"FRACK ATTACK": AN ENGAGING CLASSROOM ACTIVITY TO INTEGRATE SUSTAINABILITY

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Chemical engineers face increasingly complex problems whose solutions often require interdisciplinary teams and significant interaction with diverse stakeholders.[1] Moreover, recently revised ABET criteria for student outcomes (to be implemented in the 2019–20 accreditation review cycle) include "An ability to recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge."[2] To address these challenges, engineering education requires curricular experiences that integrate active learning and teamwork to critically evaluate broader impacts of basic engineering concepts and practices. Engineering classroom activities focused on researching and discussing contemporary societal issues with engineering context from multiple perspectives may help better prepare students for these challenges. Additionally, these activities may offer opportunities to incorporate empathy into engineering education, which is receiving increasing attention.[3,4]

One contemporary issue with significant engineering considerations is the advancement and proliferation of hydraulic fractured oil/gas well stimulation, or "fracking."[5] Fracking has substantially increased oil and gas production in existing reservoirs and has enabled exploration and production of otherwise inaccessible oil/gas resources. Fracking has also received negative attention for its environmental impacts, including land surface and geological disruptions, significant water use, and pollution. Described as both "revolutionary" and "disastrous," fracking has driven an economic boom within the past decade.[5] Chemical engineers involved with fracking, or other similarly complex problems, may benefit from considering multiple and often conflicting perspectives on these problems. This article presents an in-class activity aimed at encouraging students to consider multiple perspectives on fracking while addressing chemical engineering practice inherent in fracking operations.

The general approach of the "Frack Attack" class activity can be readily adopted to critically evaluate many other contemporary and/or contentious issues ranging from the impacts of energy technologies such as nuclear or wind power to the public's perspectives on engineering, or diversity within the engineering profession. Engineering educators have reported on integrating sustainability and social justice topics within core engineering courses, including mass and energy balances and engineering thermodynamics.[6] Others have reported on integrating sustainability throughout entire chemical engineering curricula.[7] These studies discuss the transformative opportunities, real challenges, and strategic approaches to incorporating sustainability into engineering education. Previous work by the authors[8] demonstrated the basic efficacy of the "frack attack" class activity approach and also provided valuable guidance for the current work. For example, responses to new open-ended questions were recorded to permit more qualitative assessment of student opinions and the impacts of the activity. During the activity, the instructors were more engaged in facilitating inter- and intra-group dialogs to support better information exchange. Additionally, quantitative data collected from student responses to pre- and

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post-activity questions were statistically analyzed to assess significance of changes. Finally, the activity was extended beyond the engineering elective classes reported previously[8] to a core chemical engineering course—fluid mechanics—where it reinforced technical content on pump sizing.

Classroom Activity. Informed by research-driven pedagogy[9] and developed from previous efforts,[8] "Frack Attack" is a classroom activity designed to combine active learning, critical thinking, and teamwork to critically evaluate sustainability topics in contemporary engineering contexts. It requires students to first assess their knowledge and opinions on a topic, next view short informational videos on the topic, and then research and discuss the topic from multiple perspectives before reassessing their knowledge and opinions. The activity is intended to establish relevance of the topic and allow students opportunities for inductive, active, and cooperative learning.[9] The activity was explored in three chemical engineering courses at Montana State University: one freshman-level ("200," n = 70) and one senior-level ("400," n = 20), with both being elective courses on sustainable energy; and one core-curriculum sophomore-level fluid mechanics course ("300," n = 40).

Procedure. Preceding the "Frack Attack" activity day, students received formal instruction from a university librarian or course instructor regarding online research methods and sources and their biases, and were encouraged to bring a portable electronic device to the next class (personal or library-loaned). The activity consisted of five randomly assigned student groups with a specific focus of fracking in the context of: (1) science/technology; (2) economics; (3) policy; (4) society; and (5) the environment. Each class then watched two short (about 5 minutes) informational videos on fracking [one produced by industry (Marathon Oil Corporation)[10] and another by a science literacy advocacy group (SciShow)[11]]. These videos were chosen to represent diverse perspectives on both the engineering and impacts of fracking. During the videos, students were encouraged to take individual notes about the content presented and any bias inferred—reinforcing concepts presented by the librarian or course instructor. After watching the videos, students were encouraged to discuss their notes before proceeding with their research on their group-specific foci. Students then researched online during class, discussed and summarized their findings within each group, and subsequently shared via instructor-facilitated class discussion. Two instructors were involved in the activity—the course instructor and a faculty collaborator—although the same instructor coordinated the activity during all three courses. Participation by multiple instructors may also convey a valid concern about student learning.[9] As students investigated the topics and discussed within their assigned group, the instructors walked around the room to promote student engagement and productive group discussion in all focus areas.

Measures. Pre- and post-activity assessments included collecting both quantitative and qualitative data to evaluate student understanding, perspectives, and opinions on fracking, as well as on the activity itself. Anonymous student responses were recorded via i-clickers (elective classes) or bubble-sheets (fluids class). Ten pre-/post-activity statements were presented to students with a 5-point scale: Strongly Agree (A); Agree Somewhat (B); Neutral (C); Disagree Somewhat (D); and Strongly Disagree (E). The scale was converted to corresponding 5–1 numeric values (5 = strongly agree) for quantitative analysis. The 10 pre-/post-activity statements presented to students included:

1. *I understand what fracking is;*
2. *I understand the economic impacts of the natural gas industry;*
3. *I understand the social impacts of natural gas well development on communities;*
4. *I understand the effects of gas drilling on the natural environment (streams, rivers, fish, wildlife);*
5. *I understand the implications of natural gas drilling for water quality and/or quantity;*
6. *I understand natural gas drilling procedures and practices;*
7. *I understand government regulations relating to gas well drilling;*
8. *I understand the jobs or job-training opportunities related to gas development;*
9. *I support fracking;*
10. *If I owned land, I would consider signing a lease for gas well development.*

Students were also asked "prior to this course, where did you get information on fracking," and "during this activity, where did you get information on fracking," with options of: media (news apps, radio, television, movies); industry publications; nonprofit organizations; government publications; or other. They ranked the options with a 5-point scale of possible responses: All (A); Lots (B); Some (C); Little (D); or None (E)—which were converted to corresponding 5–1 numeric values for quantitative analysis. Following the activity, students were also presented the statement, "This format was effective in my learning" with 5-point scale response options of: Strongly Agree (5); Agree Somewhat (4); Neutral (3); Disagree Somewhat (2); and Strongly Disagree (1).

Finally, students were encouraged to submit anonymous written responses to the following open-ended questions, which were later transcribed:

1. *If you changed your opinions, what factor(s) persuaded you to do so?*
2. *How was this approach better or worse than a "traditional lecture?"*
3. *Anything you would suggest to improve (the activity)?*

RESULTS AND DISCUSSION

Student responses to each of the 10 pre-/post-activity statements and the five pre-/post-activity questions regarding their sources of information were aggregated to produce a pre- and post-mean for each. These means were analyzed for each of the three courses in a one-way multivariate analysis of variance (MANOVA) with occasion (pre and post) used as the independent variable and the pre- and post-means used as the dependent variables. An alpha level of 0.05 was established for all tests of significance. The MANOVA was significant for the 200 course, $F(15, 120) = 57.02$, $p < 0.001$, partial eta squared (ES) 0.88; the 300 course, $F(15, 60) = 30.26$,

TABLE 1
Means for pre- and post-survey responses for all three courses
(standard deviations are in parentheses, and significant results are bold)

	200			300			400		
I understand:	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES
What fracking is	**3.79 (0.92)**	**4.73 (0.62)**	0.27	**3.34 (1.05)**	**4.66 (0.53)**	0.39	**4.12 (.33)**	**4.56 (.51)**	0.22
The economic impacts	**3.46 (0.99)**	**4.55 (0.50)**	0.32	**3.08 (1.00)**	**4.16 (0.59)**	0.31	**3.59 (.71)**	**4.25 (.45)**	0.24
The social impacts	**3.33 (1.13)**	**4.58 (.50)**	0.34	**3.34 (1.02)**	**4.03 (.68)**	0.14	3.82 (0.73)	4.13 (0.62)	0.05
The environmental effects	**3.57 (1.08)**	**4.44 (.59)**	0.20	**3.63 (1.08)**	**4.21 (0.62)**	0.10	3.29 (1.05)	3.63 (0.50)	0.04
The implications for water	**3.46 (.94)**	**4.45 (.56)**	0.29	**3.21 (1.17)**	**4.24 (0.54)**	0.25	**3.00 (0.79)**	**4.19 (0.66)**	0.41
Gas drilling procedures	**3.04 (0.94)**	**4.67 (0.54)**	0.53	**2.32 (1.07)**	**4.39 (0.59)**	0.60	**3.29 (0.92)**	**4.31 (0.48)**	0.34
Government regulations	**2.31 (1.06)**	**3.74 (.73)**	0.38	**2.13 (1.04)**	**2.74 (0.83)**	0.10	**1.76 (1.03)**	**2.81 (1.05)**	0.21
Related job opportunities	**2.89 (1.06)**	**4.08 (.77)**	0.29	4.00 (1.04)	3.97 (1.05)	0.00	3.00 (1.00)	3.31 (0.79)	0.03
I support fracking	3.00 (1.06)	3.00 (1.11)	0.00	3.00 (0.87)	3.13 (1.02)	0.01	3.35 (1.06)	3.44 (1.03)	0.00
If I owned land, I would consider signing a lease for gas well development	2.87 (1.46)	2.62 (1.44)	0.01	3.00 (1.38)	3.29 (1.29)	0.01	3.24 (1.60)	3.00 (1.67)	0.01
	200			300			400		
Source of information before course and during activity (post):	Pre	Post	ES	Pre	Post	ES	Pre	Post	ES
Media	**3.20 (1.07)**	**3.29 (1.09)**	0.002	**3.08 (0.78)**	**2.66 (1.34)**	0.04	**3.23 (.66)**	**2.19 (1.17)**	0.25
Industry	**2.40 (1.04)**	**2.79 (1.09)**	0.033	**1.92 (1.02)**	**2.55 (0.92)**	0.10	2.12 (0.99)	2.31 (0.95)	0.01
Nonprofits	**2.61 (1.02)**	**2.76 (1.25)**	0.004	**2.18 (1.11)**	**3.05 (0.98)**	0.15	**2.00 (0.79)**	**2.63 (0.96)**	0.12
Government	**2.71 (.96)**	**2.73 (1.16)**	0.000	**1.97 (1.00)**	**2.42 (1.08)**	0.04	**2.18 (0.95)**	**3.00 (0.97)**	0.16

$p < 0.001$ ES .88; and the 400 course, $F(15, 17) = 16.88$, $p < 0.001$, ES 0.94. Thus, there was a significant difference between pre- and post-tests for all three courses. The means, standard deviations, and the between-subject effect sizes for the pre/post comparisons are shown in Table 1. Partial eta squared (ES) was used to measure the effect size for each comparison. Generally accepted values are 0.01, 0.06, and 0.14 for small, medium, and large effect sizes, respectively.[12] Significant differences are in bold.

In regard to understanding the various issues relating to fracking, the student responses showed significant gains from pre-survey to post-survey in all areas in the 200-level course. All p values for the questions regarding understanding were less than 0.001. Self-reported understanding increased in most foci areas even though a student only actively researched one foci area. The main areas where it did not lead to increased self-reported learning are in "400" with respect to social, environment, and jobs. The "300" course showed no change with jobs. This may be due to increased understanding before the activity or attention shifting to other group foci during the activity.

Tables 2 and 3 indicate the percentage of students in each course who agree/strongly agree or disagree/strongly disagree to the statements of "I support fracking" and "If I owned land, I would consider signing a lease for gas well development," respectively. The pre/post changes in student responses were not statistically significant. These data suggest that the activity was itself effectively objective, allowing the students to arrive at their own position based upon the information provided to them alongside that which they collected and discussed during the in-class research. The data also suggest that while students report being more informed, their collective opinions remained statistically unchanged. While some students in each course changed their opinions, a similar number of students changed their opinions in an opposite manner. Table 4 presents select comments from students within each course explaining why they changed their opinions.

Students reported some changes in the source of information on fracking pre-activity and during the activity; however, these changes were not uniform among cohorts and inferences were difficult. The 200-level course student responses showed a significant change only for industry publications, indicating on the post-survey that they used industry publications more during the fracking activity. For students in the "300" course, the pre- to post-survey responses were significantly different for two of the information-source questions. These students were more likely to get fracking information from industry publications and nonprofits during the module. The mean for "media" went down from pre-survey to post-survey, but this difference was only significant for the 300- and

TABLE 2
Student responses (%) to: "I support fracking."

% Student Responses	200-Level		300-Level		400-Level	
	Pre	Post	Pre	Post	Pre	Post
Agree or Strongly Agree	26	32	28	43	39	39
Disagree or Strongly Disagree	32	41	33	30	28	28

TABLE 3
Student responses (%) to: "If I owned land, I would consider signing a lease for gas well development."

% Student Responses	200-Level		300-Level		400-Level	
	Pre	Post	Pre	Post	Pre	Post
Agree or Strongly Agree	33	28	49	53	59	50
Disagree or Strongly Disagree	53	57	41	25	29	44

TABLE 4
Select student responses to: If you changed your opinions, what factor(s) persuaded you?

200-Level
"Changed my opinion due to better informed of social, economic, and environmental effects of fracking. Bad outweighs good."
"My opinion changed slightly, no longer heavily against fracking, due to jobs and environmental benefits."
"Greater info on environmental impacts caused me to cautiously support fracking rather than strongly support."
"Did change my opinion due to societal and environmental impacts making it less beneficial."
"Changed opinion from learning more factual info about hazards of fracking."
"Did not know how fracking works or its environmental, social, political impacts, now I do."
300-Level
"My opinion changed due to our quality and ground water status, and wider-spread issues."
"Some of the findings made me change my opinions on the social impacts, they are not as bad as the media makes it seem like."
"Slightly changed, as had only heard negative before. Now sees the economic benefit if done right, still not fully in support."
"Support fracking more now, not pure evil as media says, and while negative impacts are bad there are more positive impacts."
400-Level
"More positively; the factual oil company's video and video saying there are no problems if fracking is done right contributed."
"Anti-fracking due to amount of water used in fracking, and increased earthquakes could lead to unforeseen consequences."

400-level courses. For the 400-level course, the pre- to post-survey responses were significantly different for the media, nonprofits, and government publications. Future work on activity development will consider abandoning or modifying these questions to elucidate student-preferred information sources. This information may reveal some level of critical thinking and analysis of information sources and their inherent biases.

Quantitative data for post-activity student responses to "This format was effective in my learning" are presented in Figure 1, both as number and percentages of student responses.

These self-reported data suggest general student agreement with the activity being effective in their learning, which is supported by many of the students articulating reasons for this agreement within their written comments. A few students in the 300- and 400-level courses mentioned their preference for lecture-based classes, which is perhaps influenced by the normativity of the lecture approach and its longer tenure within the curriculum. A few representative student comments are included in Table 5.

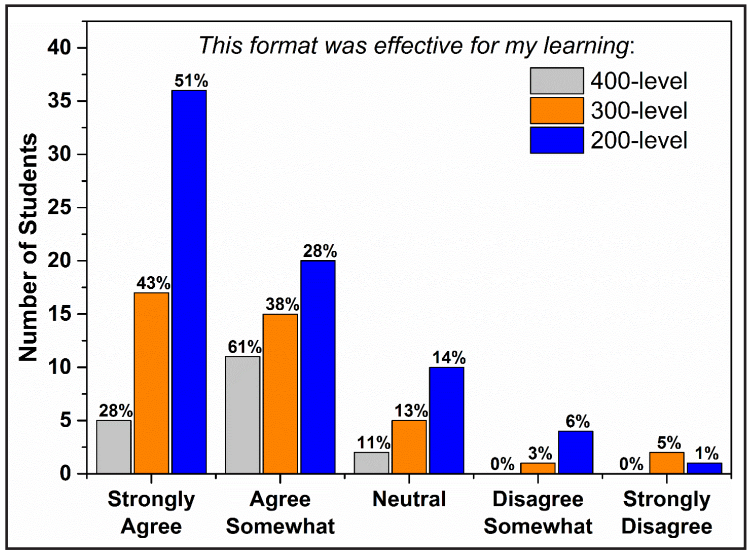

Figure 1. *Student responses to "this (class) format was effective in my learning."*

TABLE 5
Select student responses to: How was this approach better or worse than a "traditional lecture"?

200-Level
"Better, more involved and more visual."
"Interesting, felt like I was learning more and writing less."
"It was more engaging and intuitive."
"Very informative and good to see all sides compared to what was previously taught (now less bias)."
"This methodology of group learning is good in that less power was given to one person, and therefore had a reduced possibility for biased info. Group learning is also good for learning more effectively by teaching others. The drawback was that the group size made it difficult to learn and communicate."
"Working with peers is always more engaging for me. By having a class-wide discussion, we hear many points of view rather than just the professor; we can learn a lot from each other."
300-Level
"Good to do individual research and then talk with everyone about what was learned."
"This approach was more interactive and kept my attention better than a lecture."
"Lot better as the process of searching helps me remember the information learned instead of just taking the information from a source."
"Lot more involved which is enjoyable, but not as efficient information as in a lecture."
400-Level
"Getting more responsibility and interest and making students involved."
"Everyone was engaged, but was less effective than regular lecture. Would have taken notes and felt like it was more relevant to exams."

General inferences from these data include the apparent (self-reported) effectiveness in student learning and enjoyment of the activity, as well as the objectivity of the activity itself. However, there is always room for improvement, as identified by both the students and instructors. For example, the activity could be structured more effectively in terms of pre- and post-activity assignments to encourage student preparation and reflection, as well as permitting more in-class time for online research and group discussions. To better understand where students are soliciting information, students could record, justify, and reflect on their information source choices. For example, the option of "media" source might be expanded to consider specific media outlets—*e.g.*, PBS, CNN, or Fox—or Twitter, etc. Additionally, better uniformity of online resource instruction and in-class data collection, perhaps with no "neutral" option, would allow for improved cohort comparisons and avoided ambivalence. Finally, generalized topic-specific concept inventory tests could be employed to verify the self-reported learning effectiveness of the activity. While this activity may not be appropriate for every engineering course, it could be used in addressing many other complex "no right answer" issues.

SUMMARY

"Frack Attack," a transferable classroom activity that could be used in both core and elective engineering courses, is designed to combine active learning and teamwork to address sustainability topics in contemporary engineering contexts. The activity was explored in three chemical engineering courses at Montana State University: two elective courses on sustainable energy (one freshmen-level and one senior-level) and one core sophomore-level fluid mechanics course. Quantitative pre- and post-activity assessments demonstrate efficacy of the approach on effective student learning (albeit self-reported), and qualitative assessments based on student responses to open-ended questions indicate student engagement and preference over a lecture-based approach. Further development will include improved activity structure with pre- and post-class assignments to encourage recursive processing, more uniform data-collection processes, and inclusion of topic-specific concept inventorying.

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