THE IMPACTS OF HYDRAULC FRACTURING:

HANDS-ON ACTIVITIES FOR UNDERGRADUATE STUDENTS

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

The Impacts of Hydraulic Fracturing: Hands-On Activities for Undergraduate Students

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According to the US Energy Information Administration, over 50% of the oil and natural gas produced in the US came from hydraulically fractured wells in 2015. While the economic and geopolitical benefits of this new industry are numerous, hydraulic fracturing (fracking) is still controversial because of its negative impacts on the environment such as ground and surface water contamination, air pollution, and increases in seismic activity near deep injection wells. Yet, it is only briefly mentioned in mainstream Geography textbooks and rarely taught in introductory Geography courses at Texas A&M. To address the current educational gap on fracking, I developed and implemented educational materials and associated activities that utilize several geographic learning methods. Specifically, I (1) prepared an introductory fracking lecture for GEOG 203 students, (2) prepared a debate scenario where students present alternative viewpoints about the impacts of fracking on local communities in the United States, (3) developed a data-driven exercise using Oklahoma earthquake data where students learn to analyze, graph, and interpret scientific datasets, and (4) assessed the success of some of my learning module via before and after quizzes. In 2016 and 2017, this fracking module was successfully implemented in GEOG 203, one of the top two core curriculum courses at Texas

A&M related to environmental literacy. With this successful trial, I plan to disseminate the fracking module with an open-access publisher, making our documents freely available to all. Likewise, the hands-on exercises will be made freely available through the NAGT website.

DEDICATION

To my mother, who is always there for me anytime I need her, and my father, who's always there to provide me with his insight. I would not be where I am today without you two.

ACKNOWLEDGEMENTS

I would like to thank my faculty mentor, Dr. Loisel, for her continual guidance and support throughout the course of this research and my other projects. She has helped me develop the ideas on this project and gave me the chance to implement them in an undergraduate classroom.

Thanks also go to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I would like to thank Dr. Fry, Dr. Brannstrom, and Dr. Prout for helping me with the development of some activities. I also want to extend my gratitude to the Departments of Geography and Atmospheric Science for funding this research.

Finally, thanks to my mother, father, and siblings, Jenna and Ethan, for all of their encouragement, patience, and love.

NOMENCLATURE

EIA	Energy Information Agency
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
IRB	Institutional Review Board
NAGT	National Association of Geoscience Teachers
RGS	Royal Geographic Survey
SI	Supplemental Instruction

CHAPTER I

INTRODUCTION

Hydraulic fracturing as a method for extracting oil and gas from shale had its debut in Texas over 20 years ago (Railroad Commission of Texas 2016). Since then, the approach has been widely used and has generated a new gas boom across the United States. Fracking now accounts for over half of the oil and over two thirds of the natural gas produced in the US (US Energy Information Administration 2016). This change in production has allowed for a large increase in natural gas supplies, which has lowered the price of natural gas. This decrease in price has led to a change in electricity generation and consumption, with coal and natural gas shares nearly identical in 2015, each at approximately one third of our national electricity generation (US Energy Information Administration 2016). The EIA noted that natural gas surpassed coal for energy generation in the month of April 2015.

Despite its obvious importance in our country's current and future energy sources, hydraulic fracturing is seldom mentioned in middle and high school courses. Likewise, it is only briefly addressed in mainstream Geography College textbooks such as *Geosystems* (Christopherson 2014) and *Living Physical Geography* (Gervais 2015). I argue that fracking should become an integral part of students' geographic education because of the historical, economic, political, and environmental impacts this industry has on our country and the world.

The field of Geography is well suited to provide an educational platform from which hydraulic fracturing can be taught. The RGS defines geography as "the study of Earth's landscapes, peoples, places and environments. It is, quite simply, about the world in which we live" (Royal Geographical Society 2017). Additionally, Geography encompasses both social and natural sciences. From a geographic standpoint, hydraulic fracturing provides a great set of problem-based inquiries for students, including the spatial analysis of physical processes that shape the human experience locally as well as globally, the evaluation of human-environment connections, as well as the cause and effect analysis of this industry on the natural environment and on human health. Likewise, the geographic approach provides a means to understand the relationships and interaction among the atmosphere, the geosphere, the hydrosphere, and the biosphere, and an opportunity to engage in the politics and economics of energy. From the Geography student perspective, utilizing the geographic approach for exploring the complexities of real-world problems will allow them to create "geographic knowledge by measuring the Earth, organizing this data, and analyzing/modeling various processes and their relationships" (Dangermond 2007).

What is specifically taught in Geography courses across the state of Texas varies from school to school. Texas A&M's course catalog description for GEOG 203 (Planet Earth) describes the class as covering "Earth's physical environment including climate, water, landforms, and ecosystems; processes that control these systems and their global distributions; human effects on these processes" (Texas A&M University 2016). Students coming out of this class should have a better understanding of the processes affecting Earth's environment, improved spatial thinking abilities, learn to do college level research for projects and assignments , and be familiar with analytical tools such as GIS (including but not limited to Google Earth) and data analysis software (e.g., Excel).

CHAPTER II

METHODS

My project is presented in three different sections: (1) background research on fracking and geography education, (2) college course material development, and (3) the implementation of the developed materials in GEOG 203. The following sections detail my approach and methodology.

Literature review

First, I used current, popular textbooks to examine what students are being taught about fracking in College Geography classes. The two books I used were *Geosystems* by Christopherson (2014) and *Living Physical Geography* by Gervais (2015). Second, I performed a search on fracking to gather as much information as possible on the topic. This information was used to develop my introductory lecture on hydraulic fracturing. I gathered this information from online sources like ESRI, RGS, and the EIA, the previously mentioned textbooks, field trips I took in my previously classes to the City of Denton, and from additional primary literature.

I also reviewed multiple sources on geographic education to develop my class activities. Some of these sources include activities currently used in GEOG 203 classes and my own experience as a Geography undergraduate student at Texas A&M. Additionally, I looked at various learning types, including visual, kinesthetic, and auditory. By incorporating aspects pertaining to every learning type (visual, kinesthetic, and auditory) into at least one of my activities, I am hoping to reach out to every student and help them learn a great about fracking. Sources such as ESRI and RGS helped me articulate the learning objectives of my lessons, so that my activities were developed with a geographic teaching type in mind instead of simply the science or history of fracking. This meant asking students questions regarding spatial thinking on the graphing activity and analyzing the relationship between fracking and its subsequent effects in the debate activity.

Developing course materials pertaining to fracking

With regards to developing my educational materials, I (1) developed an introductory fracking lecture for GEOG 203 students, (2) created a graphing-based exercise that focuses on the analysis of earthquake activity over ten years in Oklahoma, and (3) prepared a debate scenario where students present alternative viewpoints about the impacts of fracking.

In order to create the graphing activity, I utilized Oklahoma Geological Survey's record of earthquakes recorded in Oklahoma from 2000 until 2016, as this data set included multiple different kinds of data types, including dates, locations, magnitudes, and depths (Oklahoma 2017). Additionally, the data needed to cleaned up and formatted so students would encounter fewer errors when using Excel to make the graphs. All of the columns were formatted to the proper data type, extraneous information was deleted, and every sheet was organized and sorted in the same manner. The activity itself required students make multiple bar and pie graphs, calculate cumulative sums and percent change, and create various kinds of scatterplots. One of these scatterplots required students to graph the longitude and latitude of injection wells versus earthquakes in 2015. The end result of this graph will look like a map, and students needed to analyze the relationship between injection well locations and earthquakes based on the created graph.

The debate activity required students to choose either pro fracking or against fracking, and then research their stance on the issue. They needed to come up with key statements about physical or environmental aspects along with policy based arguments. Additionally, they had to analyze a claim made by the opposing side and develop a counter to it. In each of these parts, they were required to utilize credible college level scientific sources and data to back up their claims, and create a debate preparation sheet that would be used to grade them on the activity.

Implementing the materials in a classroom and measuring success

The implementation of my fracking materials occurred in Nov. 2016 and Feb. 2017 in Prof. Loisel's GEOG203 course and was held over the course of two class days. The first day consisted of introducing the research project to students and getting consent forms signed. This project needed human research subject compliance because it involves students. Paperwork was submitted through Texas A&M's IRB in Oct. 2016 and received compliance. This compliance meant that the research was entirely optional for students to participate in and students needed to sign a consent form before any activities could be given to them. Those who chose not to participate received an alternative assignment from their professor.

After that, I delivered my introductory lecture on hydraulic fracturing to the students. Many of the students had little prior exposure to fracking, so this lecture provided important background information. The lecture included: (1) what is fracking, (2) effects of fracking of water pollution, air pollution, and earthquakes, (3) changes in U.S. energy use over time, (4) comparing coal to natural gas, and (5) a description of the upcoming learning activities.

The debate activity occurred on the second day of class. Students were split into their pre-assigned groups: pro or con, and they were given approximately ten minutes to share the research they gathered and plan what they wanted to Once the ten minutes were up, the pro side got to make their opening statement, followed by the con side's opening statement and their counter to the pro. Following this, they take turns going back and forth debating whatever topics were mentioned in the opening statements or during the debate. Students have around 35 minutes to one hour to debate, depending on if the class is a 50 minute class or an hour and fifteen minute class. At the conclusion of the debate, each side presents one final closing statement, with the cons going first this time. Once the debate has concluded, those judging deliberate and decide which side won. Every member on the winning side earned an additional 2 bonus points.

The graphing activity was assigned at the end of the lecture on Day 1. A brief Excel tutorial was presented to the students. The activity was completed outside of the classroom and turned in online via E-campus. Students also had walkthrough videos online to show them how to make various graph types in Excel, as well as how to perform equations. In addition, one SI session was turned into an additional Excel help session where students could come, ask any questions they might have been having, and get assistance if they were getting errors when attempting to make certain graphs. Students could also earn 2 additional bonus points if they created one additional graph of their choice from the data and explained what the graph depicted.

CHAPTER III

RESULTS

Current representation of fracking in college textbooks

My analysis of both *Geosystems* by Christopherson (2014) and *Living Physical Geography* by Gervais (2015) confirmed how little hydraulic fracturing is covered by current college textbooks. In *Geosytems*, there are only two pages, pp. 1 and 380, which mention fracking in the entire textbook. Page 380 addresses fracking with regards to the impact of deep injection wells associated with fracking on earthquakes. Page 1 provides a brief case study on shale energy and the environmental effects associated with it. However, the primary focus is not on the effects of fracking itself, but rather drilling for methane and the environmental effects of methane. The page does provide information on what methane is, water usage by wells, US EIA projections in shale gas extraction, and contamination due to leakage from the wells (Christopherson 2014).

Living Physical Geography does cover hydraulic fracturing in greater detail, with four pages (pp. 434-437) dedicated to the topic. The author covers what fracking is, how it works, what is in fracking fluid, potential contamination to drinking water, air pollution, and a summary of the pros and cons of fracking (Gervais 2015). However, the information is slightly outdated, as many of the sources are from 2012 or earlier.

Implementation of activities and assessments

The complete debate activity is presented in Appendix I. In Fall 2016, 309 students participated in the activity (Figs. 1 and3), while 124 students participated in Spring 2017 (Figs. 2

and 4). The average score on the debate in the Fall was 10.53 out of 10, with a standard deviation of 1.23. In the Spring, the average debate score was 10.42 out of 10, with a standard deviation of 1.33. On this activity, students were able to earn two bonus points if they were on the winning side of the debate, resulting in a possible grade of 12 out of 10.

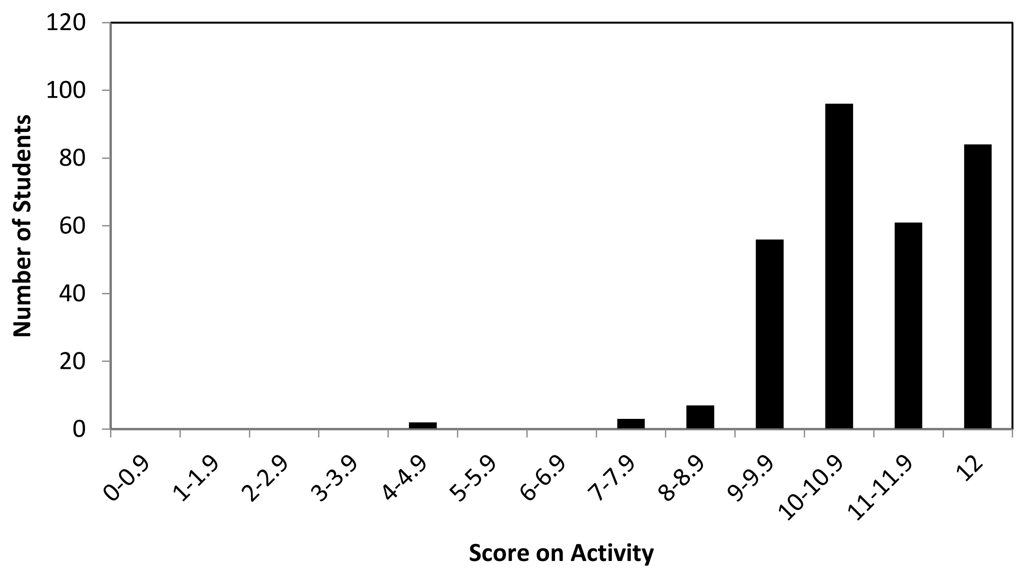

Figure 1. Fall 2016 Debate Grade Distribution

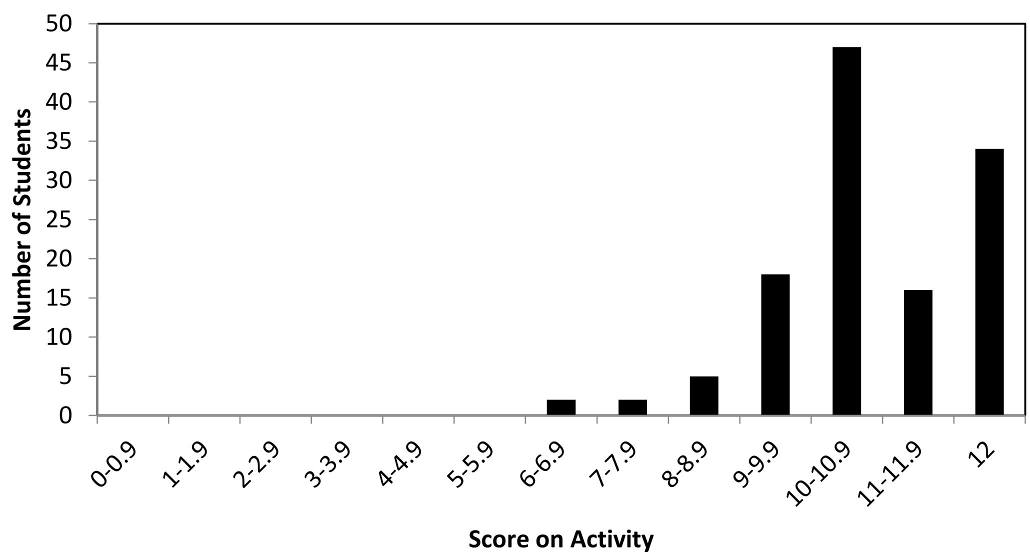

Figure 2. Spring 2017 Debate Grade Distribution

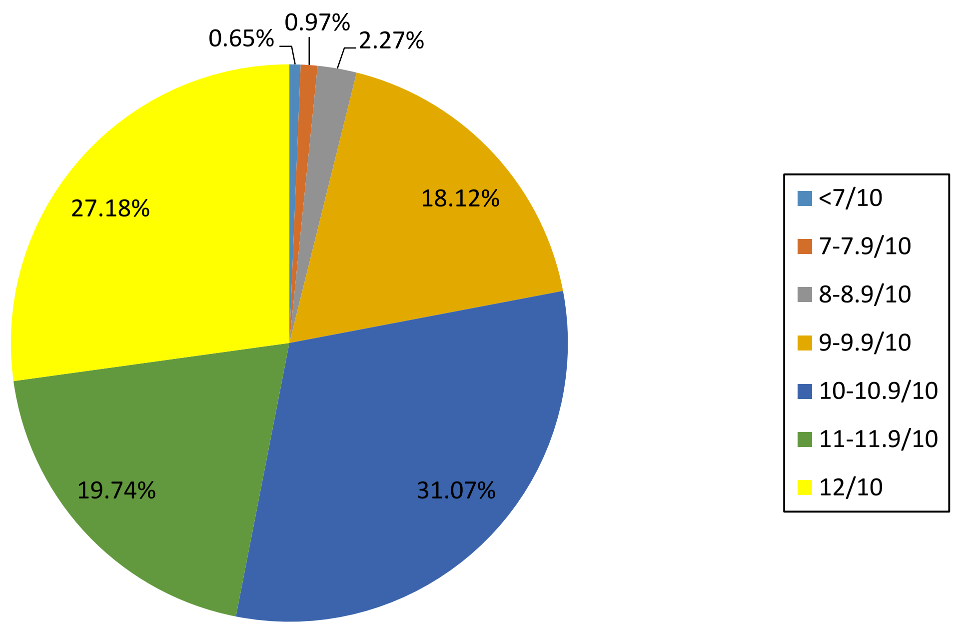

Figure 3. Fall 2016 Debate Score Percentages

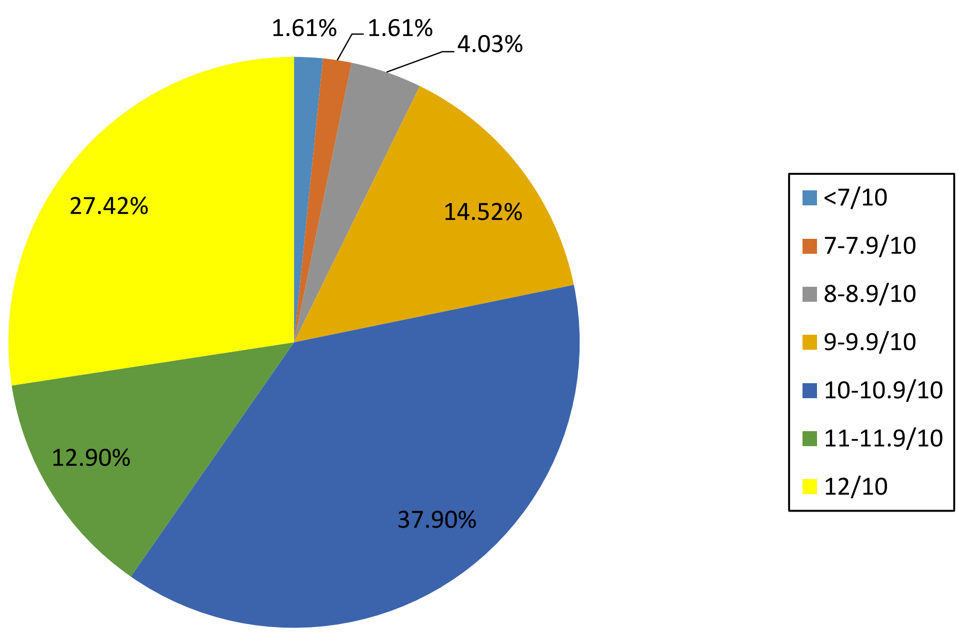

Figure 4. Spring 2017 Debate Score Percentages

The complete graphing activity is presented in Appendix II. The graphing activity was implemented in Spring 2017, with 117 students completing it. The average score was 8.228 out of 10, with a standard deviation of 2.348. Students could earn two bonus points on the activity by completing an additional graph of their choosing and describing what it showed, resulting in a maximum score of 12 out of 10. The distribution of the grades is unimodal with a large left tail, with at least one student scoring within every grade range (Figs. 5-6). The median for the graphing activity was 8.67, which is not too different from the average, showing that there is not a select group of outlying scores pulling down the average. I will provide possible reasons for the poorer scores in the Discussion & Conclusion section.

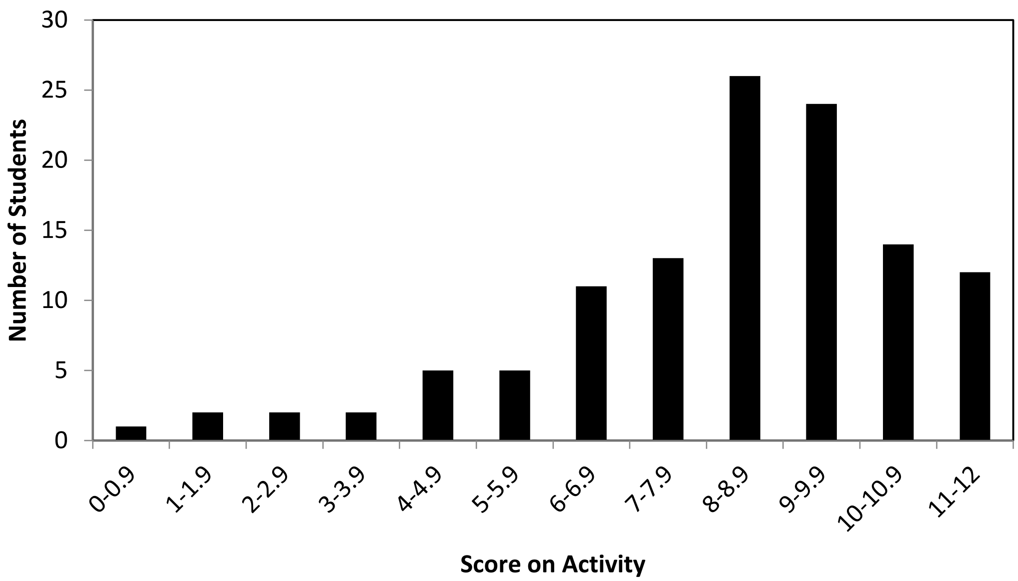

Figure 5. Spring 2017 Excel Graphing Grade Distribution

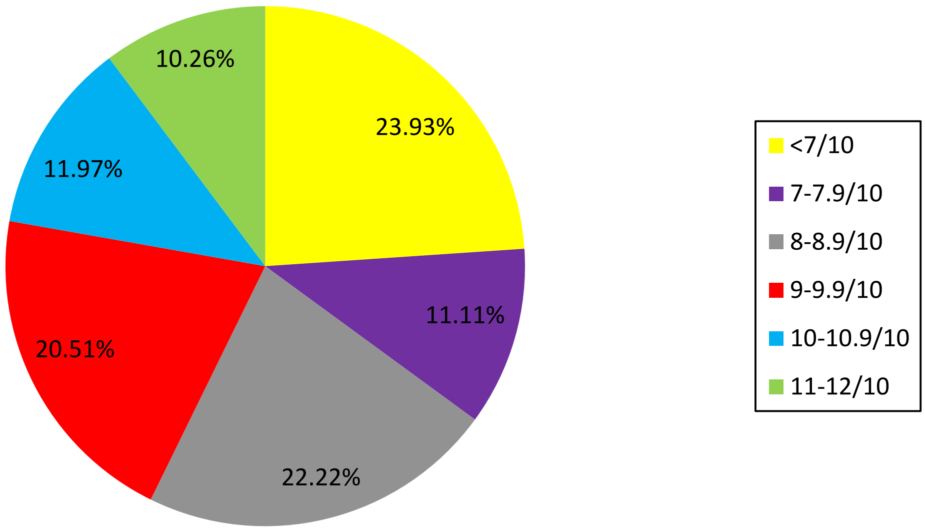

Figure 6. Excel Graphing Score Percentages

