49	0.24	5

#	Answer	%	Count
1	Since a decision has already been made, it is a dead issue so no need to continue collecting data.	60.00%	3
2	That a decision has already been made implies that there was sufficient information to make that decision. So, no more study is needed.	40.00%	2
	Total	100%	5

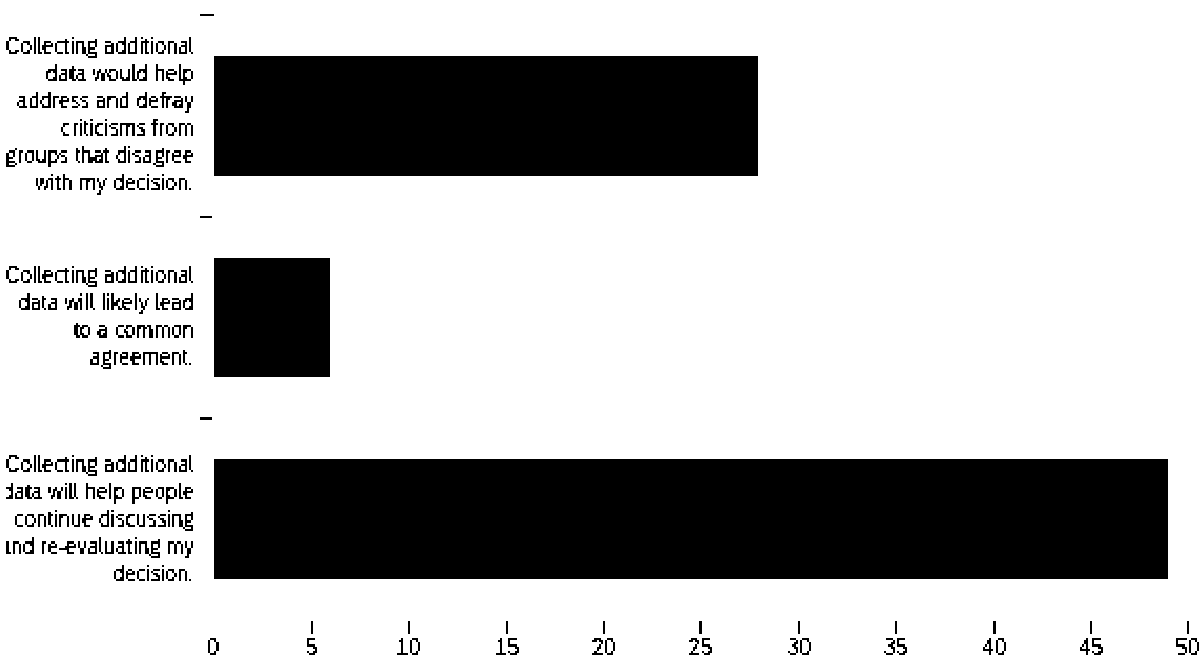
Q8W Pre - Why would you recommend continuing to study the effect of fracking on Pavilion's water supply?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you recommend continuing to study the effect of fracking on Pavilion's water supply?	1.00	3.00	2.25	0.92	0.84	122

#	Answer	%	Count
1	Collecting additional data would help address and defray criticisms from groups that disagree with my decision.	32.79%	40
2	Collecting additional data will likely lead to a common agreement.	9.84%	12
3	Collecting additional data will help people continue discussing and re-evaluating my decision.	57.38%	70
	Total	100%	122

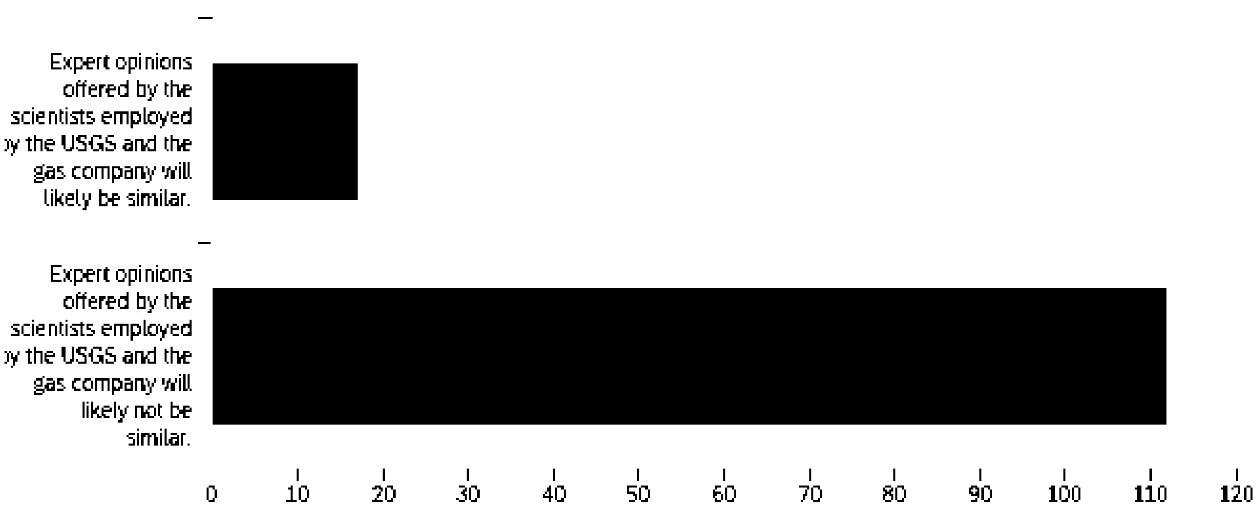
Q8W Post - Why would you recommend continuing to study the effect of fracking on Pavilion's water supply?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you recommend continuing to study the effect of fracking on Pavilion's water supply?	1.00	3.00	2.25	0.93	0.86	83

#	Answer	%	Count
1	Collecting additional data would help address and defray criticisms from groups that disagree with my decision.	33.73%	28
2	Collecting additional data will likely lead to a common agreement.	7.23%	6
3	Collecting additional data will help people continue discussing and re-evaluating my decision.	59.04%	49
	Total	100%	83

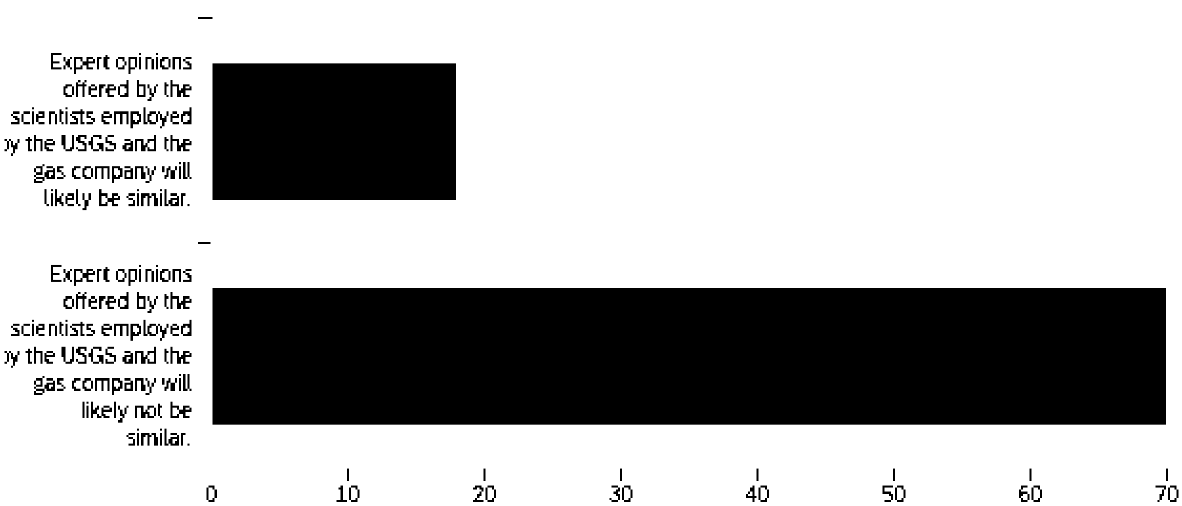
Q9 Pre - At a town meeting, a group of scientists employed by the gas company and another group of scientists employed by the United States Geological Survey (USGS) provided expert opinions on the fracking issue. Would you expect their opinions to be similar?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	At a town meeting, a group of scientists employed by the gas company and another group of scientists employed by the United States Geological Survey (USGS) provided expert opinions on the fracking issue. Would you expect their opinions to be similar?	1.00	2.00	1.87	0.34	0.11	129

#	Answer	%	Count
1	Expert opinions offered by the scientists employed by the USGS and the gas company will likely be similar.	13.18%	17
2	Expert opinions offered by the scientists employed by the USGS and the gas company will likely not be similar.	86.82%	112
	Total	100%	129

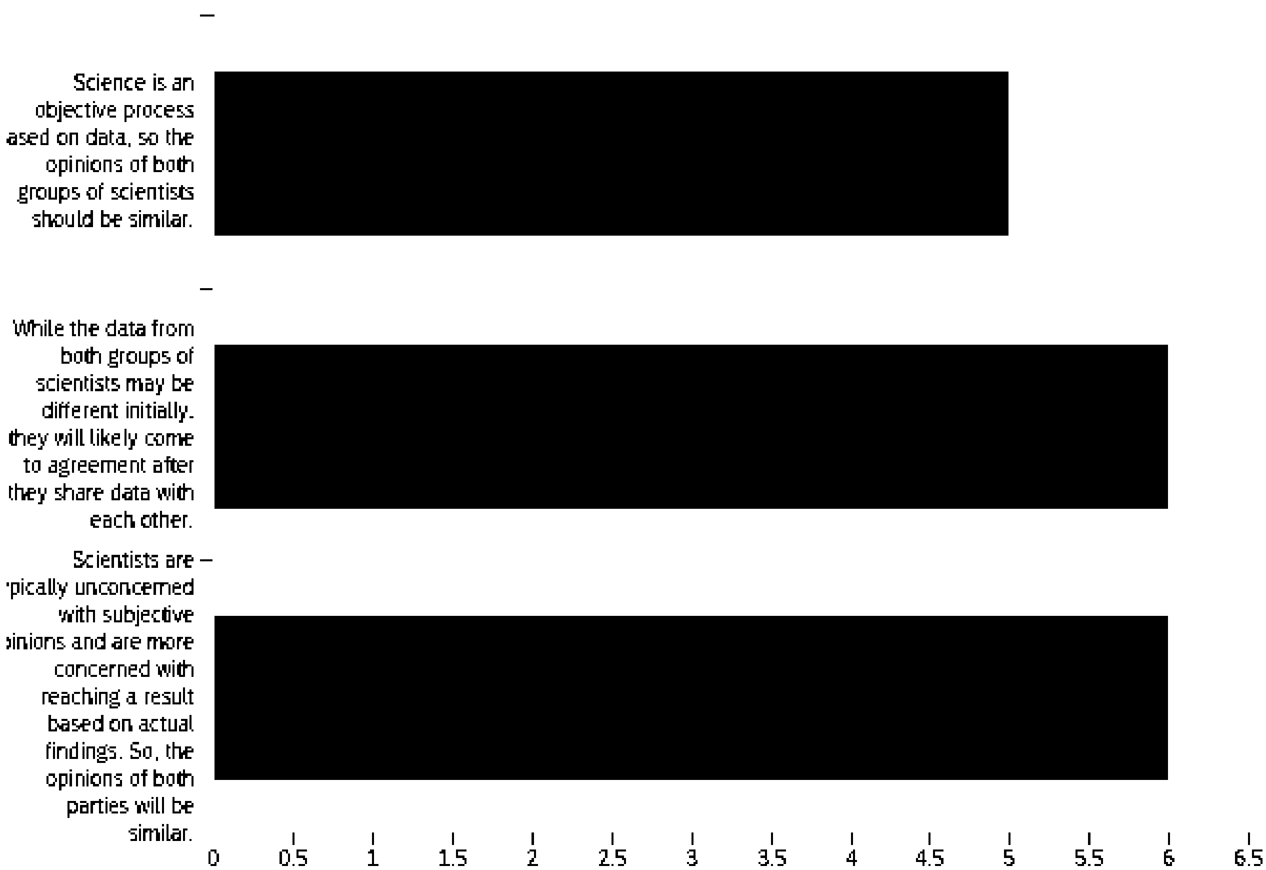
Q9 Post - At a town meeting, a group of scientists employed by the gas company and another group of scientists employed by the United States Geological Survey (USGS) provided expert opinions on the fracking issue. Would you expect their opinions to be similar?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	At a town meeting, a group of scientists employed by the gas company and another group of scientists employed by the United States Geological Survey (USGS) provided expert opinions on the fracking issue. Would you expect their opinions to be similar?	1.00	2.00	1.80	0.40	0.16	88

