Jigsaws & Parleys: Strategies for engaging sophomore level students as a learning community

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Abstract

Early chemical engineering coursework provides an important foundation in topics such as energy and material balances. A common pedagogical approach to these topics includes providing engineering analysis problems with basic context and a single correct answer. While this approach can help students develop mastery of content, it does not help students develop an understanding of authentic engineering practices, especially design problem framing and solving. Without this aspect, we risk losing students from underrepresented groups in engineering as they are less likely to have engineering relatives and friends who can help them see the real-world relevance of what they are doing in their early coursework.

We describe how we threaded a community-based, entrepreneurial design challenge focused on algal biofuel production through a core chemical engineering course. Participants included students (N=61) enrolled in a sophomore-level Chemical Process Calculations course at a large minority-serving research university in the American Southwest. Students worked in pairs on homework assignments to support peer learning. We replaced one question from each of the six homework assignments with design challenge deliverables. Students worked in subteams on one of the three algal production phases (i.e., growth, harvest, extraction). They also developed individual accountability through jigsaw sessions in which they explained their subteam's work to students from other production phases. They built whole-class consensus through "parley" sessions that involved decision matrices.

We describe the design challenge and our study, in which we investigated how a design challenge threaded through a sophomore course might provide students with a picture of authentic engineering design practices and content. More specifically, we wondered about students' perceptions of the jigsaw session, and to what extent the three different topics (algal growth, algal harvesting, and biofuel extraction) led students to learn substantially different information.

We developed coding schemes to analyze student work in the parley and jigsaw sessions. We found that the parley sessions provided opportunities for students to learn from one another. They argued from evidence and backed their ideas with research citations, sometimes leading their peers to amend their initial design decision. Even though they were assigned to a particular production phase, they investigated aspects of the other phases. We observed high student engagement throughout the design challenge.

Introduction and research purpose

Early chemical engineering coursework provides an important foundation in topics such as energy and material balances. A common pedagogical approach to these topics includes providing engineering analysis problems with basic context and a single correct answer. While this approach can help students develop mastery of content, it does not help students develop an understanding of authentic engineering practices. Without this aspect, we risk losing students from underrepresented groups in engineering, as they are less likely to have engineering relatives

and friends who can help them see the real-world relevance of what they are doing in their early coursework.

In this study, we sought to thread a design challenge through a core engineering sophomore level course, with a goal of using the design challenge to provide enhanced application of course content. We specifically examine the roles two collaborative structures—jigsaw and parley sessions—had in supporting collaborative learning.

Literature review

We review research on specific active learning strategies that influenced our curriculum design. These included project-based teaching, design learning, and active learning strategies such as jigsaw and small group collaborative learning.

Project-based learning typically involves posing a relatively broad problem or question that is ill-structured, meaning it has multiple possible answers [1]. Students collaborate to produce solutions to realistic or authentic problems, often learning professional practices along the way [2]. Although instructors provide some scaffolding and facilitate learning, much of the work is directed by the students [2]. Projects can be used as an accompaniment to traditional instruction as a way for students to apply what they are learning [3]. Past research contrasting project-based learning with traditional lecture-based instruction has shown greater gains tied to the former, especially when retention of information learned or application of information are considered [4-10].

In engineering courses, project-based learning is commonly implemented as design projects. Design projects provide students with opportunities to develop team and project management skills, as well as creative problem solving skills [11-16]. Design projects are a promising way to prepare students for industry [17]. Authentic design problems that have meaning beyond the classroom are most effective [18] as they allow students to integrate knowledge and practice [19].

Commonly, instructors include a host of active learning instructional strategies to scaffold student learning related to projects. Broadly, active learning instructional strategies have been shown to better support learning than traditional lectures [4, 20, 21]. We employed an active learning technique used commonly in the past—particularly in elementary classrooms—called jigsaw [22], which is well backed by learning theory [23, 24].

Jigsaw is a technique in which students work in a *topic group* to develop competence on a topic. Each topic group studies a different topic. Then, in *jigsaw groups*—which comprise a member from each topic group—students work collaboratively to teach each other what they have learned as they solve a problem. This approach is intended to foster interdependence and individual accountability. Jigsaw has been used in advanced engineering coursework; in most cases, data are limited to instructor observations and survey items, resulting in the finding that while students are initially skeptical, they perceive the process to be useful after participating [25-27]. Faculty have observed that students come to class better prepared [28], in part because there are social consequences for arriving unprepared [27]. Students report gaining soft skills such as teamwork and project management [29] and research shows the effectiveness of jigsaw in

engineering classrooms [30, 31]. We were interested in jigsaw for two main reasons: first, we were concerned that some students might be *social loafers,* meaning they would not put as much effort in [32]. Past research has shown that providing a meaningful task can prevent social loafing, but we also sought to address this by reinforcing the idea that every student was accountable for group work. Second, because we divided our students into three (interrelated) topic areas, we wanted them to have opportunities to learn from each other and share information across topics. This was in part because we were not sure how much overlap there would be in students' independent research across the three topics.