The pre-quiz was aimed at accessing students' prior knowledge on the key concepts pertain to hydraulic fracturing, such as setback distances and environmental effects associated with fracking. Additionally, the questions on the pre-quiz were the same as those asked on the post-quiz in order to access students' performance. In Fall 2016, while only one of the two sections was provided with the pre-quiz (total of 56 students), the post quiz was taken by 305 students. In Spring 2017, all students (n = 128) took the post-quiz; there was no pre-quiz. It is important to note that the quizzing style varied between Fall 2016 and Spring 2017, but the questions asked were the same on all quizzes (see Appendix III for the quiz questions).

The average on Fall's pre-quiz was 3.57 out of 10 with a standard deviation of 1.63, while the fall post-quiz had an average of 7.74 out of 10 with a standard deviation of 1.64. While there were a significantly larger number of students taking the post-quiz than the pre-quiz, it can be seen that students performed far better when taking the post quiz (Figs. 7-8). In Spring 2017, the average on the post-quiz was 5.63 out of 10 with a standard deviation of 2.58. However, these scores cannot be compared to the Fall's easily, as there were differences between the ways the quizzes were given. For example, the Fall students could receive partial credit on most of the questions (manual grading) vs. Spring students could not (automatic in-class polling). This lack of partial credit was a major contributor to the lower scores in the Spring semester (Fig. 9).

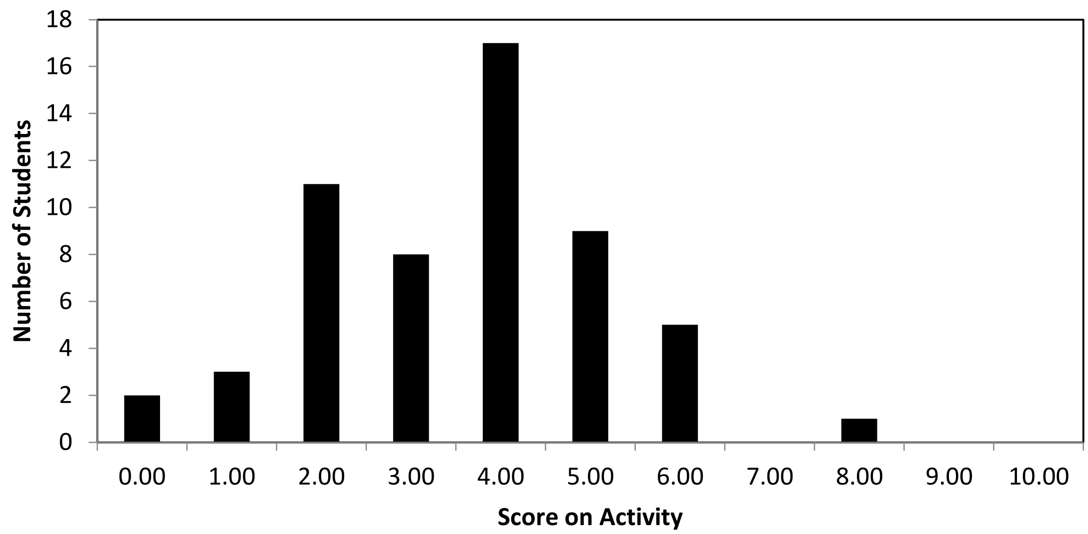

Figure 7. Fall 2016 Pre-Quiz Grade Distribution

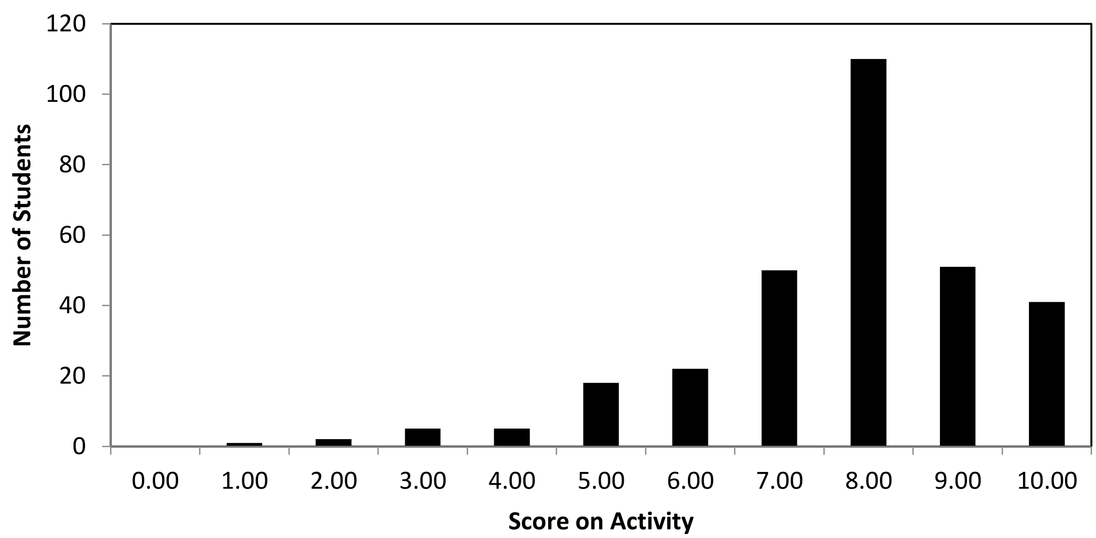

Figure 8. Fall 2016 Post-Quiz Grade Distribution

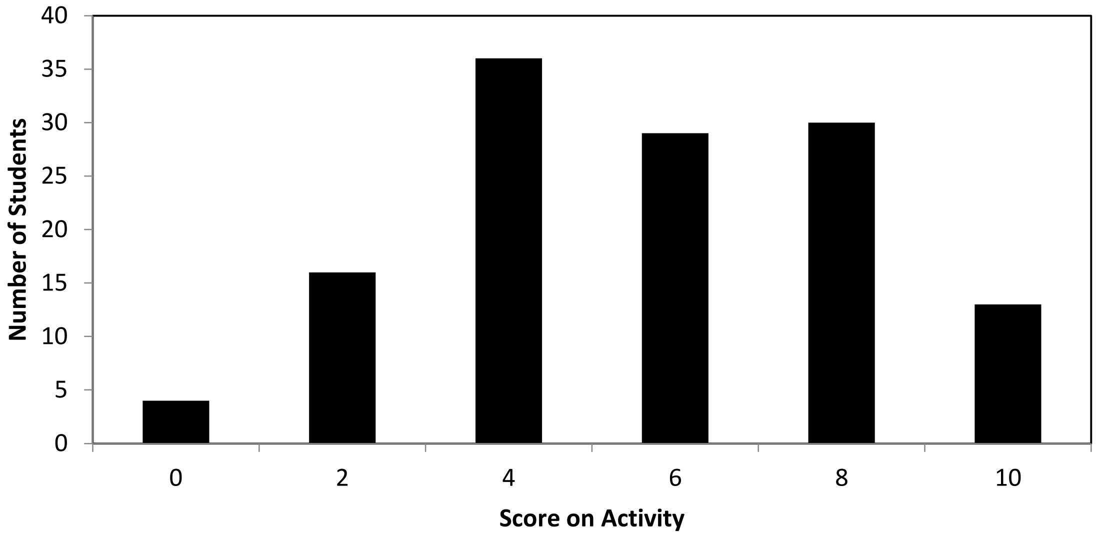

Figure 9. Spring 2017 Post-Quiz Grade Distribution

CHAPTER IV

DISCUSSION & CONCLUSION

Fracking: a key knowledge gap in current education curriculum

The most apparent outcome realized through these lectures and activities was that most students had never been formally taught about hydraulic fracturing, and many did not know what it even was. This is evident by the pre-quiz average in the Fall being a 3.57/10 (n = 56). On the pre-quiz, two out of the five questions were multiple choice ones. Thus, students often missed the short answer and fill-in-the-blank questions, but were able to “guess” correctly on these multiple-choice ones. While only a small portion of the class took the pre-quiz, there was a large increase in the scores from the pre-quiz to the post-quiz. This helps show that much of the knowledge students gained on fracking came from the lecture and their own research, rather than the prior knowledge them came into class with on the subject.

While the currently used textbooks do mention hydraulic fracturing, they do not provide enough detail on the topic. *Geosystems* does not have an detailed section on fracking. It only mentions it with regards to earthquakes and injection wells, along with discussing methane’s effects on the environment. *Living Physical Geography* does have a section on fracking, but much of the information should be updated with more current data.

Skill development

Each of the developed activities aimed at having students use and incorporate a set of skills. The debate activity had students work in large groups when debating, in addition to learning to conduct good college level scientific research. The graphing activity had students utilize Excel in order to make a battery of graphs. However, one key take away from implementing these activities was that neither of these skills was as well-developed prior to this introductory Geography classes as I believed they would be.

One change that had to be made to the debate activity between semesters was developing an outline to help the students fill out as they conducted their online research. Additionally, further modifications need to be made to the debate activity for future semesters. The biggest change needs to be a more specific list of unacceptable sources to use. Students were told that they needed to find reputable scientific sources, sites like Wikipedia could not be used, and they needed to be college level and not ones geared towards younger kids. However, it was found that many students utilized top ten and top eight reason lists as one or two of their sources. This resulted in slightly poorer debates during the spring semester, as many were citing information from these top lists instead of from credible scientific sources. Additionally, due to how old some of these lists are, the information on them is out of date. This meant that students would debate over issues where one had far newer scientific information and one had older information coming off of a top ten list. For future semesters, students will not be allowed to cite any of these top lists, and will also need to have half of their sources come from articles and papers published within the last two to three years at most. This should help facilitate a better class debate, as students will have more current information and be able to better back up their points.

The other big issue encountered through these activities was that many students could not proficiently use Microsoft Excel. This created a multitude of problems with the graphing activity, and even put a hamper on the debate activity in the spring semester. When the graphing activity was introduced after the fracking lecture, 30 minutes was set aside to give an intro to Excel tutorial to the students. The assumption was that students were familiar with using Excel and could perform some of the basic functions within it. However, not to be the case as many students had never used Excel before, or did not know how to create graphs within it. This meant that the originally planned tutorial was too complex, resulted in the tutorial lasting longer, and caused the debate introduction to be even shorter. Additionally, I had to create online tutorial videos and hold an Excel help session. This lack of Excel knowledge most likely contributed to the poorer performance on the graphing activity.

This lack of Excel skills are further alarming when one considers the makeup of a Geog 203 class. Geog 203 is primarily non-major students, with some of the common majors being business and education. This likely will not be the last time students utilize Excel and it is a useful tool to know for the workforce. Thus, further activities that could be created could incorporate more Excel portions into them. My graphing activity may have been too advanced for some, requiring them to create scatterplots that would look like maps and calculate and graph percent change. There was originally planned to be a standard deviation graph, but this was dropped as many had no idea where to begin with it. Additionally, the data had to be further modified, as students previously needed to utilize complex COUNTIF equations to figure out how many earthquakes occurred within each magnitude range. This activity could be further modified to better explain what percent change represents and include a guide to making graphs in Excel. The goal is to have students become more proficient in Excel, but based on the grade distribution from this activity further changes will need to be made on this activity.

One takeaway from these activities was the high student engagement during the debates. A large portion of every class spoke during their debate, and there was a high level of student collaboration. The scores on this activity were the highest of all three, and many students seemed to thoroughly enjoy it. This activity could be modified very easily to another topic with the same general template, allowing a professor to get high engagement out of their class and have students learn to conduct research. The research is all done at home, and the debate could last the full class, as mine did, or be shorter. None of the debates had issues filling the entire class time though, which further showed students engagement in this activity. This is an activity that while it may seem like it could be too hard to control, actually worked out better than the graphing exercise.

Future work

Hydraulic fracturing is rarely taught in geography courses, and as seen by these activities, many students do not know about the topic. With the introductory lecture, debate, and graphing activity, students were able to gain a satisfactory understanding on the topic. The activities encouraged students to conduct both qualitative and quantitative analysis, in addition to having interpreting large amounts of data. Based on the students' performance on the activities, a few changes that were previously mentioned will be made to each. Once these changes have been implemented, the activities will be made freely available for others to download and incorporate into their own classrooms as well. The debate activity can also be modified by other teachers and professors to essentially cover any topic they may want to debate in class, since my debates showed that even with 100 plus students in a class, a successful and organized debate can still occur.

Additional activities regarding hydraulic fracturing can also be created. The biggest potential one would be a sort of mapping exercise. In this, students could either analyze the change in the number of fracking wells over a set number of years in Google Earth. This would incorporate technology into the classroom, as well as have students utilize spatial thinking skills to analyze the changes. Another possible mapping activity would be to give students printed out paper maps and have them determine where a well or housing could go based on a given setback and reverse setback distance. This would allow students to interpret paper maps, scale bars, and convert units of measurements, all of which are useful skills that students should come away from Geography courses knowing. The lecture I gave in class may also be recorded and put online for instructors to use in their classrooms. There is a multitude of activities that can continue to be made on this topic, as currently students are not being exposed to fracking in many of their courses. Future research should aim to better educate students on the topic so they can make more informed decisions about fracking in the future.

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APPENDIX I

GEOG-203 Homework Assignment #5b: Fracking (debate)

Prepared by Collin Kohlmeyer

due date: February 20 or 22, 2017 at 11:59pm
last names starting with letters A through L: 02/20
last names starting with letters M through Z: 02/22

submission via hard copy of report in class
worth 5% of your final grade

(1) Overview

This assignment allows you to participate in a class debate where you will present one side of an argument while also looking for potential counter arguments.

