POLITICALLY RELEVANT TOPICS IN THE SCIENCE CLASSROOM: EFFECTS ON INTERESTS AND ETHICS

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Abstract. The Cary Institute's Evidence- and Reasoning-Based Critique and Inquiry Framework, is geared towards helping high school students learn to use data as evidence to make and evaluate arguments. A premise for this work is that if students can become skilled at *making* arguments then they should be better able to *critique* arguments. Few students will progress to careers that involve day-to-day data processing, but almost all will be bombarded with science-related issues in the media and in life. For this reason, evidence-based critique is crucial to being a scientifically and ecologically-literate citizen. The Data Exploration in Ecology Project (DEEP) developed lesson modules that were thought to be relevant and interesting. This study focused on two of the DEEP modules: 1) salt pollution and 2) hydrofracking. We aimed to discover whether there was a difference in interest and learning between the road salt pollution module and the hydrofracking module. Students found hydrofracking more interesting as well as more relevant. Likewise, students constructed more sophisticated arguments in relation to the hydrofracking module. However, limitations in the experimental design indicate that their increased sophistication could be a result of many different variables outside of their perceived relevance. Students' opinions in relation to the modules were more objective when studying road salt and more polarized when studying hydrofracking. Students were less aware that they were constructing value-based arguments in the hydrofracking module, which leads to new questions regarding the role of values when engaging students with highly motivated issues in the science classroom.

INTRODUCTION

Not every high school student will enter the field of scientific research. All students will however become citizens responsible for voting on issues which affect their individual selves, communities, and the environment. One crucial aspect of environmental citizenship is the ability to apply ecological thinking. With polarized issues in the media, such as climate change, mountain top removal, and renewable energy, citizens will have to evaluate claims in order to form an opinion. Scientific thinking is one specific subcategory under ecological thinking which involves using evidence to answer ecological questions, thoroughly evaluating evidence and arguments presented and applying this thinking to their daily lives (Berkowitz et al, 2005). The Evidence- and Reasoning-Based Critique and Inquiry Framework, which is the focus of this study, is concerned with helping students learn to use data as evidence to make arguments. A premise for this work holds that if students can become skilled at *making* arguments then they should also be able to *critique* arguments as well. For this reason, evidence based critique is crucial to being a scientifically and ecologically literate citizen. The Data Exploration in Ecology Project (DEEP) uses the Critique and Inquiry approach to create lessons that are relevant to the student. This research focuses on students' perceptions of the relevance of two units and whether this perceived relevance affects their ability to create and critique arguments using scientific evidence and principles.

Science as a topic is not necessarily viewed as "dull" by students; however many students report that science classes are either difficult or irrelevant to them (Lyons 2006, Osborne et al 2003 and Ottander 2012). Motivating students is critical to a transformative experience in science education (Pugh

et al., 2010). In order to motivate students to participate and engage in science lessons, the lessons must prove "interesting" to the student learners. A study by Ottander found that students reported learning more when they found the lessons more interesting (Ottander, 2011). Other studies have shown that the way to create interesting lessons is to relate the lessons back to the students and create a sense of urgency for obtaining certain knowledge and skills since learners engage or do not engage depending on how they see relevance (Postman and Weingarter, 2009 and Lundholm et al, 2013). Increasing the relevance of the topic by relating it to something the students are familiar with culturally, or that affects their community, would bolster interest.

There are potential implications to using relevant topics when trying to engage children in science. For instance, if a topic is value-laden or threatens a student's worldview, can they engage in the material objectively? Social intuition theory (Haidt 2001, see Figure 1) suggests that judgments occur automatically following the spontaneous intuitive reaction to an event. It isn't until after the judgment has been passed that individuals engage in reasoning when prompted to defend their stance.

If the decision or judgment was spontaneous and based on intuition, then it's possible the reasoning could be questionable. The trait of automatic decisions is a feature of Kahnemans' theory of two system thinking (Kahneman 2011), in which system two is "fast thinking". In fast thinking, the individual reaches conclusions and bases their arguments on stories instead of statistics, and is vulnerable to confirmation bias, source amnesia and relying on first-hand accounts (Kahneman 2011). If a student held an opinion on the topic prior to the lesson, they may be more likely to experience confirmation bias, or only utilize sources that support their claim. This has been illustrated in Taber's experiment where participants who were given a selection of readings regarding a topic, only selected sources that reinforced their view point (Taber and Lodge, 2006). System-two thinking has been labeled "naïve inquiry" by Dauer et al (2013). Evidence in naïve inquiry explanations are derived from personal experience and patterns in claims of authoritative persons, as opposed to evidence rooted in examination of data (Dauer et al., 2013).

This study aimed to investigate the effect of introducing politically charged topics in the science classroom by examining two DEEP modules implemented in classrooms. The modules included one on the effects of road salt and one on the politically relevant practice of hydrofracking. The first hypothesis was that student interest, as evaluated by the post-module questionnaire, would vary between the modules. The second hypothesis was that there will be a difference in the factors that determine interest with the prediction that relevance will impact interest more than pedagogy and data.

The second set of questions focused on whether or not student interest in the topic increased their "system 2 thinking" and affected their ability to construct logical and data-based arguments. Student papers were coded for use of reasoning and then compared with their responses to questionnaires and it was hypothesized that there would be a relationship between use of reasoning and perceived relevance or interest. A positive relationship, in which use of reasoning increases with perceived relevance or interest, might indicate that politically topics which students are interested in increases their ability to construct arguments in the science classroom. A negative relationship, in which use of reasoning decreases with perceived relevance or interest, might indicate that students who are already interested in the topic could fall victim to "fast thinking". Due to the politicized nature of the hydrofracking module, it was predicted that in this module students would engage in fast thinking in relation writing about their value statements.

METHODS

Study Site and Participants

This study focused on classes which incorporated the DEEP modules for Salt and Hydrofracking into their lesson plans. Nine teachers participated in these units (Table 1). The classrooms studied ranged from 9^{th}-12^{th} grade and were primarily biology and environmental science classes with the addition of one chemistry class. Eight classrooms were located in New York and one classroom was located in Connecticut. Of these nine teachers, four participated in the hydrofracking module and four participated in the salt module, with one teacher participating in both modules. 114 students completed the questionnaire regarding their interest in the hydrofracking module and 192 students completed the questionnaire for the salt module. 54 students participated in a final paper regarding the hydrofracking module and 85 students completed the paper for the salt module.

DEEP Units Utilized

In order to examine the patterns and possible causes of variation in perceived interest among students, the two module selected for were the hydrofracking and salt module. Both modules could be considered relevant to a student's life, but the hydrofracking module had political associations. Since the classrooms were situated in the Northeast, all students rely on road salt to ensure safe transportation to school during the winter months. The hydrofracking unit is relevant because at the time hydrofracking was an issue being debated by New York legislation (Nolan 2012). Four of the five classrooms which incorporated the hydrofracking unit are located in counties or next to counties which lie on top of the contested Marcellus shale region, as mapped by the New York Department of Environmental Conservation.

The first test conducted was for *perception of interest* to determine if there a difference in the way students relate to the modules. Testing consisted of using the Likert scale post-module questionnaire developed by education researchers from the Cary Institute. Students were scored on Part III of the questionnaire (Table 2 and Appendix A). Responses were broken down into three factors that affect their attitudes and interest; interest in data, relevance of the topic and enjoyment of pedagogies. Answers to all questions on the questionnaire were compiled to determine students' overall interest. Scores for the questions on relevance were compared to overall scores to determine if relevance impacted a student's interest in the topic. Final scores were also used to compare the hydrofracking module to the salt module.

To see if there was a relationship between student's overall interest in the module and their use of principle and evidence-based reasoning, the students' final papers were evaluated. At the end of each module students were required to critique a claim that was featured in an article from the popular press. Student work was evaluated with a coding scheme (Appendix B) that was created a priori to evaluate the types of reasoning students used in their arguments and to rank the sophistication of their reasoning. Upon reading examples of student work it was discovered that students drew from personal values to aid their arguments. Emergent coding was then used to quantitatively examine which values students used in their arguments and evaluate the sophistication of their use of value based argumentation. It was originally assumed that students would take neutral positions on topics and critique the argument of their article, not the practice itself, but this was not the case. As such a fifth coding scheme was developed to track student position in relation to the topic.

Statistical Tests

Anovas were used to analyze data between all the class groups and a two tailed t-test was used to determine if potential difference in interest between the salt module versus the hydrofracking module was due to chance. After coding the papers, the means of the scores from both groups of papers was found and a two tailed t-test was utilized to see if this difference was due to chance. A bivariate analysis was conducted to test whether interest in the topic was a leading factor in sophistication of final papers.

RESULTS

Student responses to the questionnaires showed that the students who participated in the hydrofracking module found the topic to be more relevant, enjoyed the pedagogies of the lessons more and had an overall higher interest (Figure 2). When comparing the mean scores with a two tailed t-test, it was discovered that these differences are significant. Students who participated in the hydrofracking module also had a higher mean score in response to questions regarding their interest in working with data, however the T-test revealed that the difference was not significant. The students all resided in, or bordering, New York State, a region in which hydrofracking is hotly contested. When comparing students' overall level of interest with their geographic location, no relationship was established. Students who live within the boundaries of the shale region do not show higher levels of interest than students who live further (Figure 3). Total interest differed by teacher (Figure 4,5 and Table 3,4). Variation also existed among school grade categories (Figure 6), with a significant difference between 9^{th} grade and 11^{th} grade, and 9^{th} grade with 10^{th} and 12^{th} grade but no significant difference between 11^{th} grade and $10^{th}/12^{th}$ grade.

After coding student papers for sophisticated argumentation, on a scale from 0-3, the mean sophistication score was compared between the hydrofracking module and the salt module. The mean score for sophistication was higher for students in the hydrofracking module than the salt module (Figure 7) and this difference was significant. To see if a higher interest in the hydrofracking module prompted a more sophisticated argumentation, a bivariate analysis was conducted with student interest on the X axis and sophistication of argument on the Y axis. This yielded no significant result (Figure 8). A case study shows that when one teacher taught both modules to the same students there was not a significant difference in interest between module (Figure 9). The T-test results (T value of -1.51) showed that there was not a significant difference between modules in the sophistication of arguments. A bivariate analysis of the case study class yielded similar results to that of the study group as a whole (Figure 10).

When coding for positionality an almost equivalent percentage of students constructed an argument opposed to the topic, 42% against hydrofracking and 43% against using road salt. A higher percentage of students in the salt module, 44%, expressed a position that was neutral or examined both sides of the argument as opposed to 34% of students in the hydrofracking module. Students in the hydrofracking module had a higher percentage (64%) of papers which took a stance for or against the issue compared to papers written for the salt module (Figure 11).

Students were found to use value based statements in 93% of the papers for the salt module and 89% of the papers for the hydrofracking module. Values that students used as part of their reasoning included economy, human life, procedural ethics (such as fairness or honesty), deontological ethics and utilitarian ethics (Figure 12). Only the hydrofracking papers mentioned procedural ethics. When the values were sorted into categories of strictly human related, strictly abstract, both and general or no value it was found that the majority of the papers mentioned values which strictly benefited humans and abstract values were featured least in students papers (Figure 13). In order to test to see if the students were aware that they were using values to supplement their arguments the arguments with values were coded on a scale of 1 to 3. The mean scores in this coding scheme indicated that students were more aware of their use of value based statements in the salt module (Figure 14) and the t-test showed this difference to be significant.

DISCUSSION

It was hypothesized that there would be differing levels of interest among students. There was a distinguishable difference among interest based on topic, in which the hydrofracking module was seen as overall more interesting than the salt unit, viewed as more relevant, and the students found more enjoyment in the pedagogies. It was also predicted that the difference in overall interest could be traced

to a difference in the three variables which made up the questionnaire; relevance, interest in data, enjoyment of pedagogies. In both the hydrofracking module and the road salt module, relevance had a greater impact than the other variables. Because the political module had a higher relevance rating, and a higher overall interest rating, incorporating current events in the science classroom may increase interest in topics. The only variable where the difference was not statistically significant was the category of "interest in data". This suggests that while the students in the more politically charged hydrofracking module found their module more relevant than those in the road salt module, it did not statistically increase their interest in working with data.

It was hypothesized that if there was a difference in student interest in the two modules then there would be a difference in the sophistication of their arguments. The students in the hydrofracking module gave their topic higher ratings in interest and relevance and produced papers with a higher mean score of sophistication. That being said, a bivariate analysis showed that there was no relationship between interest and sophistication of reasoning. Many students who showed little interest in the topic still managed to write acceptable and/or exceptional papers and some students who showed high interest in the topic wrote poorly structured papers.

The mean score for the final papers written by students in the hydrofracking unit could be a result of many different variables. This data was analyzed post-module since the school year had ended at the time of analysis. Because of this, this research was not able to structure a study group where the variables were controlled. The first variable could be the teacher. All of the teachers participating in the DEEP study were able to select which modules to teach. Only one teacher taught both hydrofracking and salt. Different classes had different teachers. Certain teachers may have emphasized different aspects of the module over other aspects. Student interest in the topic could also have been related to the style of teaching they were subjected to as illustrated by variation in interest among teacher. Another variable could be grade and academic ability. The only classes which completed and returned the final assignment for the hydrofracking module were 11^{th} and 12^{th} grade classes while papers from the salt module were written by students in 9^{th}-12^{th} grade.