One of the challenges we faced in designing our curriculum was that we felt students needed to come to consensus on a few points, in part to align to the course content. Often, rather than developing consensus among students, a decision is imposed by the instructor. However, this can render the activity into 'just another class assignment,' stripping it of some of its authenticity. Others have argued that consensus can play an important role in collaborative learning; rather than smothering individuality, it can encourage active participation by giving each student a stake, and providing a means to make decisions [33]. We created "parley sessions" and designed decision matrix activities that guided students to build consensus, progressing from individual to subteam, to team, and finally to whole class consensus.

Broadly, we investigated how a design challenge threaded through a sophomore course might provide students with a picture of authentic engineering design practices and content. More specifically, we wondered about students' perceptions of the jigsaw session, and to what extent the three different topics (algal growth, algal harvesting, and biofuel extraction) led students to learn substantially different information. We investigated these ideas guided by the following research questions:

1. Did students maintain their own ideas or always come to consensus?
2. Did students have opportunities to learn about phases other than the one they were assigned to investigate?
3. To what extent did the jigsaw session foster students' perception of the need for individual accountability and support peer learning?

Methods

We present a balanced approach to threading a community-based, entrepreneurial design challenge throughout the semester, focused on algal biofuel production. Participants include students (N=61) enrolled in a sophomore-level Chemical Process Calculations course at a large minority-serving research university in the American Southwest. Students worked in teams on homework assignments and design challenge deliverables. We divided the class into three large teams, each focused on one of three production phases (i.e., growth, harvesting, extraction). We divided the large production teams into smaller subteams of 3-5 students.

The class met in a learning studio style classroom for three 50-minute lecture sessions and one 50-minute recitation session per week. This classroom included round tables, each with three laptop computers and nine chairs, abundant white boards, screens on all sides of the room, and a central instructor podium.

We replaced one question from each of the 6 homework assignments with design challenge deliverables (Figure 1). Some deliverables focused on building technical writing and communication skills. For instance, in week 3, students turned in a two-page project proposal written for potential investors, concisely detailing the history and development of the field, clear and measurable objectives, and any constraints and assumptions. The week 5 deliverable was a written project status update. The week 7 deliverable included an annotated bibliography with a minimum of 6 sources and sample process calculations, in which students identified important process variables and applied knowledge gained in class by proposing at least two calculations.

Other deliverables mapped to the course content. For instance, the week 11 deliverable was embedded in the phase worksheet (e.g. choice of community for the growth phase) that was due as homework that week. The week 13 deliverable was a process description with a flow chart, including each material stream, flow rate, and component clearly labeled and described.

Each production phase team presented in week 14 and delivered their final video in week 15. The video detailed what the challenge was, possible solutions, and what they learned from the challenge. In order to support subteams to come to consensus as teams, we designed "parley" sessions and substituted three lecture class periods with "parley" sessions. During these sessions, students built whole-class consensus using decision matrices. Prior to class, they identified criteria, conducted independent research, and made an individual choice. In class, they met for 15 minutes in their respective subteams to come to consensus on members' decisions. These subteams then worked for 15 minutes in their production phase teams to come to consensus across subteams. Each production phase team elected a "champion" to present the team consensus to the class. The champions presented evidence from the previous discussions for the last 20 minutes of class.

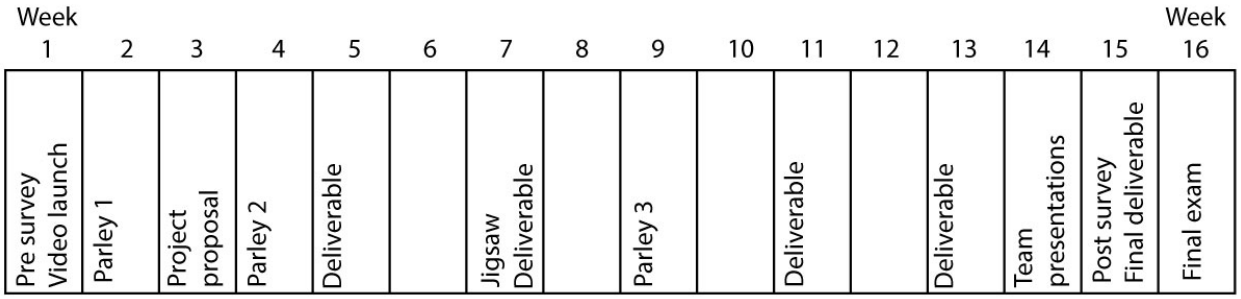

Figure 1. Overview of the course structure.