#	Answer	%	Count
1	Expert opinions offered by the scientists employed by the USGS and the gas company will likely be similar.	20.45%	18
2	Expert opinions offered by the scientists employed by the USGS and the gas company will likely not be similar.	79.55%	70
	Total	100%	88

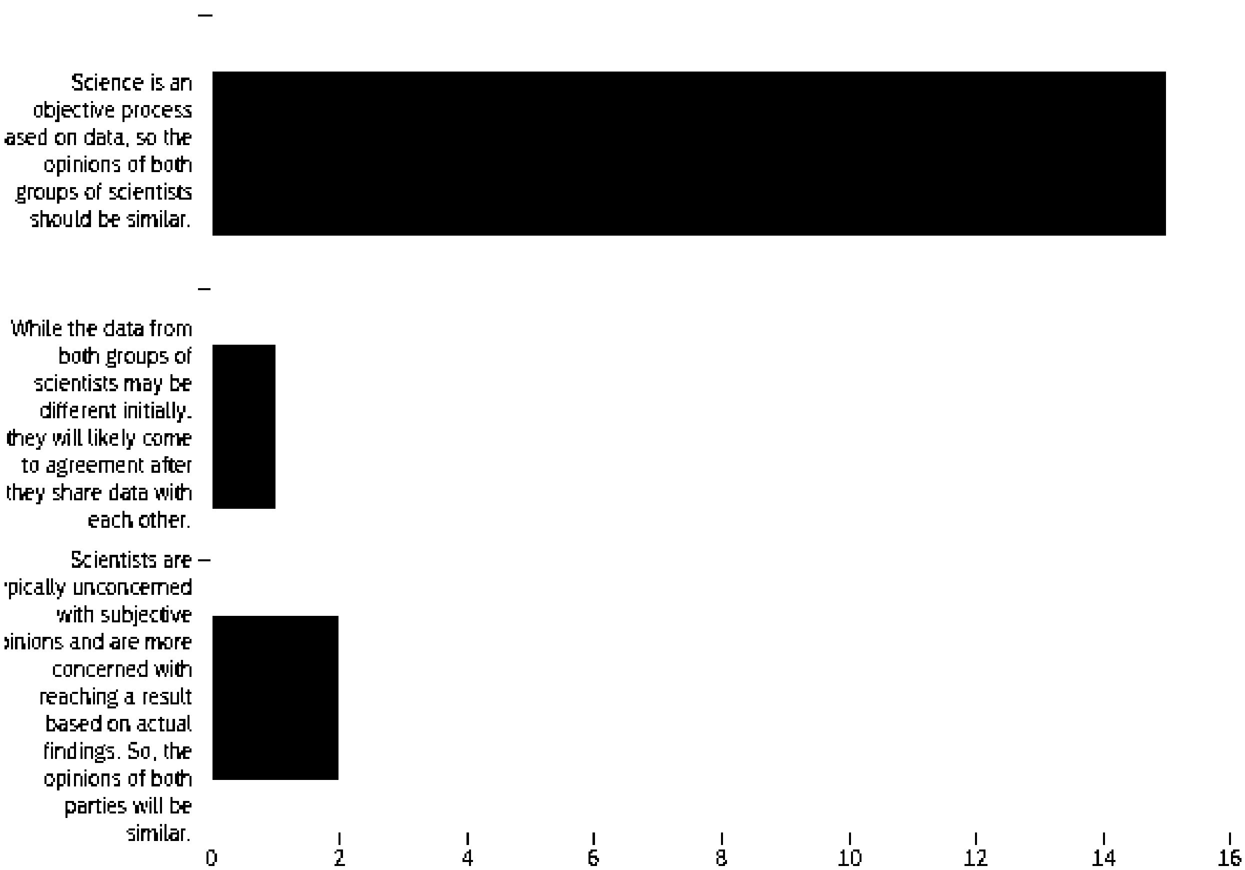
Q9W Pre - Why would the opinions of both groups of scientists likely be similar?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would the opinions of both groups of scientists likely be similar?	1.00	3.00	2.06	0.80	0.64	17

#	Answer	%	Count
1	Science is an objective process based on data, so the opinions of both groups of scientists should be similar.	29.41%	5
2	While the data from both groups of scientists may be different initially, they will likely come to agreement after they share data with each other.	35.29%	6
3	Scientists are typically unconcerned with subjective opinions and are more concerned with reaching a result based on actual findings. So, the opinions of both parties will be similar.	35.29%	6
	Total	100%	17

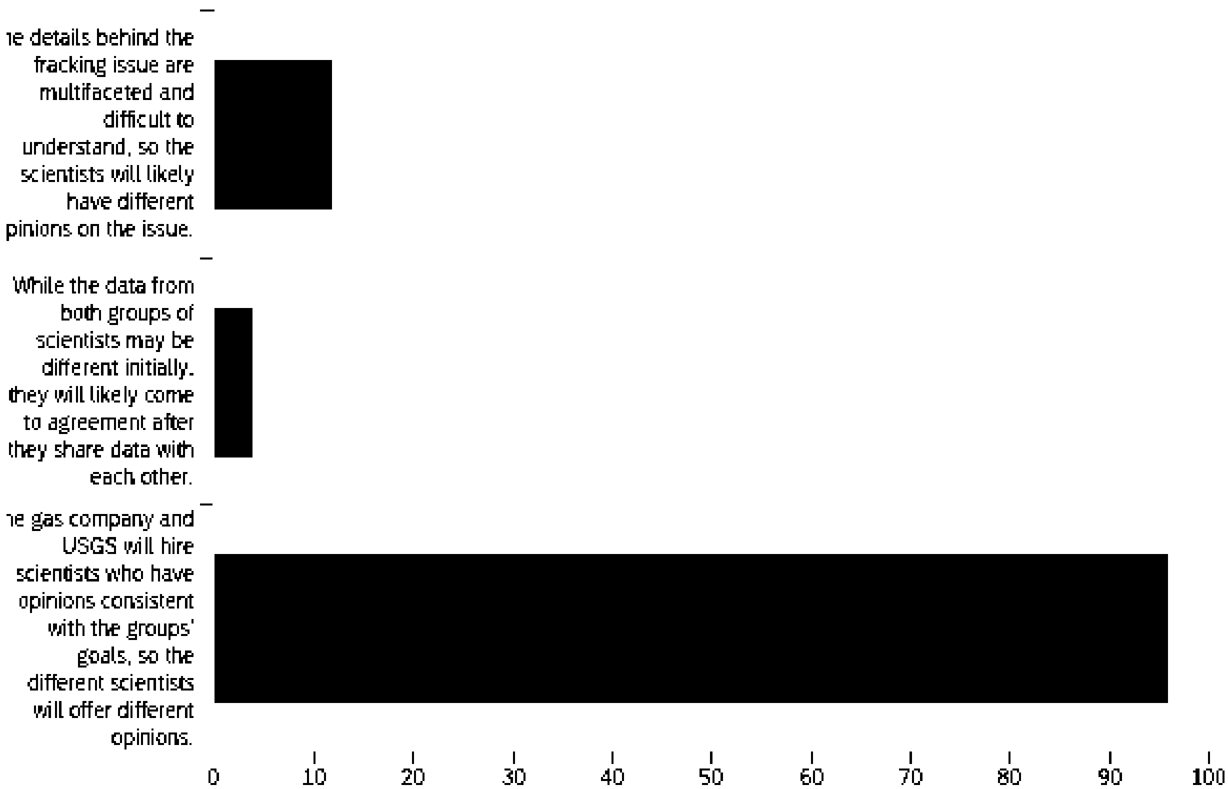
Q9W Post - Why would the opinions of both groups of scientists likely be similar?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would the opinions of both groups of scientists likely be similar?	1.00	3.00	1.28	0.65	0.42	18

#	Answer	%	Count
1	Science is an objective process based on data, so the opinions of both groups of scientists should be similar.	83.33%	15
2	While the data from both groups of scientists may be different initially, they will likely come to agreement after they share data with each other.	5.56%	1
3	Scientists are typically unconcerned with subjective opinions and are more concerned with reaching a result based on actual findings. So, the opinions of both parties will be similar.	11.11%	2
	Total	100%	18

