Incorporating Bioenergy Education into Agricultural Youth Based Programs:  
A Pilot Study

By

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4-H, an agriculture based youth program, promotes a variety of curricula in both agriculture and Science, Technology, Engineering and Math (S.T.E.M.) topics. However, science based curricula provided by this organization gravitates away from the programs agricultural roots. An effort was made to pilot a test on lesson plans that would serve to connect agriculture and S.T.E.M. topics in a youth based curricula. The subjects of study focus on the feedback from leaders of volunteering 4-H clubs. Neither short nor long term lessons showcased a substantial advantage over the other in this pilot study. However, several results showcased interesting connections in the style of curricula provided to the leaders and it's combination of S.T.E.M. and Agriculture topics. Numerous options exist for future endeavors of this study and the utilization of these curricula.
Introduction

The purpose of this research was to determine whether the length of time for a specific curriculum effected it’s success in an agriculture based after school program. The curricula used to enhance Science, Technology, Engineering and Math (S.T.E.M.) topics into this setting focused on the concept of bioenergy education. This research aims to gather data to determine what the most effective way to introduce this subject matter to a youth program that previously had limited availability to this type of curricula.

Energy that is derived from biomass is called bioenergy. Biomass is organic material in a non-fossilized form and includes, but is not limited to: agricultural crops, forestry, agricultural and forestry wastes and by-products, manure, microbial matter, and industrial and household organic wastes (PNAS, 2009). Biomass from the agricultural industry can be an important resource in the drive to find clean, sustainable energy sources. Two such examples include crop residues and waste from livestock. According to the Union of Concerned Scientists; United States agriculture could provide up to 155 million tons of residues and 60 million tons of manure for producing bioenergy in 2030. Because these residues are a by-product of today’s primary crops, such residues can be used to produce energy without expanding the amount of land agriculture now occupies (USDA 2009). Development of the technologies, practices, and policies needed to use agricultural biomass resources responsibly will ensure that communities across the country benefit both financially and environmentally while the nation curbs its oil and coal use and global warming emissions (USC, 2016).

Fermentation can be used in agriculture settings to produce bioethanol, and foods such as yogurt, cheese, beer, cider, and wine. Fermentation is a chemical reaction where more complex organic materials are broken down (oxidized) into simpler compounds and energy is released, all without the presence of oxygen. Sugars can be converted to acids, alcohol, and methane via the fermentation processes. An organic molecule serves as the electron acceptor because oxygen does not (oxygen serves as the terminal electron acceptor in aerobic respiration). Fermentation is one of humans’ earliest form of food preservation technology, allowing food to be preserved products and not just perishable items. It allowed for the expansion of products derived from agricultural related crops, expanding seasonal constraints of food products. Presently, fermentation serves as a key generator of biofuels (Zilberman and Kim, 2011). Ethanol is produced by Saccharomyces cerevisiae, biobutanol by Clostridium acetobutylicum, and methane by a number of microbes.

Anaerobic digestion creates gases such as methane through numerous microbes breaking down complex substrate (organic material such as sewage) via fermentation reactions. The gases produced from this process can be burned to create bioenergy. Anaerobic digestion can be instrumental in agriculture waste removal on farms and ranches. It can provide a safe way to dispose and control manure waste and run off, and gas production that could otherwise be detrimental to the environment. Depending on the size of the farm, anaerobic digesters provide the tools necessary to utilize the excessive amounts of manure produced by livestock to create biogas, a source of ener-
Farmers can then use the biogas to heat or power the farm, or they can take it one step further by purifying it and selling it as renewable natural gas to alternative locations. Using this process on the farm can aid in improved water quality, lower the manure methane emissions, and allow for nutrient return to the soil. Common feedstocks of anaerobic digestion include: sewage sludge, organic farm wastes, municipal solid wastes, green/botanical wastes and organic industrial and commercial wastes (Monnet, 2003). Currently, most farm manure is collected and stored outdoors to decompose. This practice can lead to unpleasant odors, harmful air pollutants (such as ammonia, hydrogen sulfide and particulate matter) and greenhouse gasses (such as methane and nitrous oxide) being released (Cuellar and Webber, 2008). Biogas and digestate, the two products produced during the Anaerobic digestion process, can be reused in the form of clean energy. Biogas can be used to produce electricity and heat and digestate can be used as a fertilizer or processed into compost to increase its quality (Monnet, 2003).