(2) Learning Objectives

The main learning objectives are to: (1) analyze both the positive and negative consequences of hydraulic fracturing, (2) discern credible information from pseudo-scientific facts, and (3) present scientific content in a debate format.

(3) Instructions

Part I: Debate Prep

You will need to find a partner in class, with each of you taking 1 side of the issue: either the positive effects or the negative effects of fracking. You will come up with 2-3 key statements and at least 1 counter argument. For each of these, you will need to find additional data and information along with credible sources to support your claims. You can work with your partner by finding a counter to one of their key statements, along with telling them your key statements so they can come up with a counter argument.

(a) Key statements: These are your main points that you will be arguing for. For each key statement that you come up with, you must find supporting information from at least 1 to 3 credible scientific sources to back up your claims. You must support your statements with evidence; otherwise they are simply your opinions. You also must find graphs, data, or figures that back up your claims. Some great places to find information on fracking are the EIA, USGS, and state websites in states where fracking is prevalent (ex: Oklahoma, Texas, Pennsylvania). You will need to come up with 2 to 3 key statements that you can bring to the debate. For these key statements, at least one should be about physical processes or effects of fracking, and at least 1 should relate to policies on fracking. You will be graded on whether your key statements are accurate and reflect your side of the argument, the quality of your sources, if you used graphs and data, and the originality of your claims.

> Example: If my topic is “Should students use tablets or standard textbooks in school?” I could make one of my key statements be “Tablets can hold hundreds of books on one single device.”

(b) Counter argument: The counter argument will require you to look at an opposing side’s view. You can either use your partner’s key statement or come up with your own opposing view. Once you have this opposing viewpoint, you will want to come with a rebuttal, refute the claim, or acknowledge that while their view is an issue, it is not as bad as they say it is because of XYZ reasons. This gets you to see that there are other views than just your side of the argument. A good debater must acknowledge these views so it comes across that you have looked at all sides of the argument and you are showing why your side is better. If you do not look at the alternate view, it comes across as being very biased/closed minded. You will need to come up with at least 1 counter argument, and then provide supporting information, 1-3 credible scientific sources, and graphs/data to back up your claim.

> Example: If my topic is “Should students use tablets or standard textbooks in school?” an opposing side’s view might be that “Tablets are very expensive to purchase for each student.” My counter argument to this claim could be that while the costs of tablets are initially higher, one tablet can be used for multiple textbooks and digital books are cheaper than print textbooks, thus the long term cost of a tablet is cheaper than buying each student all the paper textbooks.

(c) Deliverable: Turn in a typed paper copy of your 2-3 key statements, with the supporting information, figures/graphs/data, and the credible scientific sources for each. On your paper copy, you will also include the counter argument, with the supporting information, figures/graphs/data, and the credible scientific sources. Your sources need to be properly formatted (see the end of the document), and if it is a website, include the url, not just that it came from the EIA for example. A bulleted format is acceptable for your paper copy – it does not need to be in long paragraphs, but supporting information should be in complete sentences.

> A note on sources: Your sources need to be credible scientific sources. You may use 1 newspaper article as a source, but no more than 1. Also, a website like www.weatherwizkids.com is NOT a credible source and you will lose points if you use something like this as a source.

Part II: The Debate

(d) On the day of the debate, you will need to bring your printed out debate prep with you. At the start of the class, you will get with your side of the debate so you all can share your claims and counter arguments with each other and discuss what you want to present when speaking. You will have 10 minutes to prepare what you want to present. You may want to nominate someone as secretary to make a list of all the claims so you can quickly see everything that you’ve come up with and so you do not repeat the same thing over and over. You will also need to nominate 1 person as your side's representative for the debate.

(e) After the 10 minutes of prep time at the start of the class, your professor will begin the debate. Each side will take turns speaking, and different people on each side need to speak (one person cannot do all the talking). If the other team wants to make a counter claim or has a question to pose, their representative will raise their hand. After the speaking side has finished their claim, the moderator will call on the representative, who will then direct someone on their team to speak. You will have up to 45 minutes to debate. The winning team will be determined by the persuasiveness and accuracy of their arguments, the originality of their arguments, and their overall performance in the debate. ***All participants on the winning side will receive 1 bonus point on their grade for this assignment.***

(f) Debate rules:

- When speaking, make sure to say your name first, so that others can address you directly or say X previously said Y and Z.
- Do NOT interrupt the other side speaking. If your side wants to make a statement/claim, then have your representative raise their hand and wait to be called on.
- Do not only present 1 single argument. You want to make multiple claims for your side and not just focus on 1 single thing.
- Make sure to back up you claims with data and additional information. If you do not, then you are only telling your opinions.
- If you get a graph or figure from somewhere, make sure to say where it came from (for example, say this graph came from the US EIA in 2015).
- You can print out any graphs/tables and show them on the document camera while presenting.
- Stay calm. We don't want a heated argument/yelling match.
- If you continually break the rules of the debate, you will lose points on your grade.

<u>Part III: The written portion of the assignment</u>

Turn in your printed debate prep IN CLASS. It must contain the following:

(1) 2-3 key statements
(2) at least 1 counter argument
(3) at least 4 credible references
(4) at least 4 pieces supporting information/data

References can be websites, books, encyclopedias, articles, etc. See below for formatting examples:

website:
NASA, http://science.nasa.gov/. page visited on 09/01/2015

article:
Ghose T., 2015, Rising sea levels more dangerous than thought, Scientific American Magazine.

book:
“Geosystems”, 9th edition, R. Christopherson, 2015, Pearson, 619 p.

(4) Grading

2 → credible scientific sources (0.25 per source)
2 → key statements
2 → counter argument
2 → data/supporting information (0.25 per piece)
1 → participation
1 → originality of statements
2 Bonus Points → Winner of the debate

Outline

- Key Statement #1 (Physical Processes/Effects)
  - Supporting Info
  - Source/s (properly formatted)
- Key Statement #2 (Policy Related)
  - Supporting Info
  - Source/s (properly formatted)
- Key Statement #3 (Optional)
  - Supporting Info
  - Source/s (properly formatted)
- Counter Argument
  - Opposing Side’s View
    - Supporting Info
  - Your Side’s View or Counter to Their Claim
    - Supporting Info
  - Source/s (properly formatted)

APPENDIX II

GEOG-203 Homework Assignment #5a: Fracking (earthquakes)

Prepared by Collin Kohlmeyer

due date: February 26, 2017 at 11:59pm
submission through the Turnitin link (available on e-campus)
worth 5% of your final grade

*** ***Turn in this document (with all your answers typed in) AND your Excel plots******

(1) Overview

This graphing assignment is designed to introduce you to Excel as a statistical, graphing, and analytical tool. It is also intended to make you reflect on the relationship between earthquake frequency and magnitude, and deep injection wells associated with hydraulic fracturing (fracking) in Oklahoma.

(2) Learning Objectives

The main learning objectives are to: (1) analyze a large dataset from the Oklahoma Geological Survey, (2) present results using types of graphs (frequency diagrams, bar graphs, pie charts, etc.), (3) apply a series of basic statistics to your dataset, (4) analyze your findings, and (5) discuss your results.

(3) Instructions

Introduction

You have recently been hired by CK Analytics to help out with some recently acquired earthquake data for the state of Oklahoma. The previous person working on the data was let go recently, and you are getting the spreadsheet in the condition that she left it in. Each page of the spreadsheet contains every earthquake recorded in that year (see file HW05a_EarthquakeData.xlsx in the Homework Assignment folder).

The dataset comes from the Oklahoma Geological Survey (OGS). Like any government dataset, the file contains a few technical terms and abbreviations, defined here:

Category	Description
id	Internal identification number assigned by the OGS
origintime	Estimated date and time of the earthquake
latitude	Estimated latitudinal coordinate of the earthquake epicenter
longitude	Estimated longitudinal coordinate of the earthquake epicenter
depth	Calculated depth of the earthquake, in kilometers
err_lon	90% confidence interval for location uncertainty, in kilometers
err_lat	90% confidence interval for location uncertainty, in kilometers

err_depth	90% confidence interval for location uncertainty, in kilometers
err_origintime	90% confidence interval for location uncertainty, in seconds
county	County within which the earthquake was located
prefmag	Preferred magnitude, Richter scale units

Task 1: Graphing

Your boss asked you to produce the following graphs for him:

(a) Produce ***a single bar graph*** showing the number of earthquakes within each range of magnitudes for every year (all on one graph). In other words, your graph should have 9 groups (2008 through 2016, inclusively) that each contain 8 bars. Each one of these bars represents the number of earthquakes within each of the following ranges of magnitude: ≤1, 1-1.4, 1.5-1.9, 2-2.4, 2.5-2.9, 3-3.4, 3.5-3.9, ≥4. Note that some ranges won't have any data; that's okay. In this plot, 'years' will be along your x-axis, and 'number of earthquakes' will be along your y-axis. Use different colors for each magnitude range (for example: red for 1-1.4, yellow for 1.5-1.9, etc.), and provide a legend.

(b) Based on your bar graph, ***select two years*** that you deem different from one another in terms of earthquake numbers and magnitudes. Make ***a pie chart*** showing the percentage of earthquakes occurring within each magnitude range for each one of the 2 years you selected (so you will make 2 pie charts).

(c) Make ***a bar graph*** showing the number of earthquakes of magnitude ≥ 3.0 per year since 2009. In other words, 'years' will be along your x-axis, and 'number of earthquakes with M ≥ 3.0' will be along your y-axis.

(d) Show the percent change in magnitude ≥3.0 earthquakes between each year by creating ***a percent change graph (scatter with straight line)***. To achieve this task, you must calculate the percent change from year to year. In this plot, 'years' will be along your x-axis, and 'percent change in the number of earthquakes' will be along your y-axis.

(e) Show the cumulative number of magnitude ≥3.0 earthquakes that has occurred since 2008 using ***a cumulative curve graph (scatter with straight line)***. To achieve this task, you first need to add up magnitude ≥3.0 earthquakes. In this plot, 'years' will be along your x-axis, and 'cumulative number of earthquakes' will be along your y-axis.

(f) Make ***a scatter plot with error bars*** that shows the average magnitude per year plus or minus one standard deviation (SD). In this plot, 'years' will be along your x-axis, and 'number of earthquakes' will be along your y-axis.

Task 2: Data analysis

Your boss then asked you to answer the following questions in order to analyze the results

(g) In what year did the most earthquakes occur? _________________

(h) What year had the highest numbers of earthquakes with a magnitude ≥3.0? ______________

(i) How does the number and distribution of earthquakes change from 2009 to 2016? ______

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(j) Compare and contrast the two pie charts you made in (b). Why did you select those 2 years?

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(k) Describe the percent change curve you made in (d). Why do the highest points occur when they do? Is it appropriate to use this graph when describing changes in earthquake activity? Briefly explain your answer.

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(l) How does the cumulative curve graph you made in (e) compare to the percent change graph? Which of these to graphs would be more accurate to use when showing change in earthquake activity?

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(m) Which year had the highest earthquake magnitude average? Which year had the largest and smallest standard deviations, and what does it mean?

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Extra credit
Looking at the data, create one (or more) additional graph(s) of your choosing. It must be a 'correct' graph (i.e. do not make a pie chart to show the number of earthquakes occurring each year). Describe your graph, why you choose to make it, and what it is showing.

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(4) Grading

6 points → Task 1
4 points → Task 2
2 bonus point → Extra credit

APPENDIX III

Hydraulic Fracturing Quiz

Worth 10 Points

1. Describe the change in oil production and the number of wells in the Eagle Ford Shale Region since 2008. What impact has this had on the local economies? (3 Points)

2. T/F- No earthquakes greater than a 5.0 magnitude have been recorded in the Oklahoma area since the increase in fracking. (1 Point)
3. Which of the following is false about fracking? (1 Point)
   a. In 2015, over two-thirds of the natural gas produced in the U.S. came from hydraulically fractured wells.
   b. In 2015, over half of the oil produced in the U.S. came from hydraulically fractured wells.
   c. Most of the earthquake activity in areas with hydraulically fractured wells is caused by the act of fracking itself.
   d. Many of the chemicals used in a company's fracking fluid are not disclosed as the company considers their fluid composition a trade secret.
4. How is fracking fluid disposed of after the completion of the well? (2 Points)

5. Identify at least one positive effect and one negative consequence of hydraulic fracturing. Provide a specific example to support each of your claims. (3 Points)