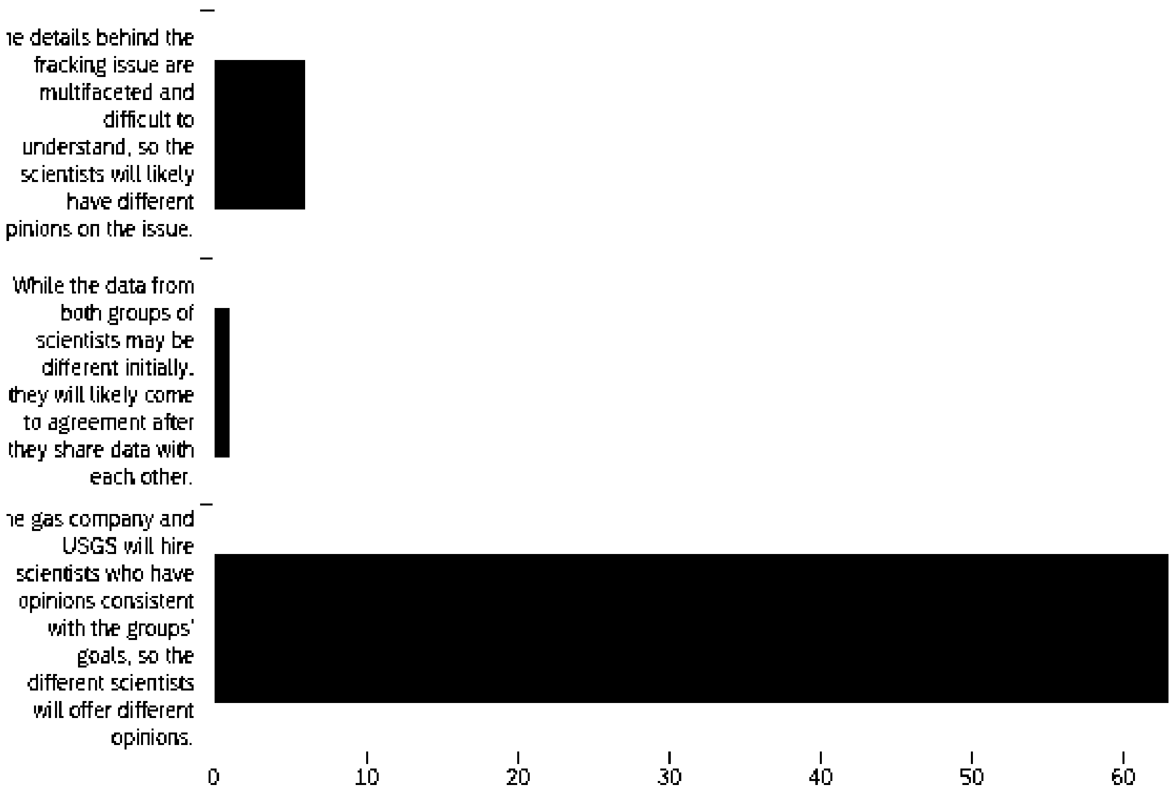
Q9WN Pre - Why would the opinions of both groups not likely be similar?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would the opinions of both groups not likely be similar?	1.00	3.00	2.75	0.63	0.40	112

#	Answer	%	Count
1	The details behind the fracking issue are multifaceted and difficult to understand, so the scientists will likely have different opinions on the issue.	10.71%	12
2	While the data from both groups of scientists may be different initially, they will likely come to agreement after they share data with each other.	3.57%	4
3	The gas company and USGS will hire scientists who have opinions consistent with the groups' goals, so the different scientists will offer different opinions.	85.71%	96
	Total	100%	112

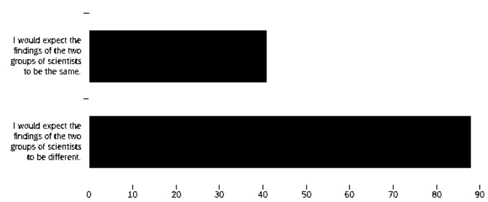
Q9WN Post - Why would the opinions of both groups not likely be similar?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would the opinions of both groups not likely be similar?	1.00	3.00	2.81	0.57	0.32	70

#	Answer	%	Count
1	The details behind the fracking issue are multifaceted and difficult to understand, so the scientists will likely have different opinions on the issue.	8.57%	6
2	While the data from both groups of scientists may be different initially, they will likely come to agreement after they share data with each other.	1.43%	1
3	The gas company and USGS will hire scientists who have opinions consistent with the groups' goals, so the different scientists will offer different opinions.	90.00%	63
	Total	100%	70

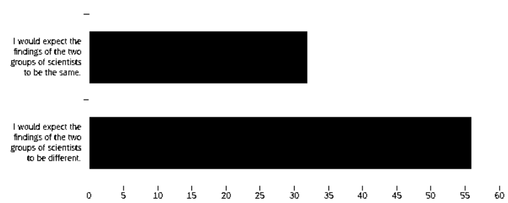
Q10 Pre - In response to the criticism about the questionable effects of fracking on Pavilion's water supply, the gas company has suggested using part of its profits to hire a team of scientists dedicated to collecting data on water quality in the area and giving regular reports to the local community. The residents of Pavilion decide to hire a different group of scientists to also conduct water monitoring. Would you expect the findings of these two groups of scientists be similar or different?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	In response to the criticism about the questionable effects of fracking on Pavilion's water supply, the gas company has suggested using part of its profits to hire a team of scientists dedicated to collecting data on water quality in the area and giving regular reports to the local community. The residents of Pavilion decide to hire a different group of scientists to also conduct water monitoring. Would you expect the findings of these two groups of scientists be similar or different?	1.00	2.00	1.68	0.47	0.22	129

#	Answer	%	Count
1	I would expect the findings of the two groups of scientists to be the same.	31.78%	41
2	I would expect the findings of the two groups of scientists to be different.	68.22%	88
	Total	100%	129

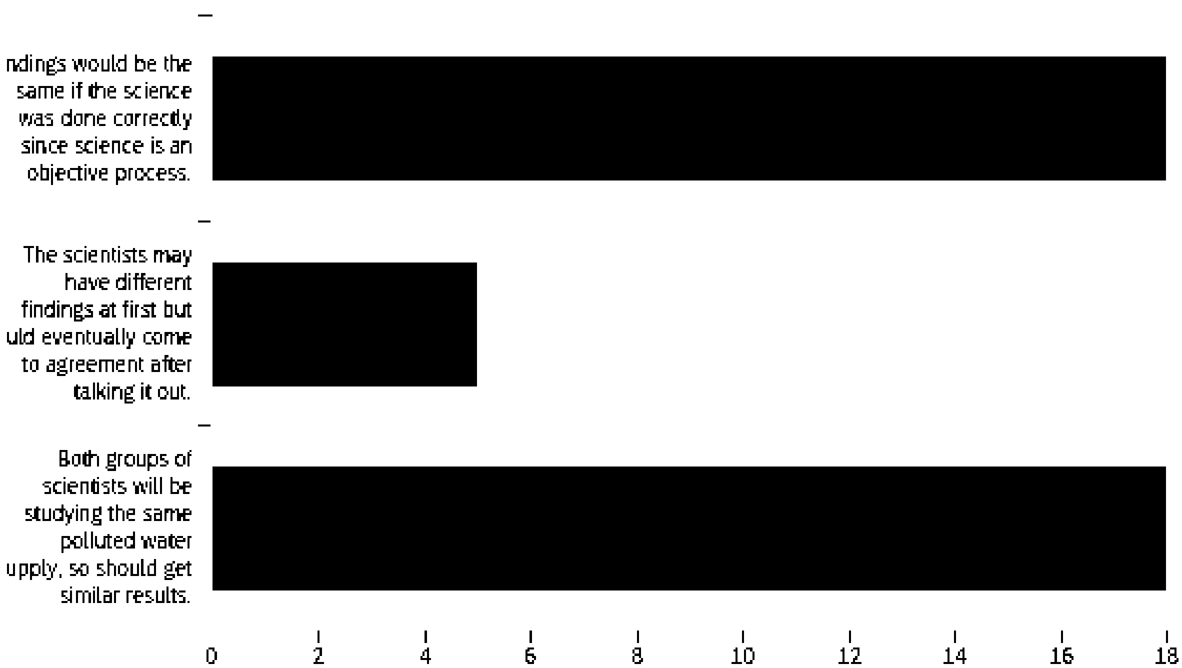
Q10 Post - In response to the criticism about the questionable effects of fracking on Pavilion's water supply, the gas company has suggested using part of its profits to hire a team of scientists dedicated to collecting data on water quality in the area and giving regular reports to the local community. The residents of Pavilion decide to hire a different group of scientists to also conduct water monitoring. Would you expect the findings of these two groups of scientists be similar or different?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	In response to the criticism about the questionable effects of fracking on Pavilion's water supply, the gas company has suggested using part of its profits to hire a team of scientists dedicated to collecting data on water quality in the area and giving regular reports to the local community. The residents of Pavilion decide to hire a different group of scientists to also conduct water monitoring. Would you expect the findings of these two groups of scientists be similar or different?	1.00	2.00	1.64	0.48	0.23	88

#	Answer	%	Count
1	I would expect the findings of the two groups of scientists to be the same.	36.36%	32
2	I would expect the findings of the two groups of scientists to be different.	63.64%	56
	Total	100%	88

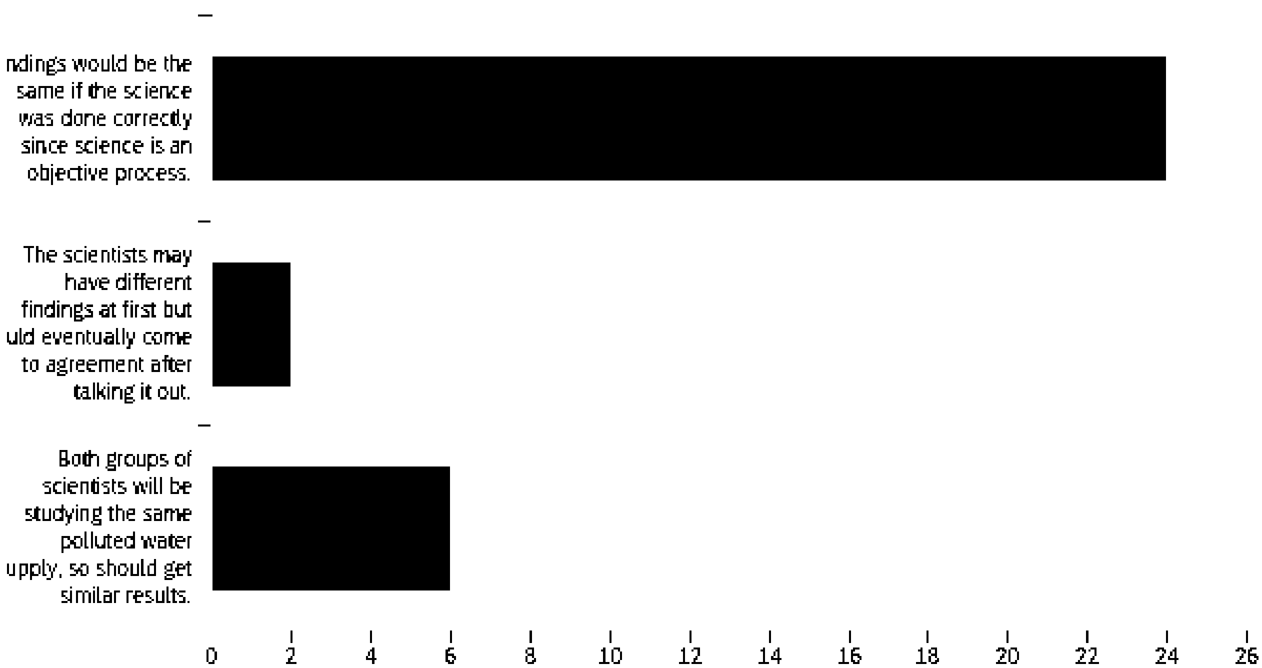
Q10S Pre - Why would you expect the findings of both groups of scientists to be the same?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you expect the findings of both groups of scientists to be the same?	1.00	3.00	2.00	0.94	0.88	41

#	Answer	%	Count
1	Findings would be the same if the science was done correctly since science is an objective process.	43.90%	18
2	The scientists may have different findings at first but would eventually come to agreement after talking it out.	12.20%	5
3	Both groups of scientists will be studying the same polluted water supply, so should get similar results.	43.90%	18
	Total	100%	41

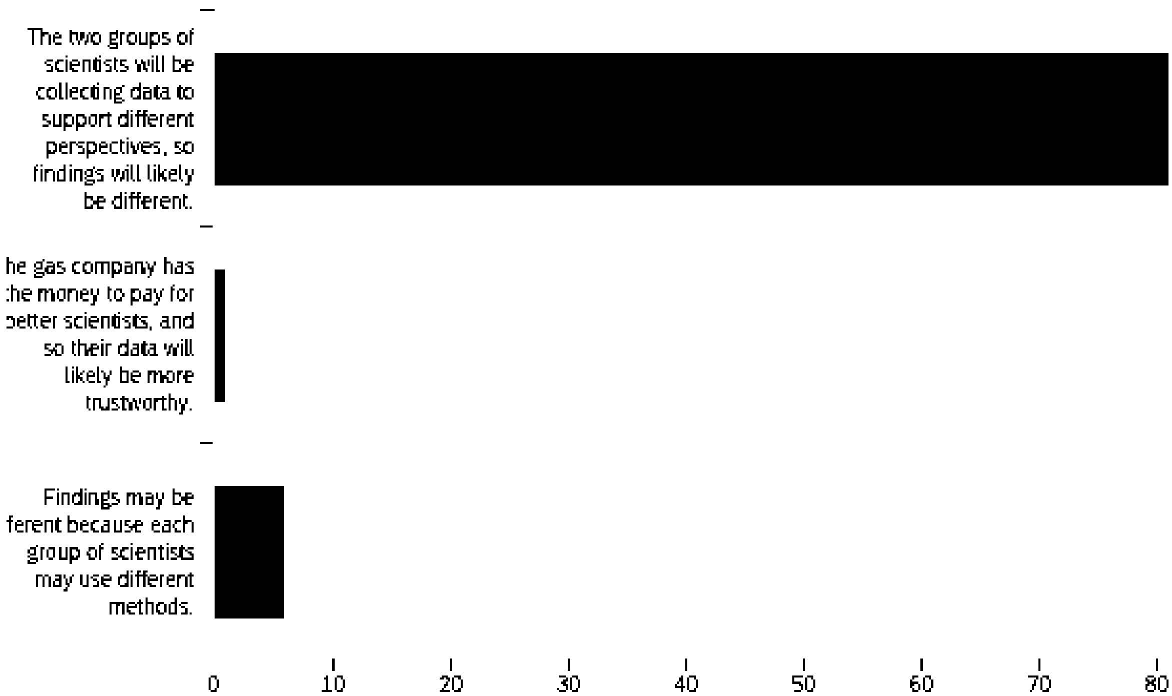
Q10S Post - Why would you expect the findings of both groups of scientists to be the same?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you expect the findings of both groups of scientists to be the same?	1.00	3.00	1.44	0.79	0.62	32

#	Answer	%	Count
1	Findings would be the same if the science was done correctly since science is an objective process.	75.00%	24
2	The scientists may have different findings at first but would eventually come to agreement after talking it out.	6.25%	2
3	Both groups of scientists will be studying the same polluted water supply, so should get similar results.	18.75%	6
	Total	100%	32

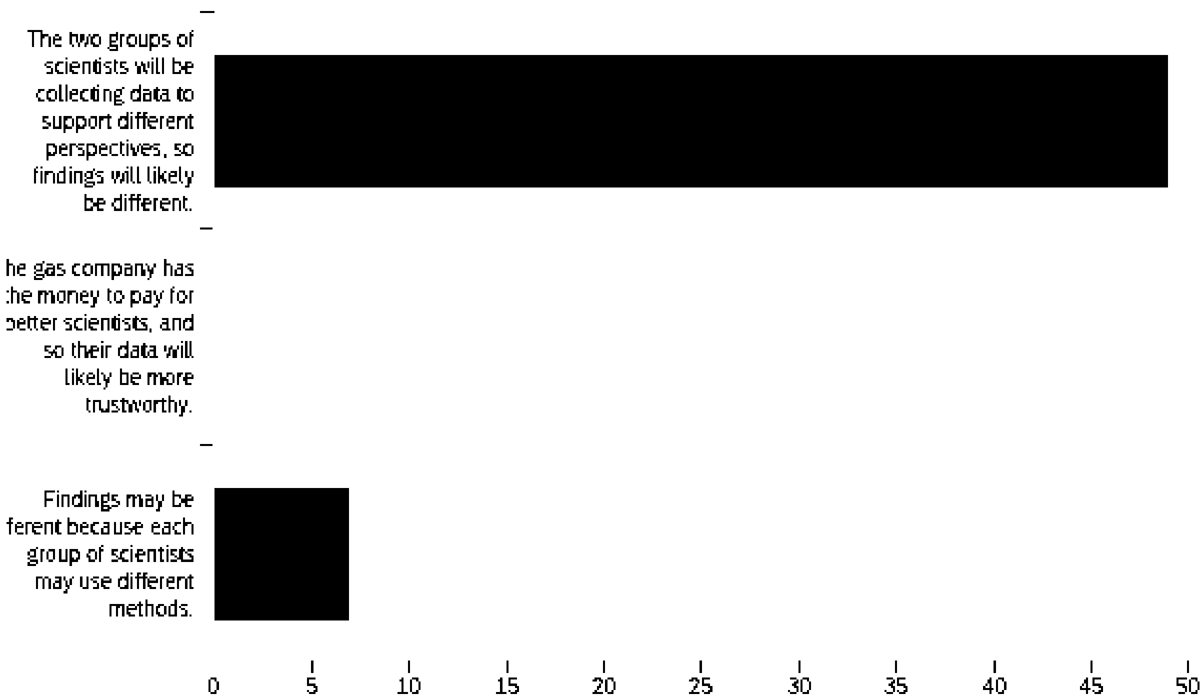
Q10D Pre - Why would you expect the findings of the two groups of scientists to be different?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you expect the findings of the two groups of scientists to be different?	1.00	3.00	1.15	0.51	0.26	88

#	Answer	%	Count
1	The two groups of scientists will be collecting data to support different perspectives, so findings will likely be different.	92.05%	81
2	The gas company has the money to pay for better scientists, and so their data will likely be more trustworthy.	1.14%	1
3	Findings may be different because each group of scientists may use different methods.	6.82%	6
	Total	100%	88

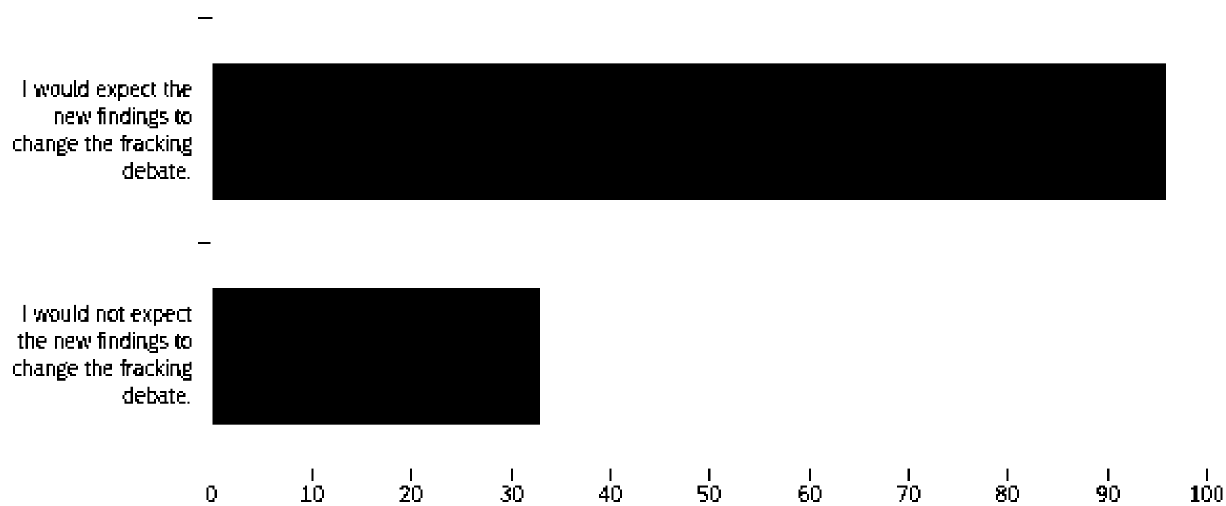
Q10D Post - Why would you expect the findings of the two groups of scientists to be different?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you expect the findings of the two groups of scientists to be different?	1.00	3.00	1.25	0.66	0.44	56

#	Answer	%	Count
1	The two groups of scientists will be collecting data to support different perspectives, so findings will likely be different.	87.50%	49
2	The gas company has the money to pay for better scientists, and so their data will likely be more trustworthy.	0.00%	0
3	Findings may be different because each group of scientists may use different methods.	12.50%	7
	Total	100%	56

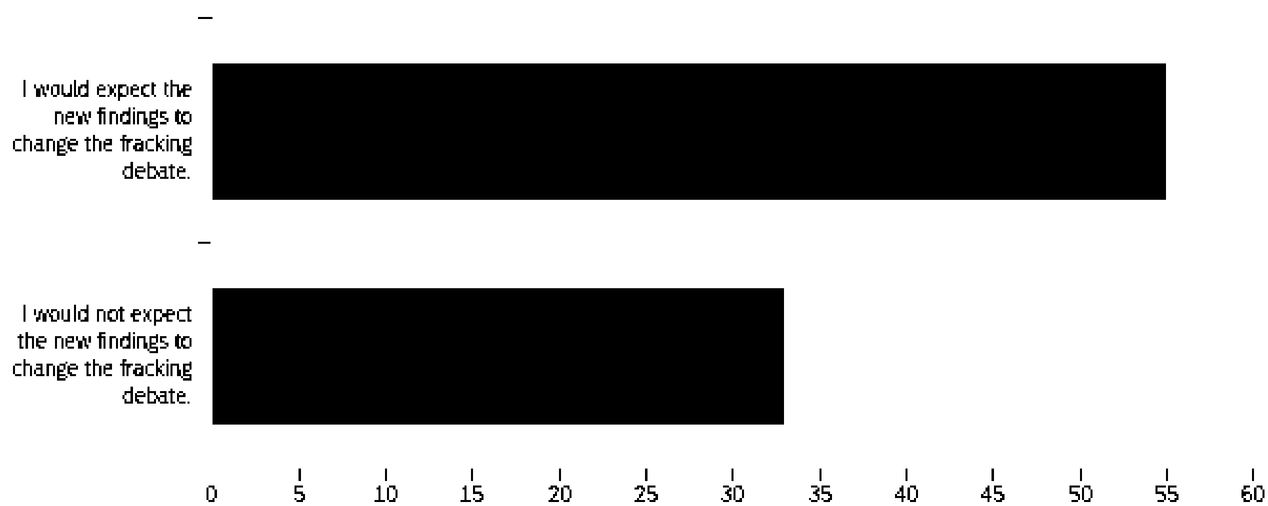
Q11 Pre - A geologist at a prestigious university publishes an article in a top-ranked journal confirming that the chemicals contaminating Pavilion's water supply are many of the same chemicals that are associated with the nearby fracking operation. Do you think this will change the fracking debate?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	A geologist at a prestigious university publishes an article in a top-ranked journal confirming that the chemicals contaminating Pavilion's water supply are many of the same chemicals that are associated with the nearby fracking operation. Do you think this will change the fracking debate?	1.00	2.00	1.26	0.44	0.19	129

#	Answer	%	Count
1	I would expect the new findings to change the fracking debate.	74.42%	96
2	I would not expect the new findings to change the fracking debate.	25.58%	33
	Total	100%	129

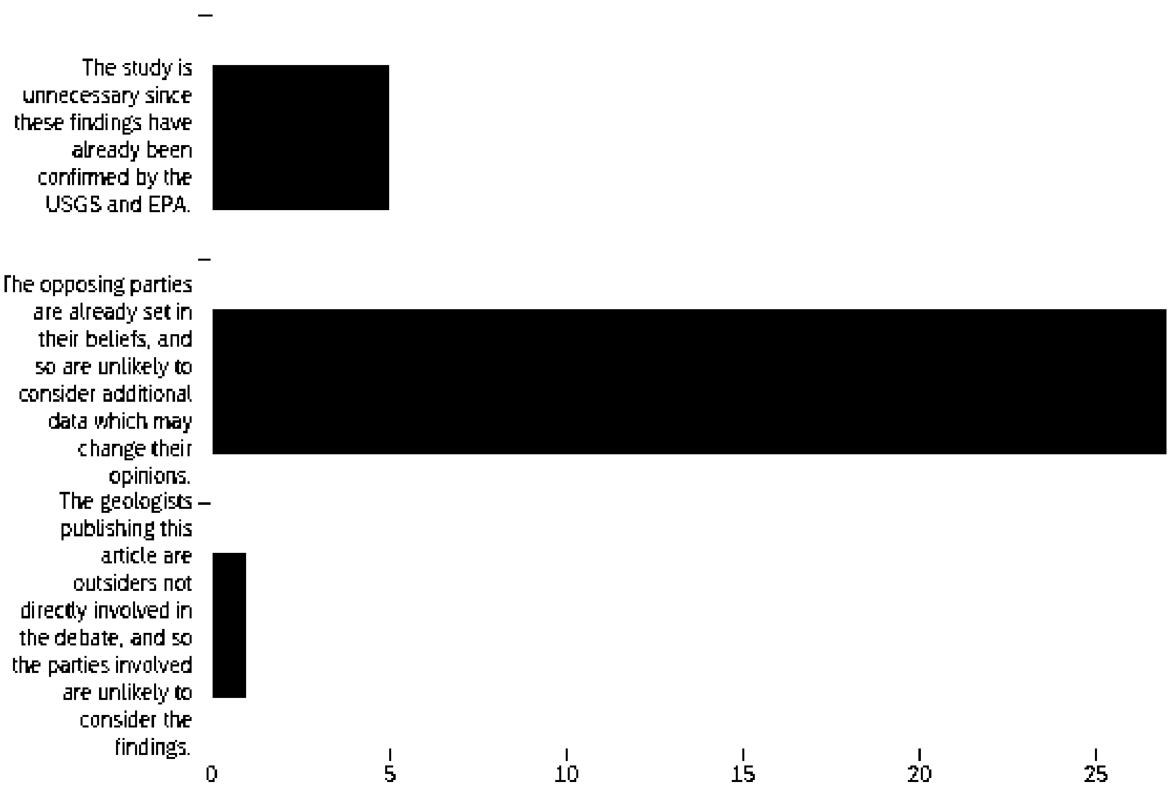
Q11 Post - A geologist at a prestigious university publishes an article in a top-ranked journal confirming that the chemicals contaminating Pavilion's water supply are many of the same chemicals that are associated with the nearby fracking operation. Do you think this will change the fracking debate?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	A geologist at a prestigious university publishes an article in a top-ranked journal confirming that the chemicals contaminating Pavilion's water supply are many of the same chemicals that are associated with the nearby fracking operation. Do you think this will change the fracking debate?	1.00	2.00	1.38	0.48	0.23	88

#	Answer	%	Count
1	I would expect the new findings to change the fracking debate.	62.50%	55
2	I would not expect the new findings to change the fracking debate.	37.50%	33
	Total	100%	88

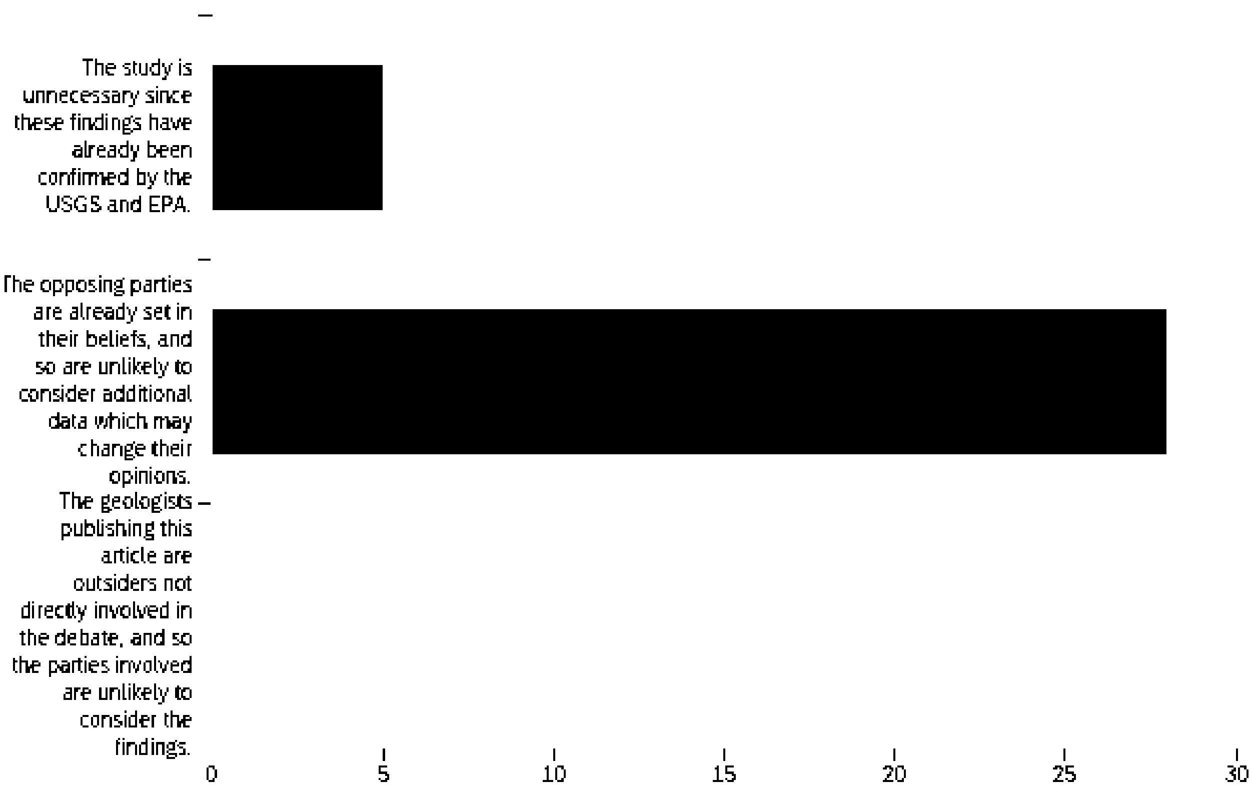
Q11WN Pre - Why would you not expect this to change the fracking debate?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you not expect this to change the fracking debate?	1.00	3.00	1.88	0.41	0.17	33

#	Answer	%	Count
1	The study is unnecessary since these findings have already been confirmed by the USGS and EPA.	15.15%	5
2	The opposing parties are already set in their beliefs, and so are unlikely to consider additional data which may change their opinions.	81.82%	27
3	The geologists publishing this article are outsiders not directly involved in the debate, and so the parties involved are unlikely to consider the findings.	3.03%	1
	Total	100%	33

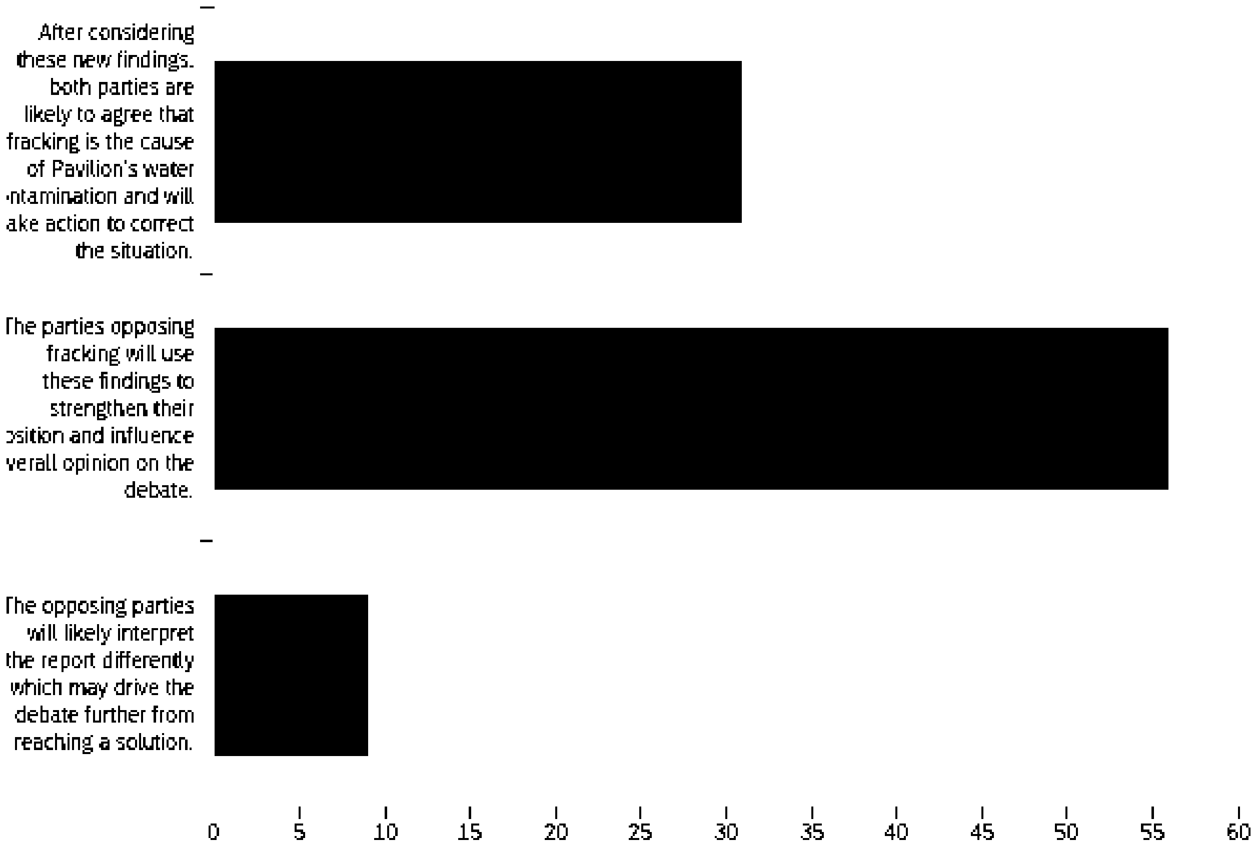
Q11WN Post - Why would you not expect this to change the fracking debate?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you not expect this to change the fracking debate?	1.00	2.00	1.85	0.36	0.13	33

#	Answer	%	Count
1	The study is unnecessary since these findings have already been confirmed by the USGS and EPA.	15.15%	5
2	The opposing parties are already set in their beliefs, and so are unlikely to consider additional data which may change their opinions.	84.85%	28
3	The geologists publishing this article are outsiders not directly involved in the debate, and so the parties involved are unlikely to consider the findings.	0.00%	0
	Total	100%	33

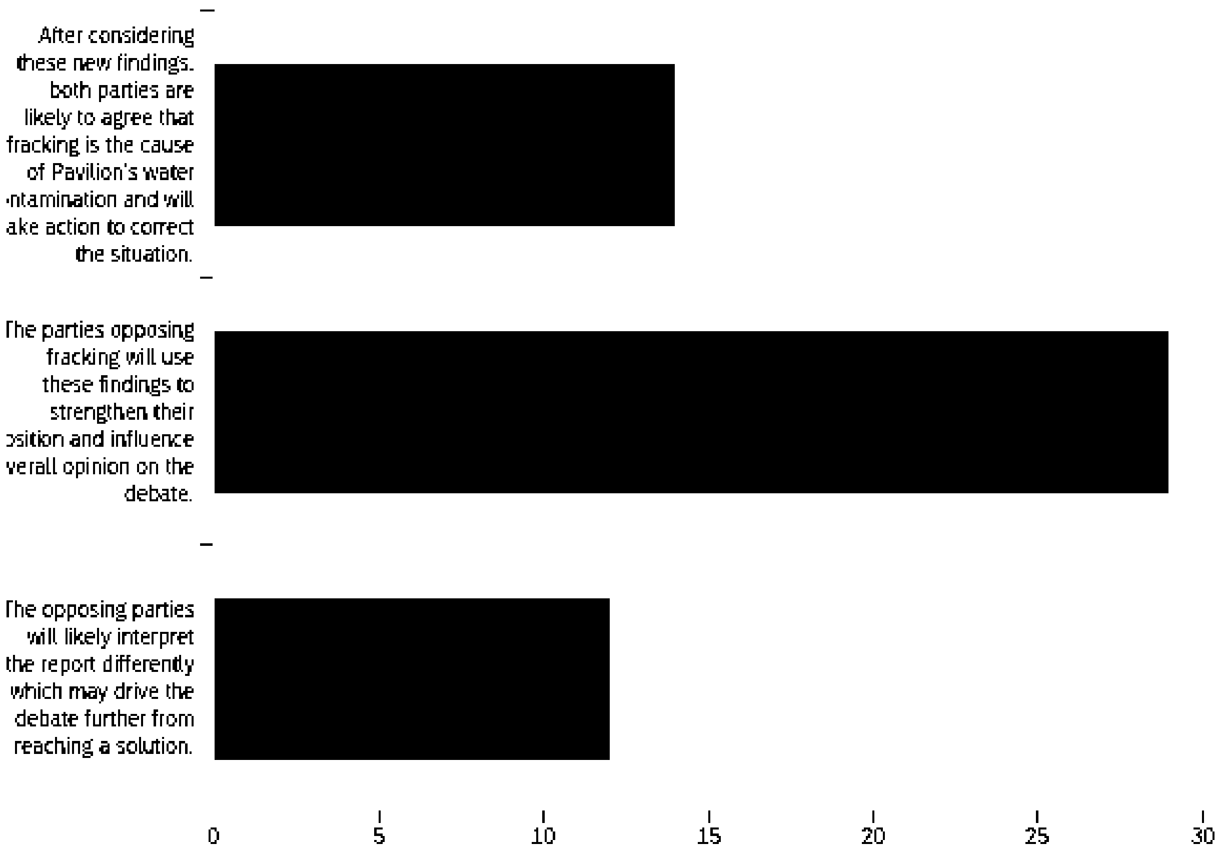
Q11W Pre - Why would you expect this to change the fracking debate?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you expect this to change the fracking debate?	1.00	3.00	1.77	0.60	0.36	96

#	Answer	%	Count
1	After considering these new findings, both parties are likely to agree that fracking is the cause of Pavilion's water contamination and will take action to correct the situation.	32.29%	31
2	The parties opposing fracking will use these findings to strengthen their position and influence overall opinion on the debate.	58.33%	56
3	The opposing parties will likely interpret the report differently which may drive the debate further from reaching a solution.	9.38%	9
	Total	100%	96

Q11W Post - Why would you expect this to change the fracking debate?



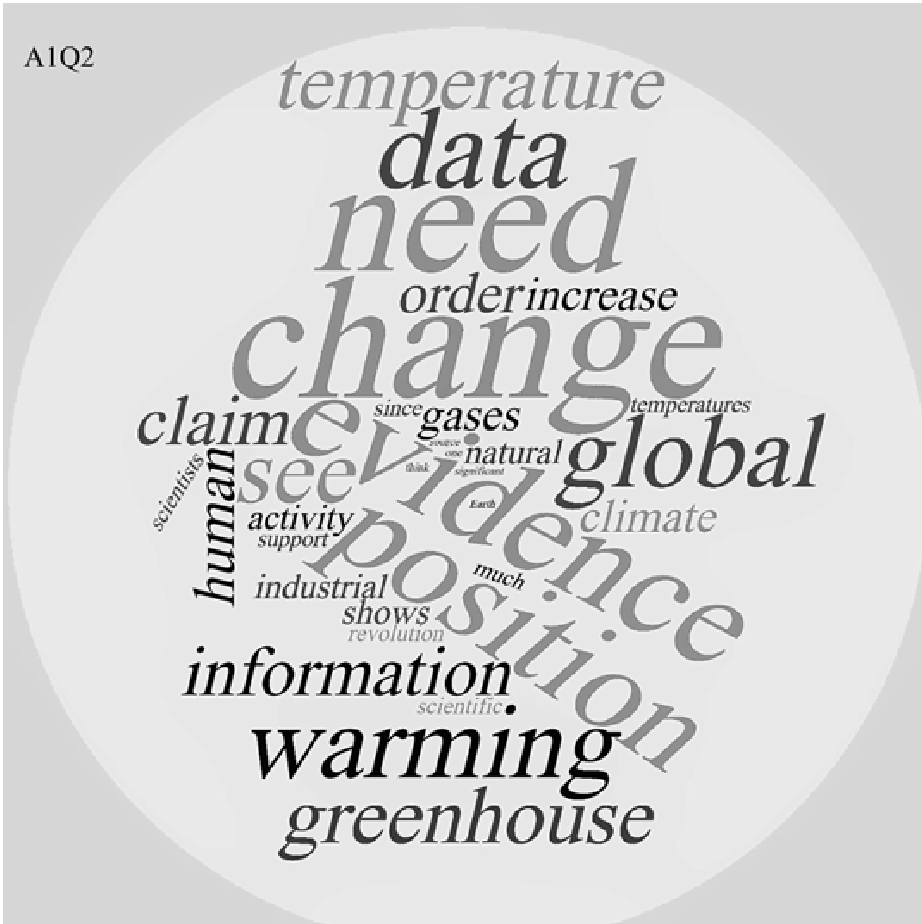
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Why would you expect this to change the fracking debate?	1.00	3.00	1.96	0.69	0.47	55

#	Answer	%	Count
1	After considering these new findings, both parties are likely to agree that fracking is the cause of Pavilion's water contamination and will take action to correct the situation.	25.45%	14
2	The parties opposing fracking will use these findings to strengthen their position and influence overall opinion on the debate.	52.73%	29
3	The opposing parties will likely interpret the report differently which may drive the debate further from reaching a solution.	21.82%	12
	Total	100%	55

Appendix C: Word Frequency Results

Frequency	Word	Frequency	Word	Frequency	Word
160	knowledge	20	statement	13	scientists
129	good	19	evil	13	technology
123	can	19	one	12	either
118	science	18	application	12	idea
109	bad	18	power	12	immoral
80	agree	17	believe	12	thing
77	scientific	17	like	11	always
64	used	17	way	11	different
62	people	17	whether	11	even
56	used	16	neither	11	however
54	example	15	inherently	11	may
38	moral	15	just	11	morals
34	think	15	understanding	11	nature
28	information	14	however	11	wrong
27	humans	14	neutral	10	certain
24	nuclear	14	sense	10	create
24	world	14	simply	10	depends
23	decide	14	will	10	lives
21	also	13	many	10	person
21	weapons	13	morality	10	positive
20	humans	13	new		
20	morally	13	others		

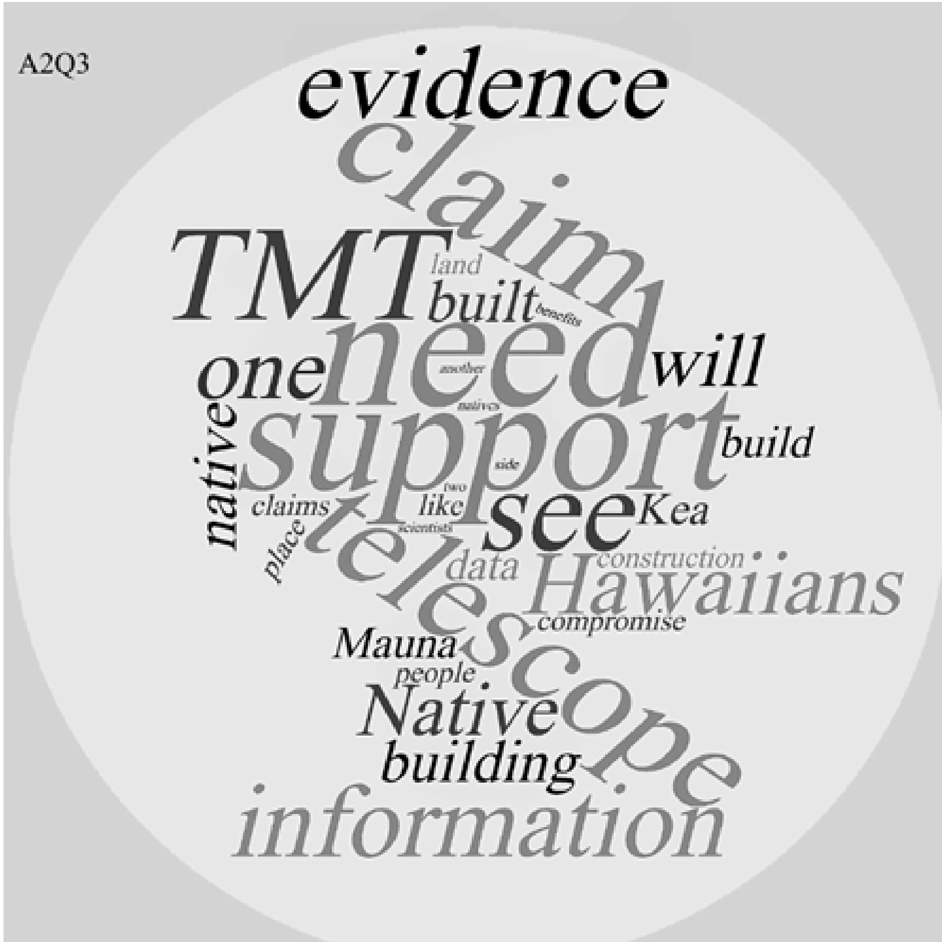
Frequency	Word	Frequency	Word	Frequency	Word
213	guidelines	29	know	16	lot
146	people	26	safe	16	yes
117	following	25	see	15	best
110	follow	23	just	15	especially
82	think	22	fellow	15	health
74	want	22	many	15	may
66	students	22	social	15	normal
61	mask	20	family	14	like
48	around	20	friends	14	someone
42	also	20	will	14	spread
42	others	19	college	14	well
41	wear	19	risk	13	always
40	virus	18	keep	13	distancing
34	recommended	18	pandemic	13	even
34	wearing	18	reason	13	say
33	campus	18	sick	12	time
32	believe	17	public	10	try
31	get	16	feel	12	due
31	masks	16	home	12	good



Frequency	Word	Frequency	Word	Frequency	Word
87	change	20	human	12	temperatures
76	need	20	order	11	much
61	evidence	18	gases	11	scientific
51	position	17	climate	11	support
48	data	17	increase	10	Earth
45	global	16	natural	10	one
37	warming	15	activity	10	significant
34	see	14	shows	10	source
29	greenhouse	13	industrial	10	think
29	temperature	13	revolution		
23	claim	13	since		

Frequency	Word	Frequency	Word
84	need	14	human
61	claim	14	believe
57	support	14	climate
56	warming	13	temperature
53	evidence	13	much
53	global	13	order
53	radiation	12	sources
49	solar	12	activity
47	data	12	main
36	see	12	one
34	information	12	scientific
23	claims	11	think
23	natural	11	also
23	revolution	11	like
23	since	11	reliable
22	amount	10	credible
22	industrial	10	increase
21	changes	10	occurred
19	change	10	presented
19	Sun	10	showing
18	cause	10	temperatures
15	time		
15	greenhouse		

Frequency	Word	Frequency	Word
55	need	15	opinion
52	change	14	benefits
38	telescope	13	important
37	position	13	location
31	Hawaiians	13	mountain
31	information	13	scientists
25	Native	11	can
22	TMT	11	one
21	evidence	11	people
20	land	11	think
18	Kea	11	way
18	Mauna	10	Hawaiian
17	see	10	natives
15	construction	10	scientific
15	native		



Frequency	Word	Frequency	Word
60	need	15	benefits
58	change	15	important
57	telescope	14	location
39	position	14	mountain
33	Hawaiians	13	scientists
27	information	13	can
25	Native	12	one
23	TMT	12	people
22	evidence	12	think
20	land	11	way
19	Kea	10	Hawaiian
18	Mauna	10	natives
17	see	10	scientific
17	construction	10	side
15	native	10	two
15	opinion		

Appendix D: SSR Aspect Analysis Results

Full SSR Aspect-Level Text Analysis for All Prompts by Cluster

Prompt		**Aspects**	**Confidence**
SMQ1		inquiry:perspective	1:0.892
SMQ1		inquiry:skepticism	1:1
SMQ1		inquiry:skepticism	1:0.756
SMQ1		inquiry:perspective	1:1
SMQ1		perspective	0.896
SMQ1		perspective	1
SMQ1		inquiry:complexity	0.950:0.886
SMQ1		inquiry	0.923
SMQ1		inquiry:complexity	0.966:1
SMQ1		perspective	1
SMQ1		inquiry:complexity:perspective	0.895:1:1
SMQ1		inquiry	1
SMQ1		perspective	1
SMQ1		perspective:inquiry	0.779:1
SMQ1		perspective:inquiry	0.912:1
SMQ1		inquiry:perspective:complexity	0.997:0.985:1
SMQ1		inquiry:perspective	1:0.899
SMQ1		inquiry:perspective	1:1

SMQ1		inquiry:perspective	1:1
SMQ1		perspective:inquiry	0.977:1
SMQ1		inquiry:perspective	1:1
SMQ1		inquiry:perspective	1:1
SMQ1		perspective	1
SMQ1		perspective:inquiry	1:0.834
SMQ1		complexity:perspective	0.765:0.699
SMQ1		perspective	1
SMQ1		perspective	1
SMQ1		perspective:skepticism	1:1
SMQ1		perspective:inquiry	1:1
SMQ1		inquiry:perspective	1:1
SMQ1		inquiry:perspective	1:1
SMQ1		perspective	0.835
SMQ1		inquiry:complexity	1:0.931
SMQ1		inquiry:perspective	1:1
SMQ1		perspective	0.901
SMQ1		perspective	1
SMQ1		perspective	1
SMQ1		perspective	1
SMQ1		perspective:skepticism	1:0.795
SMQ1		perspective	1
SMQ1		perspective	1

SMQ1		perspective	1
SMQ1		perspective:skepticism	1:0.896
SMQ1		perspective	1
SMQ1		perspective	1
SMQ1		perspective:skepticism	1:0.589
SMQ1		perspective	1
SMQ1		perspective	1
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SMQ1		perspective	1
SMQ1		inquiry	0.475
SMQ1		perspective	1
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SMQ1		perspective	1
SMQ1		perspective:complexity:skepticism	1:0.891:.0755
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SMQ1		inquiry:perspective	1:1
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SMQ1		perspective	1
SMQ1		complexity:perspective	1:1
SMQ1		inquiry:perspective	1:1

SMQ1		complexity:perspective	1:1
SMQ1		perspective	1
SMQ1		inquiry:perspective	1:1
SMQ1		inquiry:perspective	1:1
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SMQ1		perspective:complexity	1:1
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SMQ1		inquiry:perspective:complexity	1:1:0.953
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SMQ2		inquiry:perspective:complexity	1:1:0.982
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SMQ1		perspective	1
SMQ1		complexity:perspective:skepticism	1:1:0.955
A1Q1		inquiry	1
A1Q1		inquiry	0.532
A1Q1		inquiry	0.861
A1Q1		perspective:inquiry	1:0.878
A1Q1		inquiry:perspective	0.536:0.425
A1Q1		inquiry	0.839
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	0.614
A1Q1		inquiry	0.563
A1Q1		inquiry	0.791
A1Q1		inquiry	0.784
A1Q1		inquiry	1
A1Q1		inquiry:complexity:perspective	1:1:1

A1Q1		inquiry	0.646
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A1Q1		inquiry	0.875
A1Q1		inquiry	0.763
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A1Q1		inquiry	0.567

A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		perspective	0.761
A1Q1		inquiry	0.881
A1Q1		inquiry	0.783
A1Q1		inquiry	0.53
A1Q1		inquiry	1
A1Q1		inquiry	0.976
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A1Q1		inquiry	1
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A1Q1		inquiry	0.759
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A1Q1		inquiry	0.727
A1Q1		inquiry	0.768
A1Q1		perspective:complexity	1:0.877
A1Q1		inquiry	0.81
A1Q1		inquiry	0.861
A1Q1		inquiry	0.759

A1Q1		inquiry	0.776
A1Q1		inquiry	0.744
A1Q1		inquiry	0.726
A1Q1		inquiry	0.864
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	0.685
A1Q1		inquiry	1
A1Q1		inquiry	0.714
A1Q1		inquiry	0.881
A1Q1		inquiry	0.537
A1Q1		inquiry	1
A1Q1		inquiry	0.761
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	0.765
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	0.849
A1Q2		inquiry	0.726

A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry:skepticism	1:1
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A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry:perspective	1:0.986
A1Q2		inquiry:complexity	1:1
A1Q2		inquiry	1
A1Q2		perspective	1
A1Q2		perspective	1
A1Q2		perspective	1
A1Q2		perspective	1
A1Q2		perspective:skepticism	1:0.932
A1Q2		perspective	1
A1Q2		perspective	1
A1Q2		perspective	1
A1Q2		inquiry:perspective	1:1
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A1Q2		skepticism:perspective	1:0.986
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A1Q3		perspective	1
A1Q3		inquiry	1
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A1Q3		inquiry:perspective	1:1
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry:perspective:skepticism	1:1:0.886
A1Q3		inquiry:perspective	1:1
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A1Q3		inquiry	1
A1Q3		inquiry:perspective	1:1
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A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry:perspective	1:1
A1Q3		inquiry:perspective	1:1
A1Q3		inquiry:perspective	1:1
A1Q3		inquiry:skepticism	1:0.853
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		perspective	1
A1Q3		inquiry	1
A1Q3		perspective	
A1Q3		perspective	1
A1Q3		inquiry	1
A1Q1		inquiry	0.53

A1Q1		inquiry	0.604
A1Q1		inquiry	1
A1Q1		inquiry	0.706
A1Q1		inquiry	1
A1Q1		inquiry	0.552
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	0.629
A1Q1		inquiry	1
A1Q1		inquiry	0.56
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A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q1		inquiry	1
A1Q2		inquiry	1
A1Q2		inquiry	1
A1Q2		inquiry	1
A1Q2		inquiry	1
A1Q2		inquiry:perspective	1:1
A1Q2		inquiry:skepticism	1:1
A1Q2		inquiry	1
A1Q2		inquiry	1

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A1Q2		inquiry	1
A1Q2		inquiry:skepticism	1:1
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A1Q2		inquiry	1
A1Q2		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		skepticism:inquiry:complexity	1:1:1
A1Q3		skepticism:inquiry	1:1
A1Q3		skepticism:inquiry	1:1
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry	0.953
A1Q3		perspective	1
A1Q3		perspective:skepticism	0.853:0.768
A1Q3		inquiry	1
A1Q3		inquiry	1
A1Q3		inquiry	1

A2Q1		perspective:skepticism:inquiry	1:0.428:0.712
A2Q1		perspective:skepticism:inquiry	0.843:0.66:0.567
A2Q1		perspective:skepticism	1:0.648
A2Q1		perspective:skepticism	1:0.485
A2Q1		perspective:inquiry	0.691:0.525
A2Q1		perspective:skepticism:inquiry	0.661:0.839:0.852
A2Q1		inquiry:skepticism:perspective	1:0.537:0.533
A2Q1		perspective:inquiry	0.753:0.241
A2Q1		perspective	1
A2Q1		inquiry:skepticism:perspective	0.669:0.665:0.771
A2Q1		perspective:skepticism	1:0.791
A2Q1		perspective:skepticism:inquiry	0.804:1:0.884
A2Q1		perspective:skepticism:inquiry	1:1:0.875
A2Q1		perspective:inquiry:skepticism	1:0.907:0.901
A2Q1		perspective:skepticism:inquiry	0.873:0.58:0.614
A2Q1		perspective:skepticism:complexity	1:0.571:0.914
A2Q1		perspective:skepticism	1:0.85
A2Q1		perspective:skepticism	1:1
A2Q1		perspective:skepticism	0.908:1
A2Q1		perspective:skepticism:inquiry	1:0.604:0.55
A2Q1		perspective:skepticism	1:1
A2Q1		perspective:skepticism:inquiry	0.975:1:0.702
A2Q1		perspective:skepticism:inquiry	1:0.879:1

A2Q1		skepticism:perspective:inquiry	1:0.726:0.633
A2Q1		perspective:skepticism	0.9:1
A2Q1		perspective:skepticism	1:0.241
A2Q1		perspective:skepticism	1:1
A2Q1		perspective:skepticism:inquiry	0.634:0.53:1
A2Q1		perspective:skepticism:inquiry	1:0.835:0.343
A2Q1		perspective:skepticism:inquiry	1:0.545:0.557
A2Q1		perspective:skepticism:inquiry	1:0.423:0.45
A2Q1		perspective:skepticism	1:1
A2Q1		perspective:skepticism	1:1
A2Q1		inquiry	0.838
A2Q1		perspective:skepticism	1:0.654
A2Q1		perspective	0.937
A2Q1		perspective	1
A2Q1		perspective:skepticism:inquiry	1:1:0.681
A2Q1		perspective:skepticism:complexity	1:1:0.86
A2Q1		perspective:skepticism:inquiry	1:0.734:0.572
A2Q1		perspective:complexity	1:0.56
A2Q1		perspective:complexity	1:0.835
A2Q1		perspective:skepticism	1:0.875
A2Q1		perspective:skepticism:inquiry	1:0.859:0.343
A2Q1		perspective:inquiry	1:0.356
A2Q1		skepticism:perspective:inquiry	1:1:1:0.861

A2Q1		perspective	1
A2Q1		perspective:skepticism:inquiry	1:1:0.425
A2Q1		perspective:skepticism	1:0.819
A2Q1		perspective:skepticism:inquiry	1:1:1
A2Q1		perspective	1
A2Q1		perspective:skepticism	1:0.727
A2Q1		perspective:skepticism:inquiry	1:1:0.567
A2Q1		perspective	0.665
A2Q1		perspective:skepticism:inquiry	0.908:0.712:0.901
A2Q1		perspective:skepticism	0.938:0.745
A2Q1		perspective:skepticism	1:0.648
A2Q1		perspective:skepticism:inquiry	1:1:1
A2Q1		inquiry:perspective	1:0.783
A2Q1		perspective:skepticism	0.937:0.56
A2Q1		perspective:skepticism	1:0.648
A2Q1		perspective:skepticism	1:0.819
A2Q1		perspective:inquiry:skepticism	0.9:0.863:0.694
A2Q1		perspective:skepticism	1:1
A2Q1		perspective:skepticism	1:0.839
A2Q1		perspective	0.889
A2Q1		perspective:skepticism	1:0.58
A2Q1		perspective:skepticism	1:0.845
A2Q1		perspective:skepticism	0.665:0.712

A2Q1		perspective:inquiry	0.735:0.866
A2Q1		perspective:skepticism	1:0.82
A2Q1		perspective	0.86
A2Q1		perspective:skepticism	1:0.726
A2Q1		perspective:skepticism:complexity	1:1:0.875
A2Q1		perspective	0.835
A2Q1		perspective:skepticism	1:0.83
A2Q1		perspective:inquiry:skepticism	1:0.701:0.557
A2Q1		perspective:skepticism	1:0.845
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective:skepticism	1:1:0.873
A2Q2		perspective:complexity	0.988:0.896
A2Q2		inquiry:skepticism	1:1
A2Q2		inquiry	1
A2Q2		inquiry	1
A2Q2		skepticism	0.891
A2Q2		inquiry:complexity	1:0.886
A2Q2		inquiry	1
A2Q2		inquiry	1
A2Q2		inquiry:skepticism	1:1
A2Q2		inquiry	1
A2Q2		perspective	1

A2Q2		inquiry	1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry	1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:complexity	1:1
A2Q2		inquiry:perspective	1:0.895
A2Q2		inquiry:perspective	1:1
A2Q2		perspective	0.647
A2Q2		perspective	0.624
A2Q2		perspective	0.643
A2Q2		inquiry:perspective	0.751:0.633
A2Q2		inquiry	1
A2Q2		inquiry:skepticism	1:0.882
A2Q2		inquiry	0.893
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A2Q2		perspective	1
A2Q2		perspective	0.953
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A2Q2		inquiry	1
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A2Q2		perspective	1

A2Q2		perspective	1
A2Q2		perspective	1
A2Q2		inquiry	0.967
A2Q2		perspective:skepticism	0.895:0.723
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:0.896
A2Q2		inquiry:complexity	1:0.769
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
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A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
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A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective:complexity	1:1:0.849
A2Q2		inquiry	1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry	1

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A2Q2		inquiry:perspective	1:1
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A2Q2		inquiry	1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry	1
A2Q2		perspective	0.956
A2Q2		inquiry:perspective	1:1
A2Q2		perspective	1
A2Q2		perspective:complexity	1:0.836
A2Q2		inquiry:perspective	1:1
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A2Q2		perspective	1
A2Q2		perspective	1
A2Q2		perspective	0.983
A2Q3		inquiry:complexity:perspective	1:0.964:0.795
A2Q3		inquiry:complexity:perspective	1:1:0.981
A2Q3		perspective	1
A2Q3		inquiry:perspective	1:1

A2Q3		inquiry	1
A2Q3		inquiry	1
A2Q3		inquiry	1
A2Q3		inquiry	1
A2Q3		inquiry:complexity	1:0.764
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
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A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective:skepticism	1:1:0.863
A2Q3		perspective	1
A2Q3		perspective:inquiry	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry	1
A2Q3		inquiry:perspective	1:0.877
A2Q3		inquiry	1
A2Q3		inquiry:perspective	1:1

A2Q3		inquiry	0.989
A2Q3		inquiry	1
A2Q3		inquiry	1
A2Q3		inquiry	1
A2Q3		perspective	0.792
A2Q3		perspective	1
A2Q3		inquiry	1
A2Q3		skepticism:perspective	1:0.899
A2Q3		inquiry	1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry	1
A2Q3		inquiry	0.867
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry	1
A2Q3		perspective	1
A2Q3		perspective	1
A2Q3		inquiry:perspective:complexity	1:1:0.832
A2Q3		perspective:inquiry	1:0.897
A2Q3		perspective	1
A2Q3		inquiry:perspective	1:1
A2Q3		perspective	1
A2Q3		perspective:skepticism	1:0.574

A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		perspective	0.926
A2Q3		perspective	0.678
A2Q3		perspective:complexity	1:1
A2Q3		inquiry	1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective:skepticism	1:1:0.956
A2Q3		inquiry	1
A2Q3		perspective	1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		perspective	0.885
A2Q3		perspective	1
A2Q3		perspective	1
A2Q3		inquiry	1
A2Q3		perspective	1
A2Q3		inquiry	1
A2Q3		inquiry:perspective	1:1
A2Q3		perspective	1

A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective	1:1
A2Q3		inquiry:perspective:complexity	1:1:0.832
A2Q3		perspective	1
A2Q3		inquiry:perspective	1:1
A2Q1		perspective	0.937
A2Q1		perspective:inquiry	1:1
A2Q1		perspective	0.559
A2Q1		perspective:skepticism	1:1
A2Q1		perspective	1
A2Q1		perspective	0.873
A2Q1		perspective:complexity	1:1
A2Q1		perspective:skepticism	0.843:1
A2Q1		perspective:skepticism	0.975:0.903
A2Q1		perspective:skepticism	1:0.66
A2Q1		perspective:skepticism:inquiry	1:1:1
A2Q1		perspective:skepticism	1:0.799
A2Q1		perspective:skepticism	1:0.348
A2Q1		perspective:inquiry	1:0.557
A2Q1		perspective:skepticism	1:0.85
A2Q1		perspective:skepticism	1:0.884
A2Q2		inquiry	1
A2Q2		inquiry:perspective	1:1

A2Q2		perspective	1
A2Q2		inquiry:perspective	0.912:1
A2Q2		perspective	1
A2Q2		perspective	1
A2Q2		perspective	0.884
A2Q2		perspective	0.754
A2Q2		perspective	0.766
A2Q2		perspective	0.529
A2Q2		complexity:perspective	0.895:0.758
A2Q2		inquiry:perspective	1:1
A2Q2		perspective	1
A2Q2		inquiry:perspective	1:1
A2Q2		inquiry:perspective	1:1
A2Q2		perspective	0.637
A2Q2		skepticism:inquiry	0.936:0.899
A2Q3		inquiry:skepticism	1:1
A2Q3		inquiry:perspective:complexity	1:0.955
A2Q3		perspective:skepticism	1:1
A2Q3		inquiry:complexity	1:0.987
A2Q3		perspective	0.687
A2Q3		inquiry	0.972
A2Q3		perspective	0.989
A2Q3		complexity:perspective:inquiry	1:0.932:0.875

A2Q3		inquiry	0.887
A2Q3		perspective:skepticism	1:1
A2Q3		inquiry:perspective	1:0.967
A2Q3		complexity:perspective	0.943:0.994
A2Q3		inquiry:complexity	1:0.685
A2Q3		inquiry	0.899
A2Q3		inquiry	1
A2Q3		inquiry:perspective	1:1

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