There are examples of bioenergy education for both anaerobic digestion and fermentation that exist today in the United States. The Wisconsin Energy Institute boasts an anaerobic digestion lab using a waste stream to create energy and fertilizer. In addition, the emergence of organizations such as the Energy Biosciences Institute (EBI) at the University of California-Berkeley are likely to become a common occurrence and not just an exception. The EBI links crop science with basic biology, chemistry, ecology and industrial engineering with social and decision sciences (Zilberman and Kim, 2011). Rutger’s University Research Experience for Teachers in Engineering aims to develop curricula for students to use during classroom exercises and as a part of summer outreach. While this program touches on bioenergy, the main focus is on engineering and classroom based exercises. However, agriculture biomass is an important energy source in the United States; in particular, crop residues are one of the largest biomass resources (USC, 2014). Curricula being utilized for this study, integrating bioenergy education into youth based programs, included lesson plans offered by ScienceBuddies and the Oregon State University Bioenergy Education Initiative. In order to expose future participants in the Agriculture industry, our aim was to tailor these lessons to specifically appeal to youth already involved in agriculture related areas.

4-H is a youth program geared for grades 4th-12th, and has strong ties to agriculture. Many of the programs participants are from rural communities and are also likely to pursue a career related to agriculture. Therefore, 4-H leaders are the target population for this study, and will provide data through surveys, post lesson delivery, as to the lesson’s effectiveness in communicating knowledge on bioenergy, enthusiasm for the subject matter, ease of teaching, and relation to agriculture and 4-H ideas/goals. 4-H is the nation’s largest youth development and mentoring organization in the United States, with connections to 6 million youth, partnerships with 110 universities, numerous clubs, after school programs, camps and school enrichment programs. 4-H is a youth development program that is run through the United States Cooperative Extension System and the United States Department of Agriculture. 4-H began in 1902 and its over 100 year history has produced a number of curricula based education projects, including S.T.E.M. curricula, such as: Aerospace, Computer, Electric, Food Science, Geospatial,
Robotics, Small Engines and Wind Energy (4-h.org, 2016) While these topics, in particular Wind Energy, are similar to Bioenergy Education topics; our research aimed to tie these science based topics specifically to Agriculture, making it align better with agriculture-related missions of 4-H clubs which are a part of a program that is funded by the United States Department of Agriculture.

Using pre-existing lesson plans, our objective was to determine whether short or long term projects were more effective in stimulating interest and building knowledge about bioenergy in the agricultural world. The short term lesson plan was provided by Oregon State University's Bioenergy Education program and focused on Fermentation. The long term lesson plan was provided by ScienceBuddies and focused on Anaerobic Digestion. Both lessons involved breakdown of organic materials to produce gas; however each lesson varied in the amount of time needed for completion. The short term lesson plan runs for approximately 30-45 minutes, while the long term lesson plan runs approximately 3-6 weeks.

Theoretical Framework and Research Question

While learning and outreach are key ingredients to the 4-H program, many science based curricula provided by the organization expressed a distinct disconnect from the program’s agricultural roots. In order to evaluate what makes a lesson successful in 4-H clubs, a post lesson survey was developed to quantify data from the leaders who delivered the lesson plan. In this study, we identified three important factors required for lesson plans to succeed within this agricultural youth program: (i) ease of teaching, (ii) relevance to agriculture, and (iii) student engagement and learning. These three focus points were developed with the assistance and suggestion of educators at Oregon State University. The leaders (teachers) who delivered the lesson should not be required to be experts in the field of bioenergy in order to successfully teach their students, and the materials (both provided and acquired for the lesson plan) should not be difficult to attain and use. In order to integrate these lesson plans into 4-H, the connection between the two should be clearly outlined in the lesson and lesson plan so that the students are able to notice and relate to it. Successful lessons can be measured by student’s enthusiasm, energy, and take away knowledge. Information on all these criteria and focus points should be collected from the view point of the leader who delivered the lesson and their assessment of the lesson’s challenges, relevance and effectiveness.

4-H represents a wide range of ages among their members. While the program as a whole is comprised of 4-12th grade students, both of our lesson plans are geared for 6-8th grade students so that they appealed to all age ranges represented. 4-H promotes community service and leadership within their membership, which also allows the older members of the clubs to assist younger who may find the curriculum more challenging. An advanced section of both curricula being utilized always for the expansion on the age range to include 9-12th grade members as well as the 6-8th grade members. Although 4-H represents various activities (e.g.: cooking, archery, livestock, and sewing), these lessons were tested on clubs with a livestock/animal based theme. In
order for these lessons to be a success, they must be repeatable. As such, leaders were the designated individuals for data collection as they are the individuals who would deliver these curricula in future applications.