Regardless of these variables, all the students' papers followed a trend in that values strictly related to human, such as valuing human life or what resources can be utilized by humans, were referenced more frequently than abstract values such as virtues (honesty or fairness) or deontological[1] values. Alexandria Poole claims that ethics education is inhibited, in part, by privileging economics over ethics and translating "social values into economic values in terms of the willingness to pay and sell" (Poole et al, 2013), which could account for a higher frequency of utilitarian values in student writing. Abstract thinking in regards to ethics was not frequently featured in student's papers. A higher percentage of the papers on road salt referenced deontological values while a higher percentage of hydrofracking papers referenced procedural ethics. The different values mentioned in the two sets of papers, as well as their frequency, could be attributed to the articles the students were assigned. The articles on road salt focused on the impact of the environment, specifically how it harms plants. Students drawing strictly from the articles would reference these types of facts. The hydrofracking papers occasionally emphasized procedural ethics. For example, one student wrote, "It is inhuman for big shot companies to treat those innocent people with no respect". The articles assigned for the hydrofracking module did not express values such as these and it is possible that the students who used procedural ethics in their final papers either came to these ethical conclusions themselves or, what may be more likely, is that they are drawing from sentiments they have heard from their guardians and other media sources.

[1] Adhering to the ethical code that living things deserve to exist merely because they living things and not because of what they can provide for humans.

One side effect of ignoring the topic of ethics in the classroom is students' inability to articulate their values as more than mere feelings (Poole et al, 2013). Students in a typical science classroom lack the vocabulary of "value-language" and are less able to express an ethical stance. While the arguments in the hydrofracking module papers were evaluated as, on average, more sophisticated than the arguments in the salt module papers, the students in the hydrofracking module were less aware that they were using personal values in their papers. Student papers were assigned a 1, 2, or 3 depending if they wrote about values implicitly, explicitly or explicitly and acknowledged differing opinions. A large frequency of papers fell into the category of "explicit", meaning that the students were aware that they were using value statements. More students wrote implicit value statements in the hydrofracking module than in the salt module and less students in the hydrofracking module considered multiple points of view. A larger percentage of students in the hydrofracking module had arguments which aligned with a stance for or against hydrofracking while students in the salt module had a larger percentage of papers which viewed the issue objectively.

This research illustrates that students do find topics of a political nature to be relevant and they express interest in studying these issues in the science classroom. There are many contemporary concerns, such as, Climate change, evolution, sea level rise, nuclear power, mountain top removal, hydro-power and damming , genetically modified organisms, hydro fracking and stem cells, of which students will overtly or covertly receive information. All of these issues, which are often written about in a polarized fashion, can be examined and explained through science. Studying issues like these provide practice for students in examining claims and discerning science from bogus assertions. While students may respond as being more interested in politically charged science topics, an implication of studying these topics is that students may approach the issue with an already defined opinion. Students in the hydrofracking module wrote about their issue less objectively than students in the salt module. Students in the hydrofracking module were also less aware that they were supplementing their argument with value based claims. One way to alleviate this issue would be to increase ethics education in the classroom, specifically in the realm of science, so as to enable students to critique claims and articulate both scientific and ethical arguments.

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APPENDIX

TABLE 1. Study subjects and location. More teachers incorporated the salt module into their lessons and as such, more papers and questionnaires relating to the salt module were returned to Cary researchers.

Teacher Code	**Location**	**Class**	**Module**	**Questionnaires**	**Final Projects**	
				Total	Total	Matched
Monarch Butterfly	Downstate NY	AP ENV	Fracking	**35**	36	35
Giant Water Bug	Downstate NY	Living Env	Fracking	**16**		
Mayfly	Downstate NY	Living Env.	Fracking	**19**		
Stinkbug	Downstate NY	Marine Bio	Fracking	**26**		
Mosquito	Downstate NY	Env. Science	Fracking	**18**	18	**18**
Mosquito	Downstate NY	Env Science	Salt	**19**	19	**17**
Ambush Beetle	Downstate NY	Living Env	Salt	**58**	29	**25**
Cicada	Western NY	Living Env	Salt	**44**	37	**37**
Grasshopper	Downstate NY	Living Env.	Salt	**36**		
Water Boatman	Connecticut	Chemistry	Salt	**35**		

TABLE 2. Progress Variables.

Progress Variable	Source	Comments
Perceived Interest		
1. Perceived relevance	Post-Module Questionnaire 3 items from question in Part III	Scale calculated as mean of three scores
2. Data Interest	Post-Module Questionnaire 3 items from question in Part III	Scale calculated as mean of three scores
3. Enjoy pedagogies	Post-Module Questionnaire 3 items from question in Part III	Scale calculated as mean of three scores

(Table 2, cont'd)

4. Overall Interest Scale		Scale calculated as mean of all 9 scores
Ability to use evidence-based argumentation		
5. Position	Final Assignment post module	coding
6. Reasoning	Final Assignment post module	coding
7. Sophistication	Final Assignment post module	coding
8. Use of Values	Final Assignment post module	coding
9. Awareness of Values	Final Assignment post module	coding

TABLE 3. Analysis of variance for total interest by teacher in the hydrofracking module.

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
teacher	4	22.44489	5.61122	11.8432	<.0001
Error	106	50.22186	0.47379		
C. Total	110	72.66675			

TABLE 4. Analysis of variance for total interest by teacher in the salt module.

Analysis of Variance					
Source	**DF**	**Sum of Sqrs.**	**Mean Sqr**	**F Ration**	**Prob>F**
Teacher Code	5	23.06693	4.61339	8.4984	<.0001
Error	193	104.77057	0.54285		
C. Total	198	127.8375			

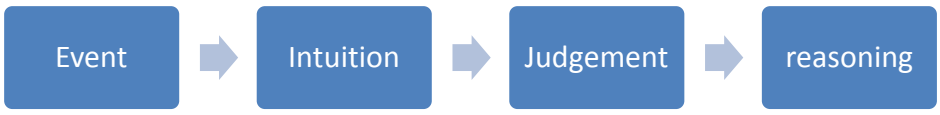

FIGURE 1. Social Intuition Theory (based on Haidt 2001). Social intuition theory where reasoning comes into play after judgment has already been made.

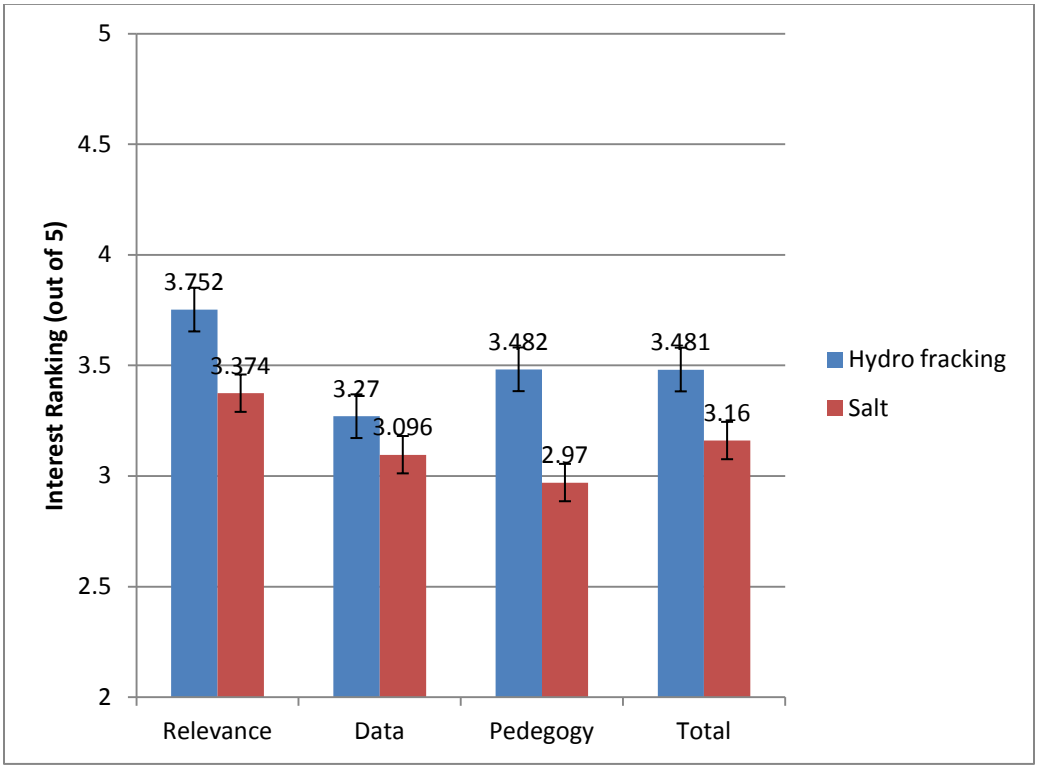

FIGURE 2. Interest in module and variables of interest within the post-module questionnaire. Difference is significant for the categories of relevance, Pedagogies and overall total interest.

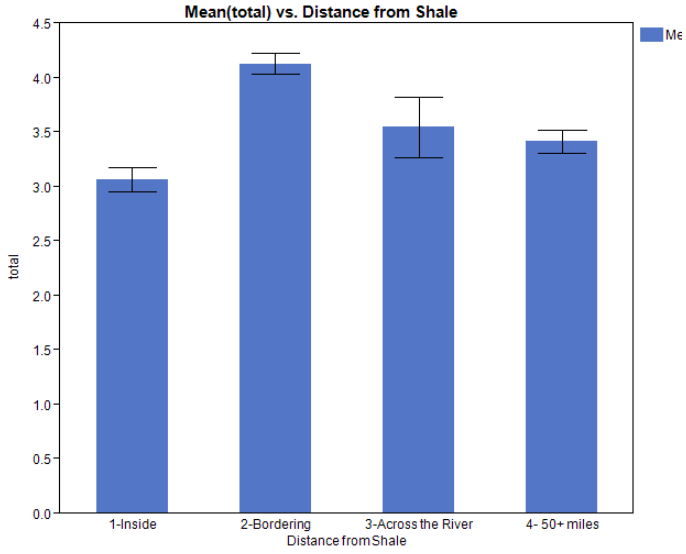

FIGURE 3. Student Interest according to geographic location. Students who live closer the Marcellus shale do not report higher levels of interest.

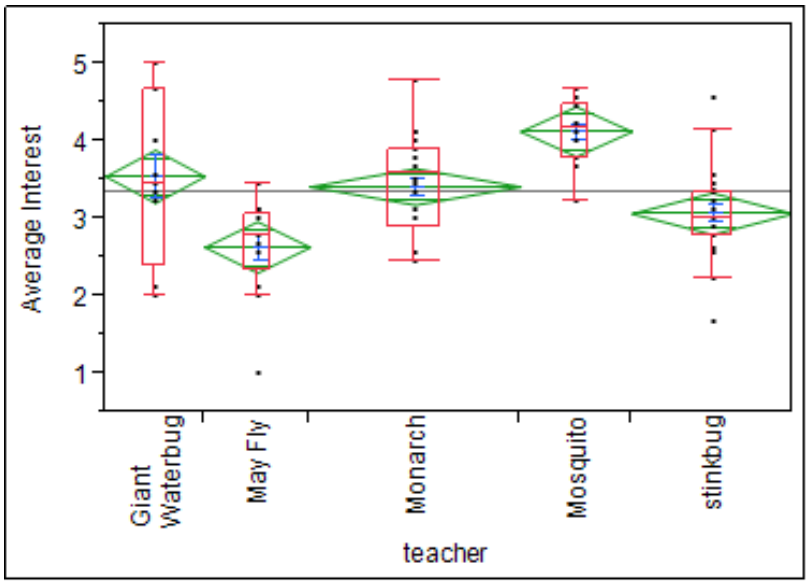

FIGURE 4. Different levels of interests by teacher for the hydrofracking module.

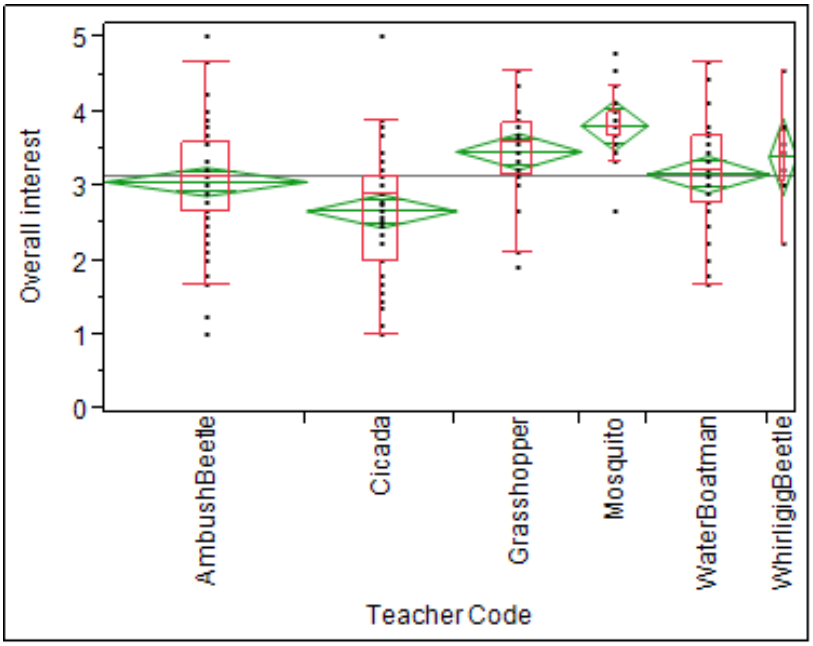

FIGURE 5. Different levels of interests by teacher for the salt module.

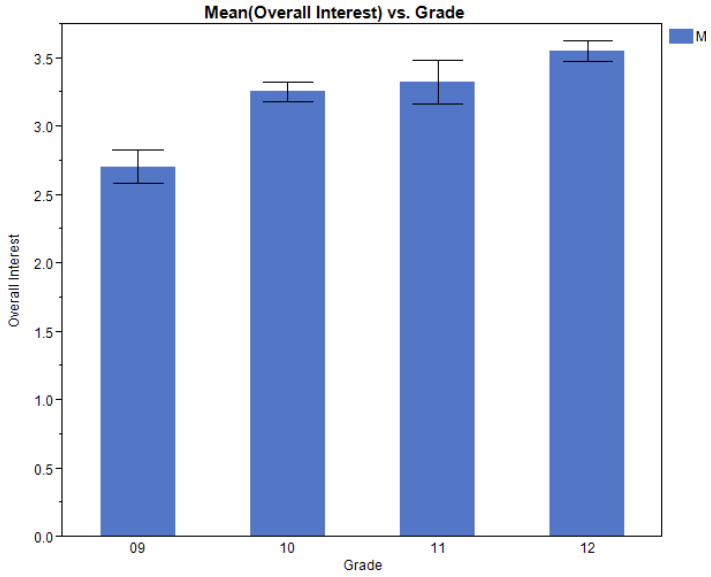

FIGURE 6. Overall interest in module by grade.

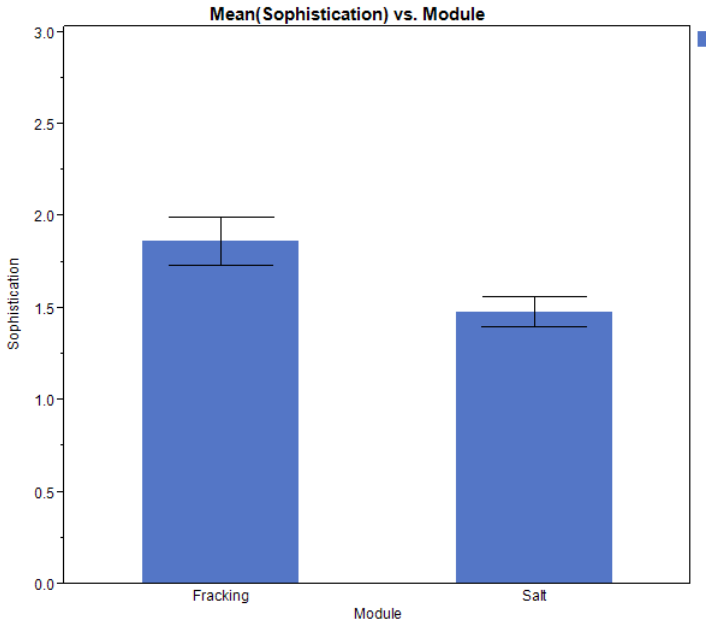

FIGURE 7. Sophistication of arguments in final paper. It was determined that the students in the hydrofracking module wrote more sophisticated arguments on average. This difference was significant.

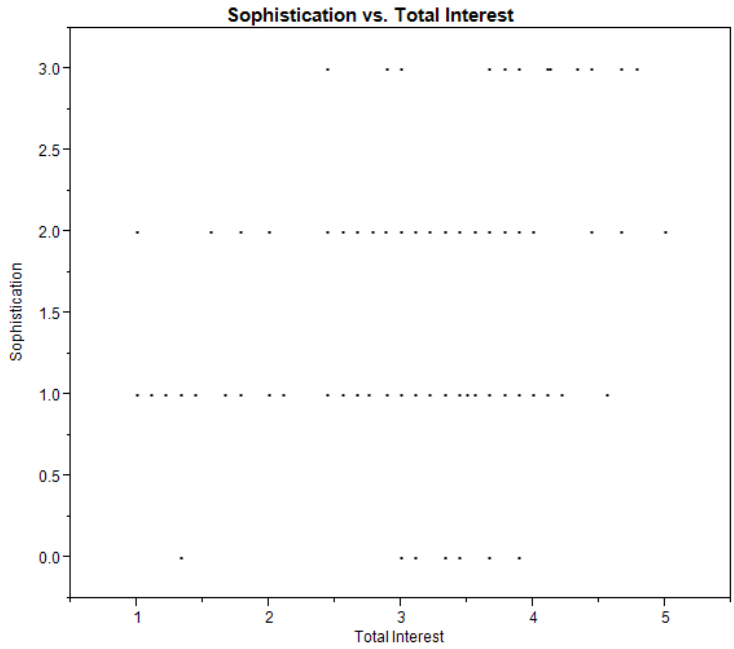

FIGURE 8. Sophistication of argument in relation to interest. There was no visible relationship between how interesting a student found the module and how sophisticated their arguments were.

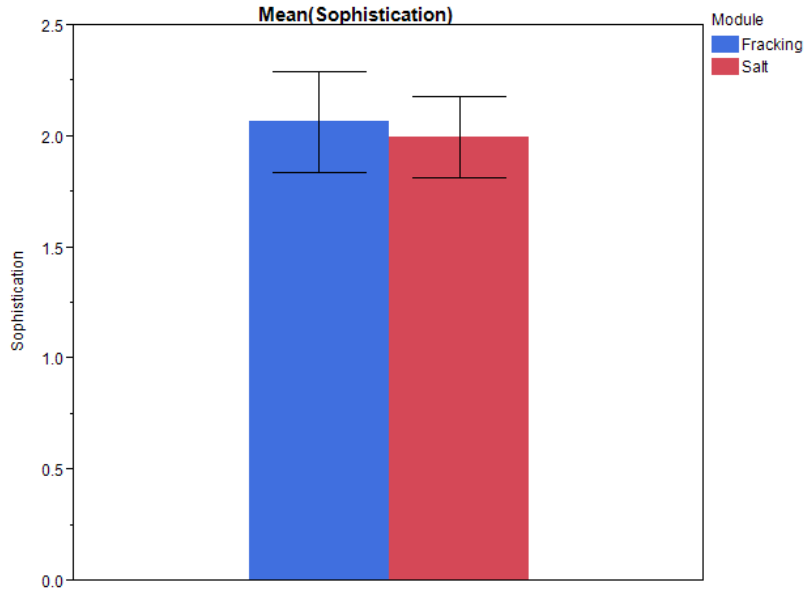

FIGURE 9. A comparison of means for the variable of 'sophistication in the case study of the "Mosquito" class. There is no significant difference between argument sophistication in hydrofracking and salt papers when the papers are written by the same students in the "Mosquito class". The difference was not significant as the T Value was -1.51 and the P value was 0.1437

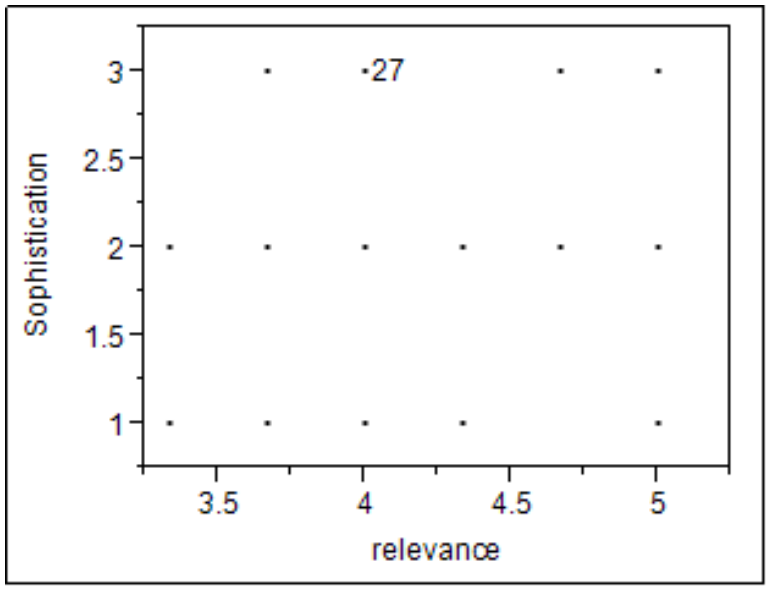

FIGURE 10. A bivariate analysis of the case study group "Mosquito". Analysis yielded similar results to the study group as a whole showing that higher interest in the topic does not necessarily result in more sophisticated papers.

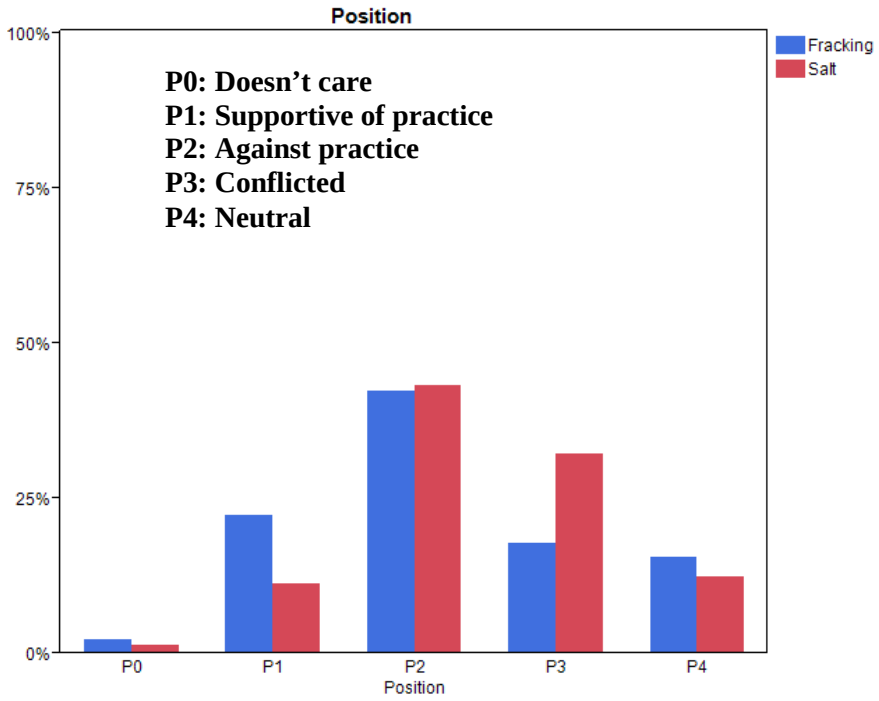

FIGURE 11. Positionality of student arguments. The percentage of student papers which aligned with one of the following positions. A higher percentage of papers in the hydrofracking module were aligned with polarized viewpoints (P1 and P2), while the salt module consisted of a higher percentage of papers which were unbiased or considered more than one viewpoint.

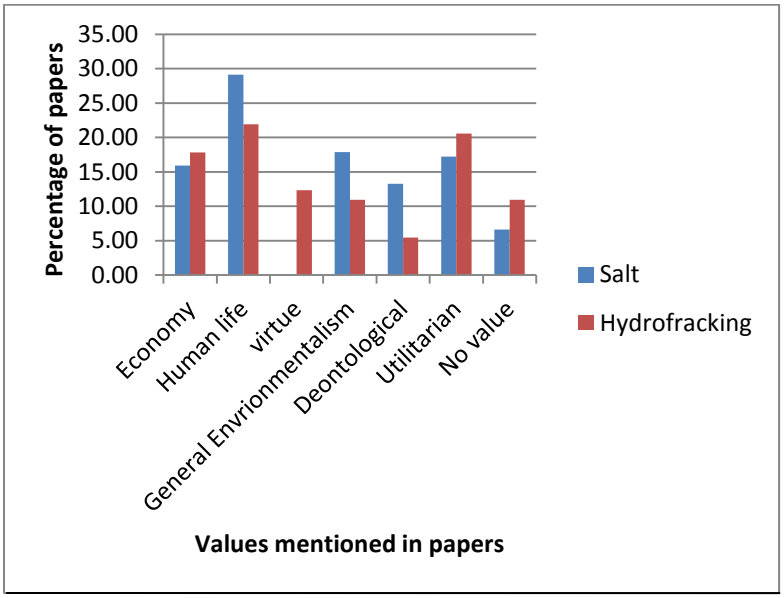

FIGURE 12. Percentage of papers which mentions coded values.

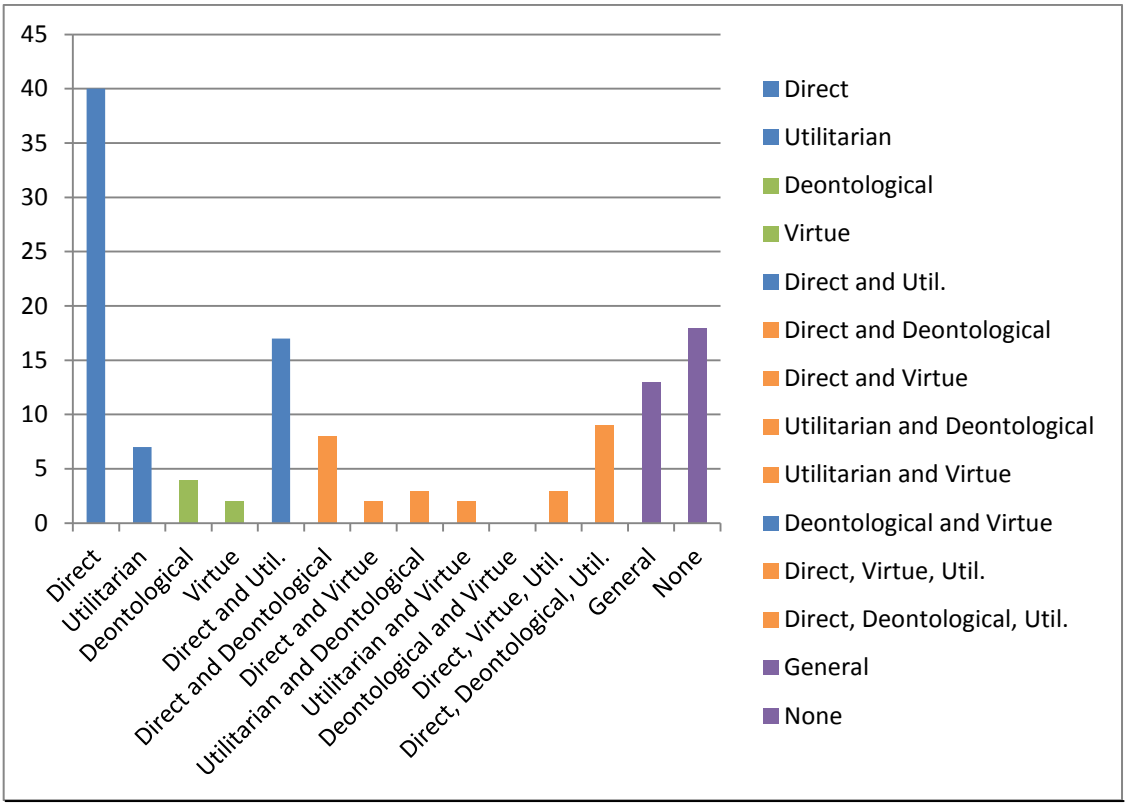

FIGURE 13. The frequency of values mentioned final papers. Blue: Strictly Human related, Green: Strictly Abstract, Orange: Mixed, Purple: General Environmentalism or No value.

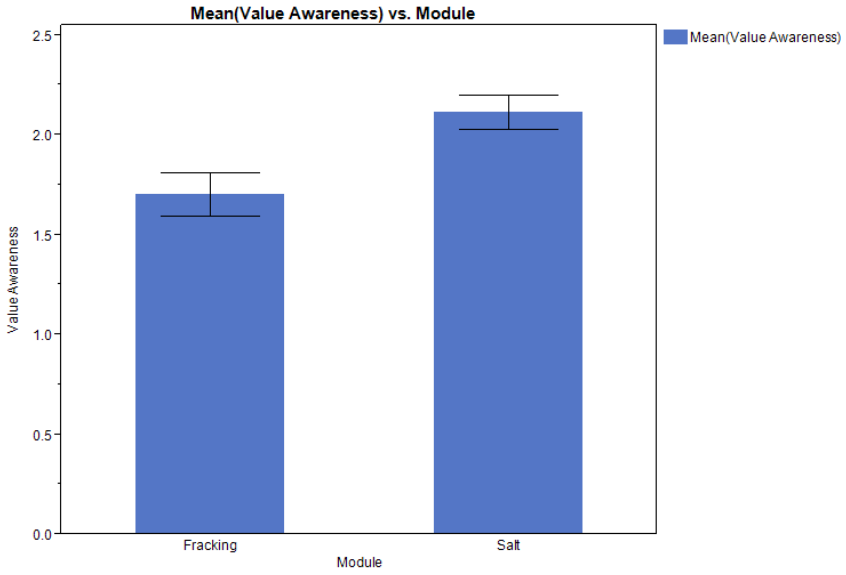

FIGURE 14. Mean score for students' awareness of their use of values in each module.

SUPPLEMENTARY INFORMATION

Sample of post-module questionnaire for the salt module.

III. ATTITUDES AND MOTIVATION: Please check (✓) the response that best indicates how much you agree or disagree with each statement, thinking about the lessons you did **during the salt module**.

	1=Strongly Disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly Agree
1. Learning about chloride (salt) levels in our water sources is relevant to my life.					
2. I enjoyed the salt lessons because we learned in several different ways (e.g., went outside, collected our own data, looked at other people's data, read articles, did some calculations).					
3. The salt lessons made me think about the importance of understanding causes and effects of pollution.					
4. I enjoyed the salt lessons because we were involved in discussions.					
5. Learning about chloride (salt) levels in our water sources has practical value for me.					
6. The salt lessons made me think about the importance of collecting my own data.					
7. I enjoyed the salt lessons because the activities were challenging.					
8. The salt lessons made me think about the importance of participating in experiments or investigations in science.					
9. The salt lessons made me think about the value of learning from other people's data.					

Summary of Progress Variables

1. Position
2. Reasoning
3. Sophistication of reasoning
4. Values
5. Awareness of Values

Progress Variable 1: Position

Source: Final assignment. The entire assignment should be read to identify the student's position towards hydrofracking/salt.

Explanation: The purpose of this variable is to see on a basic level how students view the topic. It is possible that the way the view the topic could influence their ability to use data or evidence-based inquiry and argumentation. Questions that this code might help answer are: Does the module that is deemed more politically charged lead to more decisive positions? Does lack of interest lead to more ambivalence? Is one topic deemed more conflicting than the other?

Code	Name of Code	Description of Code	Exemplar 1	Exemplar 2
P0	Doesn't care/Not important	Student shows no interest in the topic or forms a negative opinion aside from "supports or against"	"I think this research is pointless it's costing us money we can be using on things that will help us"	"It is said that chloride levels go up but that's nothing its only from scientist that have nothing better to do than come up with things that are so small and uncared about"
P1	Supportive	Student is assigned this code when they can clearly express support for either hydro fracking/salt usage despite the risks	"Yes there are some negative factors in hydraulic fracturing but whenever change occurs risks must be made"	"I believe that the proper amount of salt should be applied to the roads to keep them safe"
P2	Against	Student is not in favor of salt or hydro fracking and feels that the negative factors outweigh the positive factors	"The article to me proves that hydro fracking is bad"	"I agree that salt is bad for the environment and we should not be using it"
P3	Conflicted	Student recognizes the benefits of salt or hydro fracking but also feels that it is not done correctly in the current situation[2]	"It's hard to determine what is more important though - human lives or the environment. I think both are equally important and that's what makes this such a hard decision" [salt module]	"I believe hydro fracking could be a successful source of cleaner energy but there needs to be a better way to deal with the produced water"
P4	Neutral	Student takes an objective stance on the issue and it cannot be determined for sure what their opinion is		

[2] This is distinguishable from against because if a student is "against" they are coming up with alternatives that do not involve road salt or hydro fracking or they are designing tests to prove it is bad

Progress Variable 2: Reasoning

Source: Final assignment. The entire assignment should be read and it should be noted when a student uses different tactics of reasoning. *Note: only the critique section should be analyzed in the student assignment.*

Explanation: The purpose of this variable is to see how often students use principle-based arguments and compare it to their use of evidence-based arguments

Code	Name of Code	Description of code	Exemplar 1	Exemplar 2
R0	Claim without evidence	Students make a claim without any type of reasoning and/or referencing article or sources and/or they summarize their article without critiquing it, making claims, or offering suggestions for an improved study - Basically an "incomplete paper"	This paper is typically less than a paragraph and obvious that the student did not use reasoning	
RY	Summary	Student summarizes article(s) then makes claim, but does not provide a path of reasoning for reaching those claims		
RP	Principle-based reasoning	Principle-based reasoning is when students use logic and/or scientific concepts to support their arguments but do not reference any type of evidence in the article or data.	"Hydrofracking is safe to the drinking supply because they use a steel pipe which is strong so it doesn't crack"	"Through osmosis salt pulls the water out of plant cells causing them to shrivel up and the plant dies due to lack of water"
RM	Methods	Student critiques the methods used to come to the conclusion in the article they read and either supports the methods or explains how they are inadequate	"studies must be reproduced by more than one scientist and this was only done by the EPA"	
RS	Reliability of source	Questions reliability of source or defends the reliability of source	"The author works for the petroleum industry so he may be biased"	"David Worthingham does not seem biased because he expresses raw data"

RL	Critiquing logic or interpretation of results	Student notes when a claim is not fully supported in the article or they explain how the claim is correctly supported. If student *only* shows how information is missing in their critique than the code is RQ, if they show that information is missing and explain *why* it's a problem then RL	"The article mentioned nothing about any previous substances being found or not found in the well water **so it is difficult to prove that these substances came from hydrofracking"**	"Correlation doesn't necessitate causation but the alternative explanations are weak in comparison. Worthington could have strengthened his argument by explaining how the hydrofracking affects the ground water contamination"
RR	Relevance	Student notes that the study does not impact everyone or that the research is not universal/applicable everywhere	"the study was conducted in Wyoming, so it doesn't mean that all fracking sites pollute"	"The study was looking at ice in Seattle. Other places where it is colder or there is more snow, there may be more need for salt"
RA	Authority as evidence	Student mentions results from other scientists' tests and uses this as evidence to support their claim/critique	"When the EPA tested the water they found the following list of chemicals…."	"Recent studies conclude that we have enough gas to last us for….."
RQ	Quality of representations or information	Student acknowledges that information is missing from the article (in the critique, *not* in suggestions for further research[3])	"The article doesn't tell us what the chemicals 'similar to household products' are. Just because they are similar, doesn't mean they aren't dangerous"	"With addition of new research and information this article could become significantly more convincing. Knowing the normal ranges in parts per billion, for substances like thermogenic methane and diesel and gasoline range organics would provide the standard of comparison in determining the danger to human health of the substances found by the EPA in the drinking water"
RO	Personal experience, observation	Student comes to conclusions based on visual evidence or first-hand experience	"Last winter my family's car got stuck on the ice and the tires caught on fire because of friction"	"Sidewalk salt kills plants and grass or anything growing on the ground by the edge of the road, you can see that they're dead by the end of winter"

[3] Typically the students will write their suggestions in the very last paragraph, or begin their suggestions with a phrase such as, "for further research I would suggest"

Progress Variable 3: Sophistication of Reasoning

Source: Final assignment. The entire assignment should be read and it should be noted when a student uses different tactics of reasoning (Progress Variable 2). A student will qualify for the highest sophistication of reasoning code for which they have a section of their assignment that is eligible.

Explanation: The purpose of this variable is to compare interest in subject (information gathered from the quantitative analysis of student questionnaires) with evidence-based reasoning ability.

Code	Name of Code	Description of code	Exemplar 1	Exemplar 2
S0	None	Student was coded with claim without evidence		
S1	Low	Student used only **Values** or **principle based reasoning** or **personal experience or observation** as evidence or critiqued the **quality of the communication** instead of the article	"This article was confusing to me. I was unsure as to where the author stands on the issue. It made me think that fracking was the cause for some of the pollutants… the article as made me confused if it was the fracking. I would improve it by making the article more clear.	"Hydrofracking is dangerous to the people who live nearby because the water can get contaminated when the fluids leak. Therefore hydrofracking is not right and a terrible way to get energy" -value reasoning -Principle reasoning
S2	Medium	Students mentioned the **methods** of the study, **authority of source**, or the **reliability of the source** or **relevance AND** the student does so in a way that is accurate	"Hydrofracking is safe to the drinking supply because they use a steel pipe which is strong so it doesn't crack. Since risks can be managed it should be good for the economy to pursue fracking"	"The EPA's study shows that the chemicals may have come from fracking. The residents of Pavillion can't be sure that they came from fracking, but it is a good indication. The residents should take care to not drink the water and further studies should be conducted"
S3	High		*see above plus "evaluate logic" variable	

Progress Variable 4: Values

Source: Final assignment. The entire assignment should be read to identify the student's values towards hydrofracking/salt.

Explanation: Record if student mentions one or more of these values. The purpose of this variable is to see how often certain values appear in students' work compared to other values. For example, when comparing students who completed both modules, it will be possible to see if a tangible concept such as "Direct benefits to humans" occurs more often in papers than something more abstract like "rights-based ethics."

Concept	Code	Name of Code	Description of code	Exemplar 1	Exemplar 2
	V0	NO Values	Student just sticks to the evidence without using values to support an argument		
Direct Human Benefits	VE	Economy/Society	Student discusses the importance of economic implications	"hydro fracking will greatly benefit the community and the country because it creates more jobs"	"If roads are icy then goods can't be moved to places and people can't go places"
	VH	Human Life	Student mentions the immediate implication to human mortality[4]	"The chemicals in the fracking water are toxic to human health"	"fatal crashes are reduced by 88% and it's important to save human lives"
Ethics	VP	Procedural ethics	Student mentions ethical notions such as honesty, fairness, justice etc.	"The samples proved that the company wasn't truthful or open"	"It is inhuman for big shot companies to treat those innocent people with no respect"
	VD	Deontological[5], rights-based ethics	Student mentions the threat to the environment without using human need to justify saving the environment	"The salt erodes the soil which is bad for the trees"	"It will ruin the habitats of animals that depend on fresh water"
	VU	Environmental utilitarian ethics	Student mentions how environmental degradation will adversely affect humans	"contaminates the water which is bad because citizens need to drink that water"	"We depend on the environment for our survival. If we suspect something might be harming the environment we should stop it"

[4] This differs from "environment for human purpose" because human purpose is more of a long term value
[5] Adhering to the ethical code that living things deserve to exist merely because they are living things, and for no other logic or purpose

Progress Variable 5: Awareness of Values

Source: Final assignment. The entire assignment should be read to identify the student's values (Progress Variable 4) and it should be noted how students approach the values they express. Students will receive code based on the one highest level of sophistication they use

Explanation: Here we're trying to see if students are aware of their use of value judgments and how that might affect their reasoning.

Code	Name of Code	Description of code	Exemplar 1	Exemplar 2
A1	Implicit	Student makes a claim that can be based in value, but does not specify what that value is	"Hydrofracking is scary and can be dangerous"	"We will lose natural resources forever" *-Doesn't say why this is a problem or whether this is bad or good*
A2	Explicit, Self-aware	Student makes a specific value statement but does not address conflicting values	"Human lives are more important than the environments"	"In this time and age we need to be concerned about the economy"
A3	Explicit and acknowledging diversity	Student considers/acknowledges multiple view points before asserting that their view is accurate	"While it is important to save human lives by using road salt, it is more important to save the environment because we depend on the environment for survival"	"There are many negative sides to fracking, like contamination of ground water…but studies suggest that these can be managed so it is best to use the gas for to fuel more jobs and a better economy"