The parley sessions focused on decisions that impact all three phases, although the topics were inherent to the growth phase. The first parley session focused on selecting a method for growing algae (Appendix B). Prior to the session, students researched open ponds and bioreactors to weigh the pros and cons of using each in algal biofuel production. The second parley session focused on strains of algae (Appendix C). Students identified criteria and possible strains to promote economic viability. The third parley session focused on sources of CO_2, working within design constraints given in the prompt (Appendix D); for instance, the CO_2 source had to be low cost. Students researched both general and specific sources. Students were encouraged to make decisions with attention to criteria important for their particular production phase. For example, although choosing between open pond and bioreactor clearly impacts the growth phase, it also

impacts how the algae will be harvested and how the fuel will be extracted (e.g. harvest pump for mass transfer to filter system, water return from extraction to bioreactor), and these decisions have energy and economic costs.

Additionally, we sought to enhance individual accountability through a jigsaw session, midway through the course. Originally we planned to prepare the students for the jigsaw session, but due to scheduling conflicts, we held the jigsaw in the recitation period directly following an exam. To avoid burdening students already anxious about an exam with the need to additionally prepare for this activity, we decided not to announce the session prior to class. Students were tasked with explaining their subteam's work to students from other production phases. We asked them to share the following in their jigsaw groups:

- Update of important findings
- What was important to know for your particular phase?
- Why was it important for your design?

At the end of the jigsaw session, we elicited anonymous feedback, asking the students to write what they'd like to see improved, what their thoughts were on the jigsaw, and what they liked.

We collected student work (e.g., see Appendix B, C & D for sample assignments) and developed coding schemes to evaluate student work on the second parley session (Table 1) and the jigsaw session (Table 2). In both cases, we developed these coding schemes inductively, allowing codes to emerge from the data [34-37]. This involved reviewing each coding scheme multiple times, refining descriptions to enhance reliability of codes that were high inference, merging redundant codes, and breaking complex codes into simpler, low-inference codes. We coded a subset of data independently, and followed qualitative analysis guidelines for discussing the nature of discrepancies between coders [38]. We additionally tested the refined coding schemes with the second author's research lab, the members of which have experience conducting qualitative analysis. All data were coded by at least 2 people, and 80% of the data were coded by 3 people. To assess interrater reliability, we calculated Fleiss's kappa, which can account for multiple raters, $\kappa = .93$, showing almost perfect agreement [39]. We attribute this high interrater reliability using low inference codes.

We calculated descriptive statistics and conducted Pearson's chi-square test to determine if the codes varied systematically by production phase.

Table 1. Scheme used to code criteria students listed for selecting an algae strain

Code	**-1**	**0**	**1**
Temperature	Not mentioned	Mentioned without elaboration *Ex: "Temperature"*	mentioned with (specific) range, concerns about too hot or cold, or fluctuation *Ex: "Temperature range 15-25C"*
Growth	Not mentioned	Mentioned without elaboration *Ex: "Growth" "biomass"*	mentioned with specific details, growth rate or biomass production rate *Ex: "Growth 24 hours per day"*

Code	**-1**	**0**	**1**
Light	Not mentioned	Mentioned without elaboration *Ex: "Light"*	mentioned with specific or technical detail, or with range *Ex: "Damage resistant to synthetic light"*
Water source	Not mentioned	mentioned without elaboration *Ex: "Wastewater"*	mentioned with specific detail or source, possibly as source of nutrients *Ex: "Grown in dairy wastewater"*
Lipid Content	Not mentioned	mentioned without elaboration *Ex: "Oil" "Lipid"*	mentioned with specific or technical detail, or with range *Ex: "Lipid content per gram"*
Harvest	Not mentioned	mentioned without elaboration *Ex: "Harvest"*	mentioned with specific or technical details about harvesting *Ex: "Ease of harvesting"*
Extract	not mentioned	mentioned without elaboration *Ex: "Extraction"*	mentioned with specific or technical details about harvesting *Ex: "ease of extracting"*

Table 2. Scheme used to code student reflections on the jigsaw activity. Students were given a score of 1 if the idea was present and a score of 0 if the idea was absent.

Code	**Description and examples**
Perspective taking	They got to understand a different perspective or point of view *Ex: "It is helpful to get different perspectives and clear up misunderstandings"*
Peer learning	They learned or enjoyed discussing with their peers *Ex: "I enjoyed having time to talk with my peers about the project."*
Smaller group	They want to work in smaller group *Ex: "It might be a little easier with less people per group"*
Time to prepare	Student says they wished they had more time to prepare, or that their peers needed more time to prepare *Ex: "There should be notice in advance so that people can prepare to talk about their topic.*

Results and discussion

Although we analyzed data from all parley sessions, we found that in parley session 1, students came to consensus unexpectedly quickly. While they used diverse sources to make the decision, only one subteam started the class favoring open ponds over bioreactors. We did observe active participation and sharing of resources, including requests for sources to be posted to the course

website. However, because a majority of students agreed at the outset, this session did not offer opportunities to investigate our research questions.

Research question 1 investigated whether students maintained their own ideas or always came to consensus. We focused on data from the second parley session to answer this question because this session offered the greatest diversity of ideas, with students suggesting numerous criteria and many strains of algae. This was also far enough into the semester that teams had begun to identify sources advantageous to their production phase (growth, harvest, extraction).

We first investigated whether students changed their minds, and where they appeared to come to consensus. In their initial algal strain selection, we found diversity in terms of the strains they selected. Students listed 13 specific strains, and a number of students listed Chlorella without specifying the species (Table 3). Of the 57 students who both provided consent and completed the parley session, 37 (65%) changed their minds at some point during the parley about which strain they would choose (Figure 2). Almost half of the students changed their mind after discussing their choice in their subteam and almost 40% changed their minds after discussing their choice with the other subteams in their production phase. Fourteen students changed their choice twice. The "official" choice of each production phase and of the whole class was Chlorella *Vulgaris*, though a number of students simply listed "Chlorella." One student persisted with his choice of Chlorella *Spirulina* throughout the parley.

We infer that the parley session provided students with abundant opportunities to argue from evidence and convince their peers to reconsider their decisions. Because students had researched different strains, they had to explain both their criteria and defend why they had made their choice. With so many options of criteria and strains, the parley session allowed students to research just three strains each, yet learn about other strains from their peers.

Table 3. Algal strains selected by students individually, in subteams, and in their production phases.

	Individual choice *(pre-class)*	**Subteam choice** *(parley)*	**Phase** *(parley)*
Chlorella	20	21	37
Chlorella *Vulgaris*	6	9	16
Nannochloropsis	10	7	0
Botryococus *Brauni*	7	5	0
Chlorella *Spirulina*	5	8	1
Dunaliella *Tertiolecta*	3	0	0
Chlorella *Protothecoides*	2	3	0
Mixed	1	1	0
Schizochytrium	1	0	0
Chlorella *Ellipsoidea*	1	0	0
Rhodophyta	1	0	0
Chlamydomonas *Reinhardtii*	1	0	0
Chaetoceros *Gracilis*	1	0	0
Chlorella *Emersonii*	1	0	0

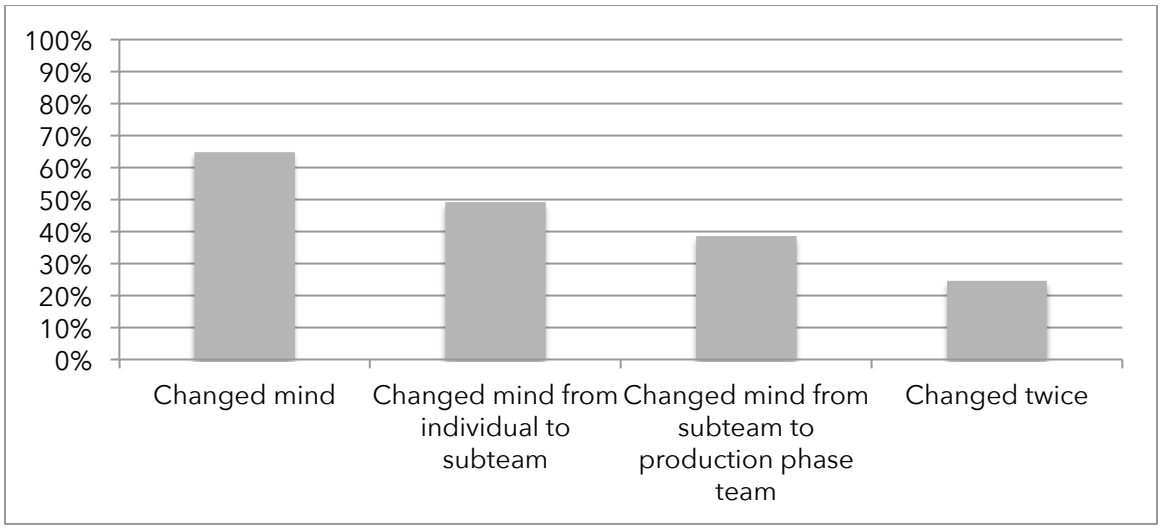

Figure 2. Over 60% of students changed their minds about which strain to select during the parley session.

Research question 2 investigated whether students had opportunities to learn about phases other than the one they were assigned to investigate. We first investigated this question by considering the criteria students chose to evaluate algal strains. Most students included criteria related to growth in some form, such as the temperature range, light quality, and nutrients algae need to grow (Figure 3). Likewise, most considered the growth rate and lipid content. We conducted Pearson's chi-square test to determine if the codes varied systematically by production phase. We found a significant association between production phase and mentioning temperature as a criterion, $\chi^2(4) = 10.81$, $p < .05$. There was no significant association between production phase and any other criterion. Based on this, we infer that students considered aspects of biofuel production that were outside their assigned production phase.

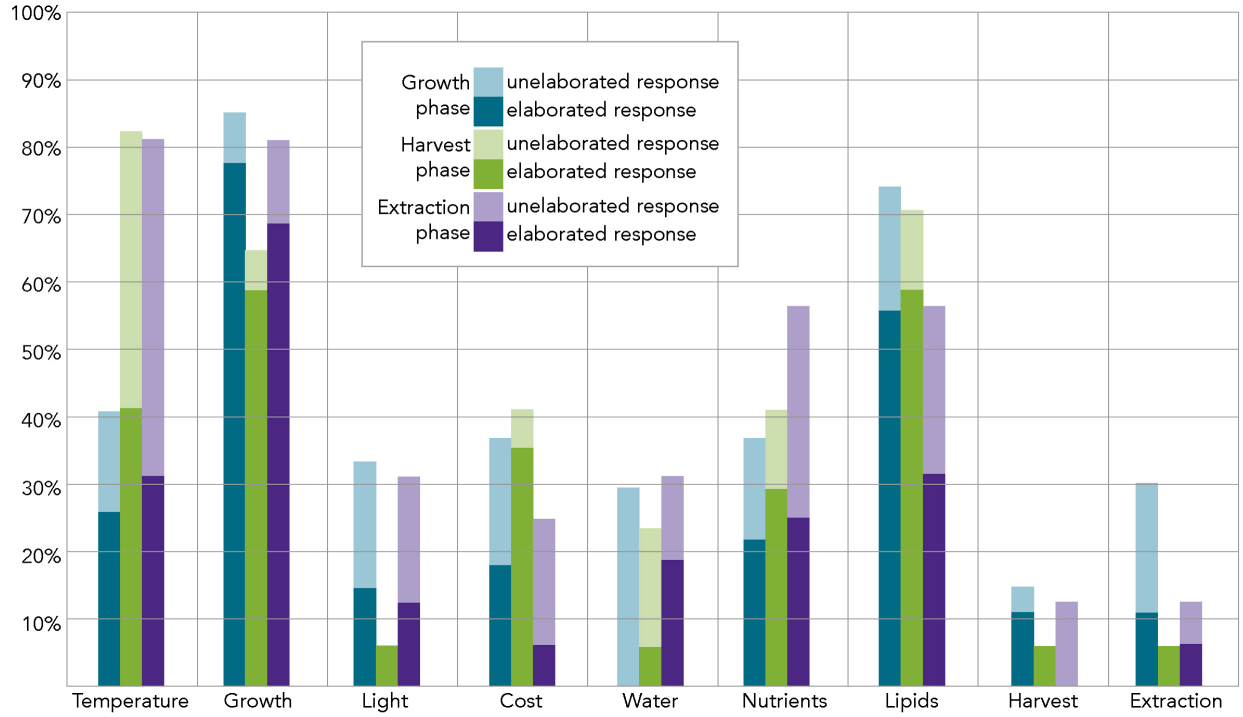

Figure 3. Students provided unelaborated and elaborated criteria. While the criteria differed somewhat by production phase, every phase converged on the same general set of criteria.

Analysis of student artifacts from the third parley session supports the premise that students carefully considered the research of other subteams. In this parley session, they were asked to choose criteria for selecting carbon dioxide (CO_2) sources. During the consolidation period for subteams, students in the growth phase (five subteams total) identified 6 major sources of CO_2: dairy farms, fossil fuel power plants, ethanol fermentation plants, air capture to CO_2 reservoirs, and purchase of compressed CO_2. From the six sources, students consolidated multiple decisions and used matrices to select ethanol fermentation as the growth phase team choice.

However, three members of a four-person subteam listed a *rogue* choice as the production phase team choice. Instead of listing ethanol fermentation, they listed Kinder Morgan. Kinder Morgan is an energy infrastructure company in New Mexico with a large network of pipelines used to transport petroleum products and carbon dioxide. No student in the growth phase team had done research on Kinder Morgan, so we initially wondered where this choice came from. We found that one subteam from the extraction phase team selected Kinder Morgan as a CO_2 source. We infer that these two extraction phase subteam members persuaded members from the growth phase to make this rogue choice, as they also convinced the members of their own production phase team to choose Kinder Morgan. This also demonstrates the enhancement of students' ability to make sense from various pieces of knowledge as well as diverse and contradictory points of view.

Across these parley sessions, we observed students making requests for their colleagues to back their work with citations, arguing from evidence, and making clear connections between engineering content and application.

Research question 3 investigated students' perceptions of the jigsaw, including whether it fostered individual accountability and supported peer learning. During the jigsaw session, most students were actively engaged, listening, questioning, explaining, and sharing resources with each other. This experience provided an opportunity for peer learning, and students took advantage of the opportunity.

Peer learning. Overall, 70% of students mentioned the benefits of working in small groups and learning from their peers (Figure 4). 8 students suggested having smaller groups for the jigsaw, "smaller groups would have been more productive overall." 18 students liked seeing the problem from other perspectives. For instance, one student explained, "The jigsaw setup was really neat because even though we are in the same there was different approaches people were taking." 31 students reported that they liked learning from their peers. For instance, one student explained, "Sharing idea between a group of students is a good idea because each one have his own idea and each one gave his own opinion so it provide the student more information."

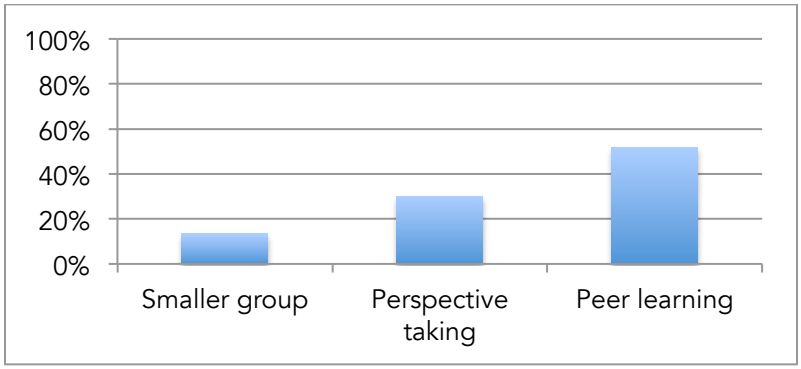

Figure 4. 70% of students brought up at least one idea related to small group collaboration, such as desiring a smaller group to have more participation, appreciating hearing other's perspectives, and having opportunities to learn from each other.

Time to prepare. 23 students wished they'd had more time to prepare. They expressed this with detail, "Having prepared discussion material would improve my ability to answer questions and explain my team's work, and it would also allow me to more actively learn from the members of the other teams"; "I would have prepared a little more if I had known we were going to have the jigsaw"; and "Although we listed sources that contain information in our deliverable, no one was actually ready to discuss it."

The purpose of a jigsaw is to help create a sense of individual accountability in collaborative learning. Although we did not originally plan the jigsaw to be like a pop quiz, we actually see value in it. Providing students with an unannounced jigsaw session, then asking them to reflect on ways to always be prepared for such sessions, we think, will motivate them to make sure everyone is prepared to explain what they are learning to their peers. We think this "authentic pop quiz" reflects real life, as there are many situations engineers may be called up to provide their judgment or expertise on the spot.

Discussion and significance

Both the parley and jigsaw sessions provided opportunities for students to learn from their peers. Like others, we found that our students were initially uncertain, but that they generally perceived the jigsaw process to be useful after participating in it [25-27]. In some cases, it made them wish they had been better prepared for the session, reinforcing the notion that this approach creates social consequences that can support learning [27].

The parley sessions served the consensus-building role we hoped for within collaborative learning. While in the first parley session, the majority of students started class with the same decision, they still backed their decisions with different sources, and the parley session provided opportunities for them to share resources. In the second and third parley sessions, they arrived with varied ideas and we observed active engagement from students as they argued from evidence. These two sessions showed that rather than smothering individuality, the parley sessions encouraged active participation by giving each student a stake and providing a means to make decisions [33]. The pre-class assignment, which led students to conduct independent research and to make an initial decision, encouraged them to come to class prepared to argue their from evidence. The decision matrix aided them to build consensus as they did so.

Although traditionally the jigsaw approach has been used to ensure students develop expertise in particular areas, we found that the parley sessions also accomplished this, providing opportunities for students to conduct independent research, then sharing what they had learned within their small subteam, and then across subteams. Although we used the parley sessions to support students to make progress on a design challenge, future work could investigate using this same approach for other purposes. The parley sessions helped foster student ownership of engineering content by providing opportunities for them to defend their ideas. Finally, this study is part of on-going efforts to improve the retention of diverse students. Future studies will examine how approaches such as the jigsaw and parley sessions contribute to these efforts by creating more opportunities for such students to understand the work of engineers and to connect with their peers.

In future iterations, we plan to use the jigsaw session as an authentic approach to a pop quiz. Although it effectively served this purpose in the course, it came too late to be very effective. In future iterations, we will explore how an unannounced jigsaw session can reinforce individual accountability.

Limitations. The purpose of qualitative research is not to produce generalizable knowledge, but rather to understand processes, in this case, that support learning. As such, our findings are tied to our context, which, as a Hispanic-serving research university, differs from other contexts. We therefore discuss the transferability of our findings [40]. By providing thicker descriptions of the activities and our analysis of them, others may design adaptations for their own contexts. For instance, approximately 20% of our students come from rural communities, and in related work, we are exploring how these students provided local knowledge of rural communities, which was important information for students designing an algal biofuel plant for a rural community. In predominantly urban populations, this information might be lacking, and may need scaffolding, or the problem may need to be changed to be more relevant to an urban population. Additionally, these activities occurred in a learning studio classroom, which afforded greater social learning opportunities. We would anticipate challenges for faculty teaching in stadium style lecture halls, as students' expectations can discourage active engagement in such spaces.

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Appendix A. Design Challenge Brief: Design an algae production facility for a small community in NM

Introduction

In the past decade, the US Department of Energy alone has invested millions of dollars into the research and development of biofuels derived from algae. This is in addition to the investment made by industrial entities who wish grab a share of the market in this promising field. So why such a push?

First of all, biofuels represent a preferred alternative to traditional fossil fuels. Unlike fossil fuels which are net emitters of carbon, biofuels ultimately pull carbon from the atmosphere creating a carbon neutral energy source. In fact, most of the fossil fuel deposits we mine from the earth today began as algae in various water systems, so the process of deriving biofuels from algae simply allows a much more rapid jump from the carbon source to energy [1]. The process of growing, harvesting, and converting algae to fuel is also something that can be done domestically, which is strategically preferred to foreign dependence on fossil fuels.

Still, with so many potential sources for biofuel, why algae? For example, corn is currently the largest source of biofuel in the US and is used to produce ethanol. But where each acre of corn can be harvested only once a year, portions of the algae grown in an acre-sized pond can be harvested every day [1]. Certain species of algae can be composed of 50-70 percent oil by mass which makes it an ideal source for producing biodiesel [2].

One of the major challenges facing biofuel production from algae is being able to grow algae at a quick enough rate to make the process profitable [3]. While algae may seem to grow rapidly in a natural environment, such as a pond, the rate isn't actually sufficient enough for fuel production and is limited by the amount of nutrients that are accessible to the algae from the natural environment.

A small rural community in New Mexico relies on the local dairy farms to support its economy. One of the problems with these dairy farms is they produce a large amount of wastewater. One of the ways that we can mitigate the amount of wastewater is to use it to support a large scale algal biofuel production facility, with added benefit of increased economic stability.

Your tasks are to grow, harvest, and extract oil from a chosen algal species. For this endeavor to be successful, 30 grams of algae must be grown per square meter per day.

Student Learning Outcomes

Students should be able to:

- research the key unit operations currently used for micro-algae based biofuel production and produce a process flowchart
- identify issues with large scale production
- propose a production facility for algae within constraints
- complete a mass balance on the production facility and determine overall conversion of algae carbon into fuel

Project Constraints

- Temperature range for algae growth 15 -25C
- Algal growth must take place 24 hours per day
- Water Sources should not be shared with farm irrigation and drinking consumptions
- Land area should be valuable farmland for food supply
- Selected NM community should have a population size – less than 10,000
- Selected carbon dioxide source must have low cost

References

[1] This American Land, 2014, https://www.youtube.com/watch?v=d5laQZbJ2mg

[2] University of Kansas, 2014, https://www.youtube.com/watch?v=Ve1tBAc1fss

[3] Our Ohio, 2012, https://www.youtube.com/watch?v=pA4a_I-rb3Q

Appendix B. Parley 1 worksheet

Parley 1

To begin the challenge, you will focus your research on exactly how you will grow your algae. For each facility type (Photo Bio-Reactor and Open Pond), what are the strengths and the disadvantages?

When you complete this worksheet **individually**, come together as a team and using a decision matrix (see attached example), compile your criteria to determine the best fit for your needs.

Attach a separate page with any additional information and necessary citations to support your choice.

First: What are the needs and constraints of your facility type?

NEEDS:	**CONSTRAINTS:**

With the above in mind, consider the strengths and weaknesses of growing algae using the methods below.

Photo Bio-Reactor Tubes

PROS:

CONS:

Open Ponds

PROS:

CONS:

My Choice	

In Class:

Choose a growth method

With your team, complete a decision matrix to choose a growth method.

As an example, a student used a decision matrix to choose a major. Based on the matrix, she chose to major in chemical engineering.

	Potential paycheck after graduation	Difficulty of curriculum	Will I need to go to graduate school?	How easy will it be to get a job?	How much do I like the subject matter?	TOTAL
Chemical Engineering	3	1	3	3	3	13
Biochemistry	1	3	1	2	2	9
Mechanical Engineering	2	1	3	3	1	10
Mathematics	1	2	1	1	1	6

	Replace with criterion 1	Replace with criterion 2	Replace with criterion 3	Replace with criterion 4	Replace with criterion 5	TOTAL
Photo Bio-Reactor Tubes						
Open Ponds						

You might change your mind as you decide which method to use. With each step, record your decision.

My Choice	
Sub Team Choice	
Team Choice	
Class Choice	

Appendix C. Parley 2 worksheet

Parley 2

For this part of the challenge you will select, as a class, the strain of algae you will use for the facility. Every strain of algae is different, and some strains are better equipped than others to serve as biomass for fuel.

Before Class:

To begin, **individually** refer to the previous worksheet and revisit your facility needs and constraints. What are some important criteria that you can use to evaluate whether a particular strain meets those needs? List those below.

-
-
-
-
-

Considering the criteria above, look at 3 different strains and research how best they fit to your criteria. What are the benefits and drawbacks? Which strain would you choose? Attach any research notes with necessary citations.

Strain 1

Strain 2

Strain 3

My Choice:	

In Class:

With your team use a decision matrix to decide which strain you think you should use.

	Add Criteria 1	Add Criteria 2	Add Criteria 3	Add Criteria 4	Add Criteria 5	Total
Strain 1						
Strain 2						
Strain 3						

With each step you might change your mind on which strain to choose. Record your decision along the way.

My Choice	
Sub Team Choice	
Team Choice	
Class Choice	

Appendix D. Worksheet for Parley 3

For this part of the challenge you will select, as a class, the source of carbon dioxide.

Algae consume carbon dioxide for normal growth during photosynthesis and adequate supply is needed to help realize large scale production. Recall, your plant is located in Vado, New Mexico. The plant size is 13000 ft^2 and stream factor 0.9 (i.e. 324 days for the year).

Before Class:

Keeping in mind the algae facilities needs and constraints, what are some important criteria that you can use to evaluate whether the selected source is viable? List those below.

-
-
-
-

Considering the criteria above, look at 3 different sources and research how best they fit to your criteria. What are the benefits and drawbacks? Which source would you choose? Attach any research notes with necessary citations.

Source 1

Source 2

Source 3

My Choice:	

In Class:

With your team use a decision matrix to decide which source you think you should use.

	Add Criteria 1	Add Criteria 2	Add Criteria 3	Add Criteria 4	Add Criteria 5	Total
Source 1						
Source 2						
Source 3						

With each step you might change your mind on which source to choose. Record your decision along the way.

My Choice	
Sub Team Choice	
Team Choice	
Class Choice	