**Research Context and Methods**

Two lesson plans, differing in length of time to complete, were compared in a 4-H club meeting setting to determine which was the most effective method to integrate S.T.E.M. ideas into an agriculture youth program. This pilot study compares 4 locations in rural areas of the Willamette Valley, Oregon. The towns used vary in size from approximately 55,000 to 3,500 to 852 people. Appendix A and B outline the two different lesson plans; Appendix A represents “short term” and Appendix B “long term” in regards to experiment length. An effort was made to select two lesson plans that were as similar as possible, the only main difference being the length of time to complete. Both lesson plans use organic feedstock to create an anaerobic reaction that produces gas. The lessons were tested by the student researcher prior to their use for this study to ensure their effectiveness. A random number generator was used to assign either the short or long term lesson plan to 4-H club leaders participating in the study. The lesson plan was delivered 24 hours prior to the delivery of the lesson to give all of the leaders the same amount of time to review the document. One hour prior to the 4-H club meeting, the student investigator met with the leaders to go through the provided lesson plans. The student investigator went through the teacher pages of the lesson plan, answering any questions that the leaders had regarding the lesson, bioenergy, or the specific topic at hand (fermentation or anaerobic digestion).

Leaders were not aware of whether they were teaching the short or long lesson plans. Post lesson delivery, leaders responded to a survey generated via Qualtrics software. The survey, as seen in Appendix C, includes reflective statements targeted to assess the lesson plan in three aspects: ease of teaching, relevance to agriculture, and student engagement and learning. The survey also allowed the leaders a chance to provide input and critique on lesson improvements and how it connects to the ideals of their club’s goals and themes. The survey was developed by the research team utilizing Qualtrics survey software. The questions that were posed on the post-lesson survey were developed based on the research teams’ cumulative background in education at Oregon State University. The post lesson survey was delivered 24 hours after the completion of the lesson plan. Leaders used in this study were chosen based off of a volunteer basis. Leaders who volunteered to pilot these lesson plans in a 4-H setting included horse and livestock 4-H clubs. All of the leaders who volunteered to participate in this study were women, and 75% of the clubs were comprised solely of females as well.

The first location to test the short term lesson plan (ST1) involved a Horse 4-H leader that had previous knowledge on bioenergy based on the data collected. The club was comprised of mostly younger students (only one student was high school aged), with a total of 8 students present for the meeting, and many with no prior knowledge of bioenergy concepts. The meeting took place in the conference room of a pizza parlor in conjunction with a sit-down business meeting. The Leader at the second loca-
tion (ST2) did not rank herself as high as having previous bioenergy knowledge, however the students were listed as more knowledgeable on bioenergy than the previous test group. This lesson was completed in conjunction with a Horse 4-H ride meeting, where students brought horses to ride for instruction, and the curriculum was completed throughout the other club meeting activities. All of the students at this meeting were middle school or high school aged (between 7-12th grades) and included a total of 5 students. While it was not listed in the curricula, both sites testing the short term lesson plan opted to divide the tasks up within the group of students present. With the smaller groups, both leaders asked each student to manage one bag from the lesson and then collaborate together to collect results.

The first site used for the long term lesson plan (LT1) was held prior to a Horse 4-H ride meeting at the leader’s barn. The leader identified the students as having very little previous knowledge on bioenergy concepts. This was a smaller club, with 4 young (6th grade and under) members who participated in this lesson. The students all had horses, and took horseback riding lessons at the barn where the curriculum was delivered. This allowed the leader to house the experiment at a central location, where all the students had access to it throughout the duration of the experiment and could work together to record results as anaerobic digestion of feedstocks within the bottles took place. In addition to the required feedstocks for the curriculum (cow manure, and vegetable peelings), this club opted to do an additional bottle to see how horse manure compared. The second site (LT2) had a variety of ages and science backgrounds (6-10th grade) within the 8 students who participated. The leader for this Livestock 4-H club opted to deliver the lesson during their local county fair while all of the club members where assembled. The students did an additional bottle for pig manure to compare to the standard feedstocks listed in the curriculum.

Results:

While trying to establish whether short or long term lessons were more successful in this agricultural based youth program, several key points of interest in the study included: ease of teaching, relevance to agriculture, and student engagement. These three focus points were chosen based on the environment the lesson was being marketed to, and the successfulness of the lesson plan as an educational tool.
Ease of Teaching

a) Figure 1. a) Ratings (0-5; 5=strongly agree, 0=strongly disagree) leaders provided through post lesson surveys. Red I-bars indicate leaders opposing scores, while no I-bar indicates that both locations’ leaders provided the same score. Colored bars represent the average between the two locations. b) Questions on the survey that pertained to Ease of Teaching.

Questions:
1) This lesson was easy to teach
2) This lesson was easy to read and follow
3) I can easily find necessary materials for this lesson
4) I would use this lesson again
5) I feel comfortable teaching another leader how to do this lesson
6) I had previous knowledge on bioenergy concepts
7) Students had previous knowledge on bioenergy concepts
Relevance to Agriculture:

a) Ratings (0-5; 5=strongly agree, 0=strongly disagree) leaders provided through post lesson surveys. Red I-bars indicate leaders opposing scores, while no I-bar indicates that both locations’ leaders provided the same score. Colored bars represent the average between the two locations.

b) Questions:
1) Material covered is relevant to Agriculture
2) Bioenergy content of the lesson is relevant for the students
3) Content covered is agriculture oriented
4) The integration of bioenergy concepts meets the needs of 4-H clubs
5) This lesson aligns with other activities used in my 4-H program.

Figure 2. a) Ratings (0-5; 5=strongly agree, 0=strongly disagree) leaders provided through post lesson surveys. Red I-bars indicate leaders opposing scores, while no I-bar indicates that both locations’ leaders provided the same score. Colored bars represent the average between the two locations. b) Questions on the survey that pertained to Relevance to Agriculture.
Student Engagement:

a) 

Figure 3. a) Ratings (0-5; 5=strongly agree, 0=strongly disagree) leaders provided through post lesson surveys. Red I-bars indicate leaders opposing scores, while no I-bar indicates that both locations’ leaders provided the same score. Colored bars represent the average between the two locations. 

b) Questions on the survey that pertained to Student Engagement.

Discussion of the Results:

Short Term Lesson Evaluation:

The ST1 leader expressed that the three main goals that she had for a 4-H meeting included: education, demonstrating leadership, and planning. In the quantitative data collection in the form of short answer questions at the conclusion of the online survey, the leader identified this curriculum as helping to meet the goals of education by informing members about current agricultural issues and advancements. In the future use of the curriculum based on this specific leaders feedback, it is recommended that further development to meet more of the goals listed by the leader, such as demonstrating leadership and planning, in order to make it more successful in this setting.
The top three goals the ST2 leader expressed as being the focus for meetings include: education, leadership and friendship. This leader was satisfied that the curriculum provided met all three of the listed goals through the students working together to accomplish the tasks of the lesson. The leader felt the students worked together and became more comfortable with each other throughout the lesson. The students worked together toward an educational goal and all learned something new.

**Long Term Lesson Evaluation:**

The LT1 leader identified her top 3 goals for a 4-H meeting as follows: learn a new skill, maintain interest in scheduled activity, and hands on learning and interaction. In regards to how this curriculum aided in meeting these goals, the leader had this to say: “Once our club members were hands on, weighing, measuring and discussing what they were doing and how they thought it was going to turn out, they were excited and invested. When I read more information I could see them starting to zone out.” She added that this curriculum helped students learn that completing the tasks requires team work and interaction.

The LT2 leader identified her top 3 goals for a 4-H meeting as getting kids involved and working with each other, learn something new, and have fun! She felt that this curriculum satisfied all three of these goals. She added: “the kids all learned something new and had fun doing it. There was a lot of laughing and good natured teasing. I liked bringing a diverse groups of kids (both in age and previous science background) together and watching them help each other and figure it out.” This particular leader split the group up and gave everyone a job but they all encouraged each other or helped brainstorm the best way to complete their part. The part the leader felt they struggled with the most was getting the feedstock into the small opening of the bottles. She added that it was a bit messy but she felt that was part of what the students found the most humor in. She added that not all of the students used gloves, and that after a lot of laughing, many enjoyed just using their bare hands to handle the feedstock and transfer the proper amount into the designated bottles (the leader added a “gross” over this observation). While the initial portion of the lesson plan was completed at the fair, the prepared bottles were taken home for continued evaluation and students without access were kept notified of the bottles progress through their private Facebook group.

**Overall Evaluation**

The data collected was very positive for both short and long term lesson plans, with no indication that one was superior to the other as is. However, there are several striking observations that can be drawn from the data collected.

**Ease of Teaching**

Both short and long term lesson plans were ranked high by leaders in ease to teach, read and follow. Leaders also felt that materials for the lesson would be easy to find. However, the most compelling findings for this category was the high scores the
leaders submitted for willingness to use the lesson again, and feeling comfortable teaching another leader how to do the lesson. High scores on these two questions are instrumental in the future use of these curricula. The lesson plans would not be successful if 4-H leaders who comprise the targeted audience would not be willing to do the lesson again, and share with their cohorts. In order to successfully incorporate bioenergy and S.T.E.M. education into this new avenue, it needs to be something that is used and leaders are willing to use in future applications.

Relevance to Agriculture

The second criteria that was deemed by the research team as necessary for these lesson plans to find success in the agricultural youth setting was that the curriculum needed to be relevant to the leaders and students who were utilizing it. This opportunity provides the unique option of providing agriculture activities, that are S.T.E.M. based, into alternative youth programs such as 4-H. The data collected pertaining to this criterion indicates that both of these lesson plans are able to adequately fill this void. The scores on question 5 (figure 2) are comparatively low compared to the remaining questions in this category. However, this is still a positive attribute for both of these lesson plans. The fact that these lessons do not necessarily align with other activities used within the leaders 4-H program shows that these curricula are meeting a need not currently being fulfilled by other supplementary education available to these leaders and clubs. This speculation can be strengthened when pairing with the high ratings provided by the leaders that the integration of bioenergy concepts meets the needs of their 4-H clubs (question 4), and that the material covered is relevant to agriculture (question 1). The high scores in these two areas indicate that the lesson plan, while not like others available to them, is clearly agriculture oriented, and the bioenergy education is a valued addition to the club meetings.

Student Engagement

The questions pertaining to the leaders observations on student engagement serve to enhance our previous findings from the alternative two categories previously mentioned. The activities seem to find more success when the leaders and members can relate to and even integrate into their specific club. The long term lesson plan, for example, provided the opportunity to tailor the lesson plan to incorporate feedstocks produced by 4-H members own livestock and animal projects. This concept presented a very positive feedback from the leaders who participated in this curriculum. Overall, looking at the leaders ratings where they felt the lesson plans were easy to use and follow, that they were relevant to agriculture, and that interaction between students was high, both lessons proved to be both successful and well suited for a 4-H setting.

Final Remarks and Implications for Research and for Teaching:

This study originated from the conjecture that agricultural settings are a prime target for using bioenergy ideas and practices to create clean, renewable, energy. The aim was to utilize education to appeal to youth already involved in agriculture to gener-
ate interest in bioenergy topics, and tying it back into their daily lifestyles. While there was no distinct separation between the short and long term lesson plans, additional tests and trials could be run to ensure that this remains the case. Future applications of this curricula could include ready-made kits available to all 4-H leaders through a library-style check out process at their local county extension service location. Every county in every state has an extension service office to cater to 4-H, agriculture and the youth of the community making the kits very accessible regardless of geography. This would allow the curricula to be easily available to students and leaders all over the country. Materials for both curricula are readily available household items, making both kits inexpensive for upkeep and assembly. Additional trials would also be ideal to promote the success of these lessons to the Extension Service program so that they would be willing and eager to incorporate these curriculum into their data-base.

Preliminary findings on this research project are promising. Additional tests are recommended for more conclusive results. In future trials, pre- and post-lesson surveys would be conducive to evaluating test points, and the difference the curriculum makes. This enables comprehensive evaluation of where leaders stand on the curriculum and what they expect from it, and whether the lesson affects the outcome, or differs from what was expected. All of the preliminary trials mentioned in this article took place during the summer season. With students being out of school in the summer, participating in 4-H events and fairs, and potentially working summer jobs, it would be recommended to do tests throughout the year to ascertain whether the time of year has an effect on the effectiveness of the curriculum. The leader from LT1 recommended “a shorter time span…or simply not doing the activity during summer break when family vacations and other activities interrupted full attendance.” An additional consideration would be to administer surveys to the student demographic along with their respective leader for a more comprehensive look at the impact of lesson plans encompassing a larger audience.

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References:


