AN EXPLORATORY EVALUATION OF A SUSTAINABLE BIOENERGY EDUCATION PROGRAM

By

KATHARINE MONROE

Bachelor of Science in Animal Science

Oklahoma State University

Stillwater, OK

2017

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December 2019

AN EXPLORATORY EVALUATION

OF A SUSTAINABLE BIOENERGY EDUCATION PROGRAM

Thesis Approved:

Dr. Shane Robinson

Thesis Adviser

Dr. Jon Ramsey

Dr. Beatrix Haggard

ACKNOWLEDGEMENTS

She is clothed with strength and dignity, and she laughs without fear of the future.

Proverbs 30:25 (NLT)

As I sit and look at the time which stretches before me, I cannot help but reflect on the people who have brought me to this point in my life. In the past two and half years I have been blessed to be surrounded by people who supported, encouraged, and constantly lifted me up so I could reach my goals. I want to start by thanking my graduate committee for all of the guidance and wisdom you have supplied over the course of my graduate career. Without each one of you I would never have been able to achieve this goal. Secondly, I want to say a big thank you to all of the faculty and staff of the Oklahoma State University Agricultural Education Department. These past couple of years the fourth floor of Ag Hall has become a second home, and that is in large part to the wonderful people who reside there. My amazing office mates have supplied me with so many happy memories. I will always cherish the laughs, the hugs, and the life chats we've shared. To the faculty, you helped me realize my dream of being an agricultural educator, and you've been nothing but supportive while I have pursued a teaching certificate alongside a master's degree. Without your guidance and understanding, I fear I may not have made it. Thank you for all you do in supporting and preparing the educators of tomorrow.

To my committee chair, Dr. Robinson, I want to say thank you for all of the advice and time you've poured into me. Thank you for all the long hours you've spent perfecting my work, and supplying me with an endless supply of encouragement. Thank you for all that you do to ensure the success of your students, I have truly enjoyed working with you and learning from you.

I want to thank my family for always believing in me and teaching me I can achieve whatever I set my mind to. Dad, thank you for teaching the value of hard work, and for always encouraging me to be the best I could be. Thank you for always being my biggest supporter, I will always be your baby girl. Mom, thank you for being a wonderful example of what a Godly woman should look like. Watching you has taught me how to be a good woman and a good wife, those are lessons I couldn't have learned without you, even with all my years of school. Hanna, thank you for being the best big sister, protector, best friend, and confidant for all these years. Thank you for all the long phone calls of venting, crying, and laughing, I couldn't have made it through this without you. To the boys, I love watching you grow into wonderful young men. You're going to accomplish so many wonderful thing in your life, and I am so proud of you. Never forget, you are capable of so much more than you think, so set your goals and work hard and I have no doubt you will reach every last one of them. Adaven, while not technically blood related you have become a sister to me over the years. I will always cherish your friendship and the memories we've made while in school. Thank you for your unwavering support and your wonderful friendship throughout the years.

To my loving husband, Robert, I could not have accomplished this without you by my side. I do not have the words to express the magnitude of appreciation and love I have for you. You have sacrificed so much so I can run after this crazy dream, and you've never complained. You have uplifted me when I was discouraged, held me while I cried, and rejoiced in my accomplishments. I am safe in the knowledge that you will always be my biggest supporter, and that is a blessing of a magnitude I cannot adequately express. I love you with all my heart and with everything I am. Thank you for constantly showing me the true love of Christ.

Finally, I want to give all the thanks and praise to my Lord and savior Jesus Christ. It is only by his grace and incredible mercy that I was allowed this amazing opportunity. He has blessed me with a multitude of wonderful people in both my professional and personal lives. He set me on this path at a time when I was lost and confused about what the future should look like, and every day since then I am reminded that agricultural education is where I am meant to be. He truly is the God who never fails. If there is any praise or glory to be had I give to Jesus, because without him none of this would have been possible.

Name: Katharine Monroe

Date of Degree: DECEMBER, 2019

Title of Study: AN EXPLORATORY EVALUATION OF A SUSTAINABLE BIOENERGY EDUCATION PROGRAM

Major Field: AGRICULTURAL EDUCATION

Abstract: As part of a USDA-NIFA grant, Oklahoma State University hosted a weeklong bioenergy professional development session for 16 agricultural education teachers, science teachers, and Extension educators across the United States. The workshop consisted of several classroom and laboratory sessions, which were modeled after the train-the-trainer method of professional development. The participants also experienced several field tours and learned about and observed the cutting-edge bioenergy research being conducted at Oklahoma State University. Participants were exposed to multiple laboratory-based, bioenergy-related experiments throughout the week. To determine impact of the professional development on educators' content knowledge, survey research was conducted prior to and at the end of the week. Then, approximately 11 months after the conclusion of the weeklong workshop, the participants were administered a modified version of the instrument to gauge their retention of the content and to determine the rate at which they applied the material presented at the workshop to their students. The study found educators' bioenergy content and pedagogical knowledge confidence levels increased substantially (in excess of one point on a four-point scale) as a result of their participation in the workshop. Although their knowledge of bioenergy declined 11 months later, their self-perceived scores ranged between *good knowledge* and *great knowledge*, indicating the workshop made a positive impact on educators' content understanding and their ability to apply bioenergy concepts in the classroom.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

Introduction

The world has never witnessed anything like the population explosion it has experienced within the last century. In the span of 100 years, the world population grew from 1.6 billion to 6.1 billion people, with rates continually trending upward (Roberts, 2011). This spectacular population growth is largely due to mental and health advancements in developing countries (Roberts, 2011). If the current growth rate continues, the world population is expected to reach nine billion by 2050 and 10 billion by 2100 (Roberts, 2011). The population growth will drive an extensive urbanization of the world's rural areas (Jiang & Hardee, 2009). "Almost all of the world population growth will occur in the urban areas of developing countries" (Jiang & Hardee, 2009, p 10). Other side effects include an escalation of immigration numbers, older populations with a lack of resources to care for the elderly, and a deficit of employment opportunities for the younger population (Robert, 2011). Although those side effects are alarming, perhaps the most worrisome of all is the impact the added stress will have on the ecosystem (Steffen et al., 2015).

Throughout history, the earth's system has been fairly stable. The last global state shift was during what is commonly referred to as the Ice Age. During this period of time, "30% of earth's surface went from being covered by glacial ice to being ice free" (Barnosky et al., 2012, p. 54). However, research suggests as the human enterprise increases, the earth's system will be pushed to a point of destabilization (Steffen et al., 2015). If humans continue to tax the earth in this magnitude, areas could become an inhospitable environment for the population (Steffan et al., 2015). As the temperature rises, the available water supply will quickly become a relevant issue, as will all agricultural processes (Barbieri et al., 2010; Koetse & Rietveld, 2009). The projected impact of this change is unclear, but left unchecked, it is expected to be dire for the human race long term (Barbieri et al., 2010).

"The main consequences of climate change as predicted by most climate models are an increase in global temperatures, changes in precipitation patterns, and sea level rise" (Koetse & Reitveld, 2009, p. 207). Agriculture and the water supply are the most commonly known entities affected by climate change (Barbieri et al., 2010; Koetse & Rietveld, 2009). Further, with the rising sea levels and expected increase in storms and flooding, transportation could be drastically affected by climate change (Koetse & Rietveld, 2009). Another unforeseen effect is the risk to human health. Climate change both oppresses some transmission of disease and creates opportunities for new transmission to occur (Wu, Lu, Chen, & Xu, 2016). Europe has noticed an increase in tick borne illnesses, which is believed to be an indirect result of climate change. By affecting the lives of vectors such as deer and rodents, changing the environment to one more suitable for ticks, and influencing human behavior, such as time spent outdoors, Europe is experiencing a rise in tick population and tick borne illnesses (Gray, Dautel, Estrada-Peña, Kahl, & Lindgren, 2008). In short, climate change can and will affect numerous unforeseen aspects of human life if left unattended.

Over the course of a decade, climate change has captured the attention of scientists, policy, and the media. The scientific communities have become increasingly interested in adaptation to climate change (Moser & Ekstrom, 2010). To bring awareness about the severity of climate change, the idea of carbon footprint was introduced. A multitude of businesses began using carbon footprinting as a management tool to be more environmentally friendly (Matthews, Hendrickson, & Weber, 2008). Interestingly, carbon footprinting was introduced outside of the research community, which helped the concept to gain popularity (Weidema, Thrane, Christensen, Schmidt, & Løkke, 2008). The hope is by keeping the carbon footprint low, the stress on the earth's system can, in some small way, be alleviated (Weidema et al., 2008).

In addition to carbon footprinting, research is now focusing on two main strategies in response to climate change: adaptation and mitigation (Semenza, Hall, Wilson et al. 2008). Adaption focuses on reducing the risk to population health, while mitigation targets reducing greenhouse gas emissions (Semenza et al., 2008). One aspect of mitigation which could help to reduce such emissions is biofuel (Liaquat, Kalam, Masjuki, & Jayed, 2010). In the near future, the world will have to begin looking for different sources of energy as, "the essence of the energy problem is that the world is running out of environmental capacity to absorb emissions" (Zidanšek et al., 2009, p. 6982). Biodiesel produces 68% less emissions than conventional diesel, and uses less energy to produce (Zidanšek et al., 2009). Using biofuels in the transportation industry is believed to be one of the more impactful strategies in reducing emissions (Liaquat et al., 2010). Along with emission reduction, the expansion and production of biofuel has the potential to create more jobs and make use of wasteland in developing countries (Liaquat et al., 2010). Countries such as India, China, Thailand, and the Philippines are producing biofuels from non-edible oils, but they are not utilizing biofuel to its full capacity (Liaquat et al., 2010). Brazil is one of the most advanced countries in the biofuel industry and has dramatically improved its economic and environmental standing through the production and usage of biofuel (Liaquat et al., 2010). Although the government usually deals with large-scale mitigation, voluntary individual mitigation is needed as well (Semenza et al., 2008). However, when asked, individuals stated they did not feel they had the time, money, or knowledge to participate in mitigation (Semenza et al., 2008).

To combat the lack of knowledge the public has about climate change and mitigation, people need to become more scientifically literate. “It is thus in the interest of everybody, scientist or not, to gain a better understanding of science and its applications, if only to learn how better to utilize its benefits and avoid its pitfalls” (Shen, 1975, p. 265). Science has always been at the forefront of society (Shen, 1975), but there has never before been such a demand for a scientifically literate populace (Lui, 2009). Although vitally important, increasing the amount of science literacy among the population is no easy feat (Lui, 2009). Despite pushes at the national level for science education reform, graduating high school students are failing to achieve a proficient level of science knowledge and are thus deemed scientifically illiterate (Lui, 2009). With the amount of belief in pseudoscience and the decline in science education, it would seem achieving science literacy is a distant goal for the immediate future (Brinkley, 2009; Lui, 2009).

There has been a multitude of research and theories conducted on improving science literacy. One such theory is bridging formal and informal education (Lui, 2009). By creating people who are both students and teachers of science, there could be a rise in literacy among the population (Lui, 2009). However, the burden of achieving science literacy is still largely placed on science teachers. However, studies show science teachers are lacking in both technological content knowledge and pedagogical content knowledge (Avraamidou & Zembal-Saul, 2009; Graham et al., 2009; Kind, 2009; Shulman, 1986). One way to increase the content knowledge of science teachers is through professional development. In a study conducted by Supovitz and Turner (2000), content preparation was found to be the most influential factor affecting teaching practices, which reinforces the importance of content knowledge and preparation when teaching. However, Shulman (1986) suggested teachers are more focused on how they teach rather than what they teach. Therefore, content knowledge is often prioritized below pedagogical knowledge (Shulman, 1986). Although teachers need to have a working knowledge of pedagogy, content knowledge is the foundation of teacher competency (Loewenberg-Ball, Thames, & Phelps, 2008).

Professional development has been shown to improve the implementation of new content and teaching methods (Lakshmanan, Heath, Perlmutter, & Elder, 2011).

One avenue for increasing science literacy is through agricultural literacy, since agriculture has been referred to as “the worlds’ oldest science” (Ricketts, Duncan, & Peak, 2006, p. 48). Historically, agriculture has been a science-related discipline, which confronts the public (Shen, 1975). However even with agricultural products prevalent in most aspects of daily life, incoming college freshmen students attending a land-grand institution were considered agriculturally illiterate (Dale, Robinson, & Edwards, 2017). Hubert, Frank, and Igo (2000) suggested incorporating agricultural themes into academic core classes has the potential to reinforce basic education for kindergarten through twelfth grade (K-12) students. This is imperative because as additional urbanization occurs, students are losing basic knowledge of their environment and environmental systems (Hubert et al., 2000). Hess and Trexler (2011) found elementary students possess rudimentary knowledge of food, but have limited knowledge of agriculture beyond food names, and no knowledge of food processing and harvesting processes. They suggest that to be able to make informed decisions about sustainable food and resources, a foundational level of knowledge must be gained during the elementary years (Hess & Trexler, 2011).

An analysis of science curriculum used to teach upper-elementary grades revealed agriculture was underrepresented (Vallera & Badzin, 2016). Even when present, it was used to teach other non-agricultural concepts, instead of presenting those which could improve agricultural literacy (Vallera & Badzin, 2016). Further, agriculture, as a discipline, had limited presence in elementary school curriculum, thereby reducing the youth’s exposure to it when their logic and reasoning skills are developing (Vallera & Badzin, 2016). There are several suggestions on how to increase agricultural presence. Three of the most important include: revising the curriculum to teach agriculture subjects directly, using agriculture to contextually highlight other subjects, and educating the teachers through agriculturally-based professional development (Vallera & Badzin, 2016).

At a time when the population is detecting the effects of climate change and mitigation is a necessity (Semenza et al., 2008), the youth of today could benefit from a basic understanding of science and agriculture so they can address and solve the problems of tomorrow. Biofuel has the potential to play a big role in mitigation; however, with the growing industry, a need exists for people to understand the science at a deeper level for progress to occur (Ragauskas et al., 2006). To educate youth who will eventually be the minds behind mitigation, teachers must know and be competent with the content of the subject they teach (Loewenburg-Ball et al., 2008).

Professional development is the primary method of delivering content to in-service teachers (Lieberman & Mace, 2010). By participating in effective professional development teachers' content efficacy increases, which can affect students' achievement levels positively (Colbert, Brown, Choi, & Thomas, 2008). The train-the-trainer model for professional development is a viable way to create the content knowledge efficacy desired among in-service teachers (Page, Iwata, & Reid, 1982). This model takes a relatively small group of teachers, provides them with appropriate training in the hopes they will reciprocate that training to their colleagues (Page et al., 1982). This model has the potential to exponentially spread the content to other educators in the surrounding area.

Purpose

The purpose of this program evaluation was to determine the changes in educators' content and pedagogical knowledge of bioenergy, after participating in a weeklong bio-based professional development workshop. The following objectives guided the study:

1. Determine the educator's knowledge of bioenergy and STEM concepts.
2. Determine the educator's pedagogical knowledge related to bioenergy and STEM concepts.

3. Determine if the educator applied the content knowledge presented to them in the workshop in their classrooms.
4. Determine if the educators retained the content and pedagogical knowledge presented to them at the workshop.
5. Describe participants' perceptions for improving the workshop for future cohorts of participants.

Assumptions

In the course of this study, the following assumptions were made:

1. Participants attended the workshop because they had a personal interest in bioenergy education.
2. Participants completed the instrument honestly and to the best of their ability.
3. Participants tried their best to retain the information presented at the workshop.
4. Participants used the resources provided them to teach bioenergy concepts to their students.

Limitations

This study has several limitations to be reported which include:

1. The instrument used was self-report, and as such was subject to personal bias.
2. The small population number of participants in this study prohibits generalization.
3. There was no demographic information collected from participants.

Operational Definitions

Climate Change – Changes in a regions climate that has taken place over an extended period of time.

Communities of Practice – Groups of people who are engaged in similar endeavors and therefore participate in collective learning (Wenger, 2006)

Extension Educators – Individuals who work to disseminate information from land-grant universities to the general public (Ahearn, Yee, & Bottum, 2003).

Greenhouse Gas Emissions – Gases such as carbon dioxide, methane, and nitrous oxide which get trapped in the atmosphere and contribute to the increase in the earth's temperature (Karl & Trenberth, 2003).

Pedagogy – The methods and practice of teaching.

School-Based Agricultural Education Teachers – A person holding a valid agricultural teaching license and is teaching agriculture in a formal school setting.

Science Teachers – An individual holding a valid science teaching license and is teaching science in a formal school setting.

CHAPTER II

Review of Literature

The world population continues to trend upward, with an expected population of nine billion by 2050 (Roberts, 2011). With this unprecedented growth of population comes a multitude of obstacles, such as an increase in greenhouse gases and increased demand on the worlds' food supply (Steffen et al., 2015). Although the scientific community seeks a solution to the concerns the population growth brings, the education community seeks to mitigate the concerns by educating the worlds' youth in the areas of science, technology, engineering, and mathematics (STEM). Fortunately, agricultural education is a natural discipline to highlight STEM concepts (Myers & Thompson, 2009; Smith, Rayfield, & McKim, 2018; Swafford, 2018) as agriculture is "the worlds' oldest science" (Ricketts, Duncan, & Peak, 2006, p. 48). Unfortunately, teachers may not always have the necessary skills to teach these concepts effectively (Scales, Terry, Jr., & Torres, 2009). Professional development is one route to equipping educators with the needed resources to teach the STEM concepts adequately.

Climate Change and Population Growth

Human population growth has long been a contributing factor in climate change. However, the inverse is equally as true, as climate change has often influenced the growth of the population (Zhang et al., 2011). The initial population estimates have been ambiguous and an unreliable number (Coale, 1974). The next available estimate is at the beginning of agriculture in

8000 B.C. when the population was believed to be around eight million people (Coale, 1974). After the establishment of agriculture, the population soared to 300 million by 1 A.D., and increased again by 500 to 800 million by 1750 (Coale, 1974). Throughout this period, the population fluctuated due to the influence climate change had on agriculture (Zhang et al., 2011).

Zhang et al. (2011) discovered, by conducting historical analysis, climate change is linked to the crisis in the human population. The authors also found agriculture, food-supply, and bio-productivity responded immediately to climate change; whereas, wars, famines, and other social crises occurred within a 5- to 30-year time frame. Although agricultural production decreased when the climate turned cold, the population continued to rise (Zhang et al., 2011). This led to grain prices increasing and labor prices decreasing. "Inflating grain prices and declining real wages bred unbearable hardship in all walks of life, triggering many social problems and intensifying existing social conflicts (Zhang et al., 2011, p. 17297). Revolutions, political reform, and rebellions followed a drop-in temperature within a 1- to 15-year time frame with wars increasing by 41% in the colder climates (Zhang et al., 2011). Famine and war have been noted as the two most influential factors on population numbers, with 10 million people dying in wars during the 1618 to 1649 time period (Zhang et al., 2011). The study concluded, "temperature change is the ultimate cause of human catastrophes, in that it affects first agro-economy and then people's livelihood" (Zhang et al., 2011, p. 17297).

However, through modern advancements in technology and health services, population growth appears to no longer dependent on climate change (Roberts, 2011). In fact, the human population is increasing at a rate which is currently not sustainable (Steffen et al., 2015). The population is expected to reach 9 billion by 2050 and 10 billion by 2100 (Roberts, 2011). With the population continuing to escalate, the human race is facing the possibility of pushing the earth beyond its planetary boundary (Steffen et al., 2015). This will likely cause the ecosystem to become less hospitable, which could have detrimental effects on current and future generations of people (Steffen et al., 2015). With societies expanding and humans producing more carbon dioxide, greenhouse gasses (GHG) are a problem. The scientific community continues to research GHGs extensively in hopes of finding a solution to this ever-growing problem (Steffen et al., 2015).

Greenhouse Gasses

Greenhouse gasses (GHG) include carbon dioxide, methane, and nitrous oxide, which get trapped in the atmosphere and raise the temperature of the earth (Karl & Trenberth, 2003). These gasses can have a life ranging from decades to centuries (Karl & Trenberth, 2003). Carbon dioxide emission is attributed largely to the burning of fossil fuels, and the other gasses are considered to be a side effect of human activity (Karl & Trenberth, 2003). These gasses are distributed across the globe, making climate change a world-wide concern (Karl & Trenberth, 2003). With the increasing use of GHG emissions, the research community is exploring possible solutions for the problem (Steffen et al., 2015). However, "Human behavior, technological change, and the rate of population growth also affect future emission and our ability to predict these must be factored into any long-term climate projection" (Karl & Trenberth, 2003, p. 1722).

Biofuel

There is a common misconception that biofuel is a relatively new invention, when in fact it has been of interest since the 1800s (Songstad et al., 2009). In the 1830s, a mixture of ethanol and turpentine was used to replace whale oil, which was expensive and diminishing (Songstad et al., 2009), for the internal combustion engine. It was designed to use the same mixture of ethanol and turpentine and could power boats up to 8 miles per hour. Unfortunately, the inventor, Samuel Morey, could not obtain any further funding to continue the project (Kovarik, 1998). Shortly after Morey, the German inventor Nicholas Otto developed a similar engine, but his patent was denied in 1861. He later became successful by producing stationary gas engines which used the "Otto-cycle," running on gasoline while still being adaptable to run on alcohol or benzene (Kovarik, 1998). Gasoline grew in popularity due to it being extremely available and inexpensive (Kovarik, 1998). In the 1890s, German, French, and British scientist and officials were worried about the longevity of oil reserves and encouraged a wide adoption of alcohol engines.

When the idea of farm chemurgy emerged in the 1920s and 1930s, it was proposed that agriculture and agricultural products could provide industry with the needed raw materials to make the alternative fuel (Carolan, 2009). During this period of time, Iowa State University developed methods to turn farm wastes products such as corn husks, oats hulls, and corncobs into industrial products (Finlay, 2004). With the new Fordson tractor hitting the market, which was designed to run on gasoline or alcohol (Carolan, 2009), Ford funded a large portion of biofuel research, and by 1931, the research had turned to soybeans (Finlay, 2004). "By 1935 Ford Motor Company used one bushel of soybeans in each car they manufactured" (Carolan, 2009, p. 92). However, as the depression hit, the grain surplus in the United States rose dramatically and the chemurgy's focus turned to bioethanol (Carolan, 2009; Finlay, 2004). As alcohol fuels gained popularity, several states offered tax incentives to mix gasoline with alcohol. In 1933, Iowa passed a law requiring fuels to include ten percent grain alcohol (Finlay, 2004). After World War II, the nation switched from researching bio-based products at a macro-level to a micro-level. Unfortunately, very few chemurgic products could compete with nonrenewable products when it came to consistency of product quality, cost of transport, price stability, and reliability of supply (Finlay, 2004).

Biofuel received an increased amount of attention, as it is a renewable source of energy (Escobar et al., 2009). Biofuel can be made from agricultural products such as sugarcane, plant material, forest biomass, and other organic matter (Escobar et al., 2009). Biofuels have numerous benefits, such as lowering the dependence on crude oil and encouraging energy industry to diversify their fuel sources (Ramos, Valdivia, García-Lorente, & Segura, 2016). The most attractive benefit of biofuel is the decrease of greenhouse gases (Ramos et al., 2016). Biofuels can be utilized individually, but it is common to add them to fuel. Examples of these blended fuels are biodiesel, ethanol, methane, charcoal, and methanol (Escobar et al., 2009). Since biofuels are largely produced from agricultural products, countries that are not fossil fuel producers are able to join the energy market (Escobar et al., 2009). These countries are seeing benefits such as increasing number of jobs, faster development of rural areas, increased energy security, as well as lessening the world's dependence on fossil fuel producing countries (Escobar et al., 2009; Ramos et al., 2016). It is important to note not all countries have the correct climate, soil, or topographic components to achieve large scale biofuel production (Escobar et al., 2009). However, about 14 million hectares of farmland are used for the production of biofuels, which equates to about one percent of the world's cultivated land mass (Escobar et al., 2009).

Biodiesel makes numerous impacts on the economy and the environment (Hill, Nelson, Tilman, Polasky, & Tiffany, 2006). The GHG emissions from biodiesel are 59% of what conventional diesel emits, which provides 93% more useable energy (Hill et al., 2006). Other benefits include a miniscule negative impact on human and environmental health, and a reduction of several air pollutants (Hill et al., 2006). Biodiesel is compatible with most diesel engines and can be used with only a slight decrease in performance (Demirbas, 2009). Research suggests by using biodiesel in the transport industry, such as cars, truck, and motorcycles, the GHG emission can be reduced dramatically (Liaquat et al., 2010). This is especially true if the countries that produce the most biofuel would also start to utilize the fuel, such is the case in Brazil (Liaquat et al., 2010). Being the most advanced in biofuel production has substantially increased Brazil's economic standing (Liaquat et al., 2010). They also have improved their environmental health by not only producing biofuel, but also using what they produce (Liaquat et al., 2010). Research suggests if heavily populated countries would emulate Brazil in the use of biofuel, GHG emissions could be reduced considerably (Liaquat et al., 2010).

For years, the limiting factor in biofuel production was the concern of taking land out of food production (Dale, Bals, Kim, & Eranki, 2010). However, research suggests by making adjustments to agricultural processes, the United States can produce biofuel on a macro-scale while still maintaining domestic and international food supplies (Dale et al., 2010). In recent years, biofuel made from algae has gained widespread attention (Mentrez, 2012). Algae has tremendous potential for being a sustainable source of energy. It has a rapid growth rate, consists of a large variety, can grow in seawater, can use nutrients from human and animal waste, and can make use of industrial sourced carbon dioxide (Mentrez, 2012). Biodiesel produced from algae occupies 100 times less land than biodiesel produced from soybeans or other crops. This would assume algae may be the only source of biofuel having minimal to no negative effects on food supply and other crop production (Piloto-Rodríguez, Sánchez-Borroto, Melo-Espinosa, & Verhelst, 2017). With the ever-increasing energy demand and the depletion of fossil fuels, it is urgent for biofuel production to occur on a macro-scale (Rodionova et al., 2016).

The Need for Science Literacy

"The American people, sparked by Sputnik, and almost as a single voice, have inquired whether their children are receiving the kind of education that will enable them to cope with a society of expanding scientific and technological developments" (Hurd, 1958, pp. 13-14). With science being prevalent in almost every aspect of daily life, it is more important than ever before for people to have a basic understanding of science and scientific processes (Dragoş & Mih, 2015). High school students begin their college careers with a minuscule knowledge of science, and as they complete their formal education, they are leaving higher education facilities with mammoth gaps in their scientific understanding (Impey, Buxner, Antonellis, Johnson, & King, 2011). Hurd (1958) pointed out, science has been the determining factor in the development of beliefs for the past 200 years. However, today, people not only have little actual scientific knowledge, they also hold an alarmingly amount of pseudo-science beliefs (Impey et al., 2011).

Hurd (1958) stated how surprising it was that science was given so little attention in the public education system. At the time, there was pressure for science education reform on a national level unlike any that had come before (Hurd, 1958). It was apparent science education needed updating for students to truly gain an understanding of science (Hurd, 1958). However, for such change to occur, science educators need to be validated and empowered (Impey et al., 2011). Therefore, increasing science teachers' content knowledge with professional development can have a corresponding increase in student science literacy (Pearson, 2010).

A Focus on Pedagogy and Content Knowledge

In 1986, Lee Shulman proposed what is commonly called the pedagogical content knowledge theory (PCK). Shulman (1986) contended research was so focused on pedagogy; the idea of content knowledge was completely missed. With the measure of teacher competency being how they teach, the research overlooked the content the teachers were teaching (Shulman, 1986). Shulman (1986) proposed a new theory that would bridge the gap between pedagogical knowledge and content knowledge. The proposed theory states teachers need to have a knowledge of content specific for teaching, which is even more extensive than just a basic understanding of the subjects they teach (Shulman, 1986). Research suggested teachers' need to possess an understanding of the material and know what aspects may be difficult for students to understand (Schneider & Plasman, 2011). Teachers must be able to explain why the content is needed and have practical examples of how those concepts are used in the real world (Schneider & Plasman, 2011; Shulman, 1986). In addition to content knowledge, teachers need to understand the way students learn (Shulman, 1986). They must have a grasp on the backgrounds of their students, and how those previous experiences will affect their learning (Shulman, 1986). Shulman (1986) proposed rolling all of these requirements into one theory called the PCK. Unfortunately, Shulmans' (1986) proposed theory remains underdeveloped (Lowenberg-Ball et al., 2008). However, the importance of teachers knowing the subject they teach, without understanding the subject themselves, decreases the probability of being able to help students learn the material (Lowenberg-Ball et al., 2008; Schneider & Plasman, 2011).

The need for science literacy and education has long been documented (Hurd, 1958; Impey et al., 2011; & Shen, 1975). However, there is now an unprecedented need for a scientifically literate populace (Harker-Schuch & Bugge-Henriksen, 2013). “Humanity is facing one of the most formidable challenges in our history- while undergoing one of the most dynamic and rapid technological expansions of our time” (Harker-Schuch & Bugge-Henriksen, 2013, p. 764). Research has shown there is limited knowledge of climate change among 16 to17 year-old individuals (Harker-Schuch & Bugge-Henriksen, 2013). In addition, even after students received a lecture about the science of climate change, they could only answer less than 60% of the questions correctly. Many of the students maintained a sense of apathy toward climate change and did not believe it was a threat (Harker-Schuch & Bugge-Henriksen, 2013). Further, although the students held a basic understanding of terms and definitions, they possessed no deeper knowledge on the causes and effects of climate change than before the lecutre. The researchers concluded simply lecturing to students about climate change would not bring about the change needed. To achieve the climate change knowledge and science literacy levels needed, the researchers suggested lecturing students about climate change and providing them with a well-rounded and in-depth presentation of knowledge on the subject matter (Harker-Schuch & Bugge-Henriksen, 2013).

Non-formal Education: A Focus on Extension

In 1914, the Smith-Lever Act founded extension education to act as a liaison between the land-grant universities and the general public (Ahearm, Yee, & Bottum, 2003). With most of the population living on farms at the time of establishment, the main focus was on disseminating practical agricultural information (Ahearn et al., 2003). When conducted correctly, extension education has the ability to increase agricultural productivity and the farmer's income (Anderson & Feder, 2004). However, the impact extension has on farmers varies greatly between programs (Anderson & Feder, 2004). With the majority of the population having moved away from the farm, extension education has been challenged to incorporate new programs and services which cater to a wider variety of people (Rivera, 2011).

As communities change and evolve, evidence suggests an integrated extension approach is needed to address the needs of the public (Jayaratne, Bradley, & Driscoll, 2009). Integrated extension is an effort to combine the efforts of two or more programs to meet the specific needs of a community (Jayaratne et al., 2009). Ideally, the programs complement each other to provide the public with the best knowledge possible (Jayanartne, 2009). With knowledge having an imperative role in shaping a community, extension education plays an even bigger role, as it is instrumental in the knowledge creation and distribution process (Bowling & Brahm, 2002).

An example of this knowledge creation role of extension would be a program created to teach STEM concepts to fifth graders through agriculture (Campbell, Wilkinson, Shepherd, & Gray, 2015). This integrated program is the result of a collaboration of the Virginia extension office, Virginia Tech, agricultural experiment stations, King Flour, and the Future Farmers of America (Campbell et al., 2015). During this one-day event, students learned science concepts through bread baking as well as rotating through five different learning stations (Campbell et al., 2015). The learning stations taught the students concepts such as DNA, animal cells, soil and natural resources, matter, solutions, mixtures, elements, molecules, and plant life cycles (Campbell et al., 2015). When the students' teachers were queried, 100% agreed that the hands-on-learning aspects successfully reinforced the topics they had already taught in class. Agriculture is a natural place to teach STEM concepts due to its unique ability to link mathematics and science to practical hands-on activities (Campbell et al., 2015; Chumbley, Haynes, & Stofer, 2015; Haynes, Robinson, Edwards, & Key, 2012; Robinson, Westfall-Rudd, Drape, & Scherer, 2018; Swafford, 2018; Wang & Knobloch, 2018;).

Formal Education: A Focus on School-Based Agricultural Education

Agricultural education was believed to have started with the passage of the Smith-Hughes Act of 1917 (Camp, 1987). However, vocational and agricultural education was being taught well before it became a federally funded program (Camp, 1987). In fact, in the years leading up to the Smith-Hughes Act, vocational and agricultural educations' popularity was steadily increasing (Camp, 1987). Leading up to the passage of the Act, the industry was undergoing a massive overhaul thanks to the technological advances brought forth by the industrial revolution (Herren, 1986).

> The advent of the interchangeable part had ushered out the need for apprenticeship-trained craftsmen who made each and every part of a machine and had ushered in the need for the mechanic who could assemble machines using standardized parts. (Herren, 1986, p. 39)

With this shift in industry came a shift in educational philosophies (Herren, 1986). Philosophers such as John Dewey were adapting to this need in industry by moving from a teacher-oriented style to more of a student-centered, problem-solving style of formal education (Herren, 1986).

The passage of the 1917 Smith-Hughes Act tasked school-based agricultural education (SBAE) with preparing individuals to join the workforce (McKim, Velez, Lambert, & Balschweid, 2017). However, with STEM jobs on the rise, preparation for the workforce had to adjust (McKim et al., 2017). Fortunately, SBAE remains a viable pathway for preparing students for STEM careers due to the preexisting STEM competencies within the curriculum (Myers & Thompson, 2009; Smith, Rayfield, & McKim, 2015; Swafford, 2018). McKim et al. (2017) called for agricultural educators to illuminate the science concepts already present in numerous agricultural concepts. Unfortunately, research suggests agricultural educators may not possess the necessary STEM knowledge to teach it effectively (Scales, Terry, Jr., & Torres, 2009).

The Need for Agricultural Literacy

Prior to the 1920s and 1930s, the majority of people were directly involved in agriculture (Birkenholz, 1993). However, after industrialization hit the populations, involvement in agriculture dropped to where 50% of the world's urban population does not produce their food (Birkenholz, 1993; Sayers, 2011). Although the country enjoyed a high standard of living brought on by industrialization, the dependence on a safe and cheap food supply did not diminish (Birkenholz, 1993). Fewer producers were working to provide a safe food supply for the US population (Birkenholz, 1993; Environmental Protection Agency, 2012). To compound the problem, the few remaining producers were faced with a large outcry from the public related to agricultural issues such as food safety and animal welfare (Birkenholz, 1993). Sadly, the chasm between consumers and producers fostered a lack of support of the industry (Kovar & Ball, 2013). With agriculture being essential to survival, and the amount of misconstrued problems and issues involving agriculture, the general population must have a basic understanding of agricultural processes (Birkenholz, 1993; NRC, 1988).

Birkenholz (1993) argued the responsibility of increasing agricultural literacy should not rest solely on the agricultural educator. Instead, he called for an integrated approach of agriculture across the entire curriculum. "The entire scope and sequence of elementary and secondary education should embrace the goal of agricultural literacy education through an integrative approach throughout the curriculum" (Birkenholz, 1993, p. 65). Traditionally increasing agricultural literacy was charged to elementary and secondary educators (Balschweid et al., 1998; Birkenholz, 1993; Kovar & Ball, 2013; Meichen & Trexler, 2003). Birkenholz (1993) contended students should not be thought of receiving a well-rounded education if they have no understanding of the significance agriculture has in their daily lives. With the population depending heavily on the agricultural industry to supply food, raw materials, industrial applications, and clothing, agricultural literacy must become a priority (Birkenholz, 1993).

"Increasingly, society will be faced with issues at the social, economic, and political interface of agriculture, which will require some basic literacy of the human designed agri-food system" (Hess & Trexler, 2011, p. 1). With the population expected to reach nine billion by 2050, feeding the world population is going to be more challenging than ever before (Sayers, 2011). A staggering 50% of the population lives in an urban setting and has very little knowledge of where and how its food is produced (Sayers, 2011). Hess and Trexler (2011) found elementary age students living in an urban area "lacked a basic understanding of food processing, manufacturing, and marketing" (p. 9). Vallera and Bodzin (2016) found elementary science curriculum lacked agricultural concepts and did very little to promote agricultural literacy. Agricultural industries such as food and fiber are essential to the survival of the human race; however, the public continued to fail in recognizing the importance of sound environmental and agricultural policies (Hubert et al., 2000). "It was determined that students of all ages, if presented information in a systematic manner, would become better decision making adults in matters relating to agriculture and the environment" (Hubert et al., 2000, pp. 527-528).

Professional Development

The first official teacher professional development took place in London in 1922 and was called the City of London Vacation Course (CLVC) (Robinson, 2011). The goal of the CLVC was to professionally, socially, and culturally invigorate and refresh teachers (Robinson, 2011). Up to 500 elementary teachers would travel to London and give up two weeks of their summer vacation to take part in educational visits, professional lectures, and glamour social events (Robinson, 2011). The CLVC was funded by the teachers and was not under the purview of the

Board of Education; although, it did gain recognition in the education community (Robinson, 2011). Although the course had a wide swath of activities, the professional lectures became the biggest attraction (Robinson, 2011). The lectures consisted of teaching strategies for all subjects (Robinson, 2011). The more seasoned teachers attended sessions designed to develop strategies in teaching difficult children, while the junior teachers attended sessions that developed their teaching styles (Robinson, 2011). The CLVC was committed to providing skills and knowledge which would have a direct practical relevance in the classroom. It also was striving to develop the teachers in other ways such as socially and culturally (Robinson, 2011).

> Though concerned with the maintenance and improvement of subject knowledge, pedagogic technique and educational thinking there was a powerful underlying agenda that sought to enrich the minds and outlook of the teacher – the very person who the teacher was meant to be. (Robinson, 2011, p. 575)

The positive impact CLVC had on teachers and the educational community was tremendous; however, sadly, it never reconvened after World War II with its last official meeting being in 1938 (Robinson, 2011).

More recently, professional development has been reported to provide opportunities for people to grow personally and professionally (Schwartz & Bryan, 1998). Professional development is designed to enhance the content knowledge, pedagogical knowledge, introduce new curriculum, and educate instructors about new teaching methods (Wilson, 2013). In the United States, teachers have an abundance of professional development opportunities including school-based learning communities, coaching, mentoring, and summer institutes (Wilson, 2013). The hope is by positively influencing and educating the teachers, there will be a positive correlation in student performance (Bates & Morgan, 2018).

Through conducting a meta-analysis, Bates and Morgan (2018) found seven elements essential to successful professional development. The elements include a focus on content, active learning, collaboration, models of effective practice, coaching and expert support, feedback, and sustained duration (Bates & Morgan, 2018). The last element is essential as “ongoing professional development allows teachers to engage in cycles of continuous learning” (Bates & Morgan, 2018, p. 625). It is important for teachers to have time to try out new instructional methods and strategies and then be able to come back and share what happened (Bates & Morgan, 2018). The follow-up portion of professional development, while crucial, is usually missing (Bates & Morgan, 2018). The optimum professional development course incorporates all seven traits; however, it is incredibly difficult to include them all (Bates & Morgan, 2018). Regardless, teachers who received 80 hours of professional development training have a deeper understanding of the content and trend toward higher student achievement (Buczynski & Hansen, 2010). Therefore, professional development should be sustained, prolonged, and intense (Darling-Hammond, Hyler, & Gardner, 2017) to impact change positively.

Communities of Practice

Communities of practice are “groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” (Wenger, 2006, p. 1). In his book, *Communities of Practice*, Wenger (1998) outlined four ways for how people learn best. The stated that people need: 1) social interaction, 2) learning that is situated in a context they understand and care about, 3) the material is deemed important and relevant to them, and 4) the learning is applied to real-world experiences.

Communities of practice (CoP) are used across the globe as a way to enhance and encourage the education of groups in all walks of life. However, not all communities are a CoP

(Wenger, 2006). To be considered a CoP, there are three characteristics that must be included: the domain, the community, and the practice (Wenger, 2006).

The domain refers to the shared interests of the group. A CoP is not merely a group of friends or colleagues, it is based on a shared domain of interest amongst the group that separates the members from the general population (Wenger, 2006). The community speaks to the activity the group performs to help each other and further their understandings of the subject matter (Wenger, 2006). These activities could include things as simple as meeting in a café to discuss the shared interest or participating in an online discussion forum (Wenger, 2006). Lastly, the practice refers to the members themselves. The members are practitioners who develop a library of resources that can be used by the group in their respective practices to further their education and understanding of the topic (Wenger, 2006). Van As (2018), found that when teacher professional development implemented a CoP approach, the teachers reported a higher level of efficacy related to instructional strategies and pedagogy. Further, the participants reported the sustained nature of a CoP is an element they would like to experience more often when participating in professional development (Van As, 2018).

One potential CoP that might be beneficial to education is one that includes SBAE teachers, science educators, and extension educators. Research shows when science content is taught in the context of agriculture, students reach a higher level of science achievement (Balschweid, 2002; Chiasson & Burnett, 2001; Haynes et al., 2012; Ricketts et al., 2006). As such, Stephenson, Warnick, and Tarpley (2008) recommended that workshops should be designed to promote collaboration between agricultural teachers and science teachers. Therefore, a CoP involving all three disciplines (i.e., SBAE teachers, science teachers, and Extension educators) has the potential to promote the collaboration that can improve students' understanding of science.

Science Fairs

"Learners' participation in science fairs have been encouraged on grounds of affording them opportunities to carry out hands-on practical activities such as scientific investigations oriented towards inquiry science" (Ndlovu, 2014, p. 2381). Educators believe science competitions such as a science fair facilitates the acquisition of new science content knowledge as well as increasing the students' interest in the subject (Abernathy & Vineyard, 2001). Abernathy and Vineyard (2001) asked students who competed in a science fair to rank the rewards they received by participating in the fair. "Fun" was ranked number one of the list of rewards, directly followed by "learning new things" (Abernathy & Vineyard, 2001). The students also listed items such as "winning prizes," "competing against others," "learning the scientific process," and "sharing ideas with others" in the list of rewards they received by competing in a science fair (Abernathy & Vineyard, 2001). Although educators may be concerned by the number of outside motivators it takes for students to participate in science fairs, they should be encouraged by the enjoyment of learning new things expressed by the students who participated (Abernathy & Vineyard, 2001).

In a qualitative study conducted by Schmidt and Kelter (2017), 41 seventh-grade students participated in a focus group to determine if by participating in a science fair, they increased their interest in a STEM related career. The students were asked questions such as, "Do you feel you learned a lot by participating in the science fair?" and, "Do you think you'd like to become a scientist?" (Schmidt & Kelter, 2017). When asked if they would pursue a career in science seven out of 23 students reported affirmatively. When prodded further, nine of 14 students reported their desire to pursue a science career was influenced by participating in the science fair (Schmidt & Kelter, 2017). Unfortunately, the students who reported not wanting to be a scientist cited it as being too difficult. These students revealed they were interested before competing, but they soon found out it was difficult work which discouraged them from pursuing a career in a science field (Schmidt & Kelter, 2017).

Ndlovu (2014) investigated the participation rates of South African schools in science fairs and the factors that reduce participation. By categorizing each school by its socio-economic levels Ndlovu (2014) was able to analyze if poorer schools participated in science fairs at the same level as more affluent schools. The findings showed poorer schools had a much lower participation rate than their more affluent counterparts. However, what was surprising was one-half of the gold medals were awarded to just two schools (Ndlovu, 2014). This essentially made it a non-contest for the schools that did not receive any awards (Ndlovu, 2014).

Human Capital Theory

The original intent of the Human Capital Theory was to explain the monetary and psychic gains made by investing in human capital (Becker, 1993). Shultz (1961) noted the difference between the increases of national output and the increases in man hours, land, and other reproducible capital is most likely due to the increase in human capital. Becker (1993) gave schooling, medical care, on-the-job-training, migration, education, and training as examples of investments in human capital. In 1993, Becker commented on the different investment opportunities saying,

> They differ in their effects on earnings and consumption, in the amounts typically invested, in the size of returns, and in the extent to which the connection between investment and return is perceived. But all these investments improve skills, knowledge, or health, and thereby raise money or psychic incomes. (p. 11)

Becker's comment aligns with Shultz's (1961) comment of "such investments in human capital accounts for most of the impressive rise in the real earnings per worker" (p. 1).

“Economist have long known that people are an important part of the wealth of nations” (Shultz, 1961, p. 2). However, the concept of investment in human capital was a sensitive issue for many of the nation’s economists, as the very idea of human capital still carried the negative connotations related to slavery (Shultz, 1961). The idea of looking at people as capital goods is confusing and even offensive to some, as the nation prides itself on freeing men from bondage, and eradicating indentured servitude (Shultz, 1961). With those deep-seated moral objectives in mind, the notion of human capital seemingly contradicts every one of those objectives (Shultz, 1961). Although this is an understandable misunderstanding, human capital actually endeavors to increase the quality of life for those who invest (Shultz, 1961). “By investing in themselves, people can enlarge the range of choice to them. It is one way free men can enhance their welfare” (Shultz, 1961, p. 2).

“Education and training are the most important investments in human capital” (Becker, 1993, p. 17). After adjusting for disparities in family backgrounds, abilities, and the direct and indirect costs, research shows having a high school and college education in the United States substantially increases a person’s income (Becker, 1993). The data from multiple countries with differing cultures and development stages shows a person who has a higher level of education will almost universally earn well above the average wage (Becker, 1993). Shultz (1961) contended the previously unexplained 36 to 70 percent rise in income is a result of the additional education of workers.

More recently, Pil and Leana (2009) used the human capital level of elementary educators to predict student achievement. As expected, the researchers found a positive effect on student achievement when the educator possessed a higher level of human capital. Interestingly the researchers found human capital related to specific setting, such as teaching mathematics, had more impact on student achievement than general education levels (Pil & Leana, 2009).

> The implication is that employment practices that promote stability in teacher assignments in particular schools, along with professional development that is specific to the subject matter, may be better investments by school districts than is the current focus on general education attainment. (Pil & Leana, 2009, p. 1117)

Therefore, what impact does an intense weeklong professional development series have on educators self-perceived abilities to teach curriculum related to biofuels?

CHAPTER III

Methods

Educators attended a session of the sustainable bioenergy workshop held at Oklahoma State University in Stillwater, OK June 18-22, 2018. The educators were recruited through various outlets including word of mouth, social media, educational websites, and 4-H offices. The workshop was divided into classroom and laboratory sessions, led by Oklahoma State University scientists, and included offsite field tours and participant group discussions. Educators not only received technical science information, but also received training on statistics, experimental design, analyzing data, poster designs, and oral presentations. This program followed the train-the-trainer method with the hopes of increasing teacher biofuel content efficacy.

Purpose of the Study and Objectives

The purpose of this program evaluation was to determine the changes in educators' content and pedagogical knowledge of bioenergy, after participating in a weeklong bio-based professional development workshop. The following objectives guided the study:

1. Determine the educator's knowledge of bioenergy and STEM concepts.
2. Determine the educator's pedagogical knowledge related to bioenergy and STEM concepts.

3. Determine if the educator applied the content knowledge presented to them in the workshop in their classrooms.
4. Determine if the educators retained the content and pedagogical knowledge presented to them at the workshop.
5. Describe participants' perceptions for improving the workshop for future cohorts of participants.

Research Design

This program evaluation used the survey research design method (Privitera, 2017). The evaluation was summative in nature as it occurred during Year 1 of the three-year grant project. However, because the grant will continue for another two years, the results of this evaluation will be used to improve participant experiences at future workshops, which is the purpose of conducting a summative evaluation of a multi-year project (Newcomber, Hatrey,& Wholely, 2015).

A mixture of quantitative and qualitative paradigms was used to evaluate the impact of the program. A printed version of a quantitative instrument was administered in-person as a data were collected through an instrument prior to and at the end of educators' participation in the weeklong workshop. Additionally, the instrument was administered again, via electronic mail, 11 months after the workshop concluded as a form of a deferred analysis. In addition to quantitative items, a series of qualitative questions were asked on the follow-up (i.e., deferred) instrument. Specifically, the quantitative items on the instrument were designed to answer Objective One and Objective Three, and the qualitative questions on the instrument were designed to answer Objective Two and Objective Four.

Participants

Sixteen educators participated in the weeklong professional development session. The participants consisted of SBAE teachers, secondary science teachers, and Extension educators. These educators were recruited through various social media and educational websites, 4-H offices, and word of mouth.

Program Phases

The program consisted of a five-day professional development session performed by researchers at Oklahoma State University in Stillwater, OK as part of a funded USDA-NIFA grant award. The program began on June 18 and ended on June 22, 2018 and provided educators lodging, meals, transportation, and a travel stipend. Throughout the week, educators rotated through a series of educational sessions related to bioenergy and were exposed to various research experiments related to bioenergy (see Appendix C). Bioenergy-related laboratory kits were provided to educators with the expectation that they work in small groups to identify the problem and conduct the expected laboratory experiments within each module. In addition, field trips were planned to complement the experiments and allow educators to see and experience various bioenergy-related products at numerous stages and phases of development across numerous research centers in Oklahoma. Guest speakers in social and technical sciences were integrated throughout the week to help educators understand the importance bioenergy and how to teach it best to middle and high school students. Each day ended with a group discussion where participants reflected on the information featured that day. At the conclusion of the week, the educators received their own bioenergy kit which contained all the necessary supplies to replicate the experiments they learned during the sessions.

Specifically, the weeklong professional development workshop began on June 18, 2018 with educators taking a bioenergy assessment followed by an informational session to them on the topic of biomass (see Appendix C). The second day (June 19) was spent studying bioplastics, alcohol, plant growth, and oil extraction. In addition, educators learned how to detect and explain statistically and practically significant differences between and among research variables of interest. This session helped educators understand how to help their students design an experiment and use appropriate statistics to detect differences. The following day (June 20), the educators enjoyed field tours of Oklahoma State Universities local research stations. They also traveled to Ardmore, OK to tour the Noble Research Center's main campus, where they observed and learned about the machinery and equipment used to plant and harvest the biobased crops. The workshop concluded with an informational training on designing a poster for a science fair project related to bioenergy. The same instrument was administered to the participants again before they were released from the workshop.

Instrumentation

At the time the study was conducted, the grant team had just completed its first iteration of a three-year program. No evaluation instrument had been developed to measure the program's impact. Therefore, to evaluate the program, a researcher-developed instrument was created by a graduate student, under the guidance of an assistant professor and a professor, in plant and soil science. The graduate student, assistant professor, and professor all had various levels of experience teaching about and conducting research related to biofuels and bioenergy products. As a result, they were able to serve as content experts in developing the items measured. In addition, to accommodate the needs of this evaluation, the instrument was aligned to the PCK theory (Shullman, 1986). In accordance with PCK theory, the Likert-type scale instrument contained 11 content knowledge and six pedagogical knowledge items using a five-point Likert-type scale. Additionally, the instrument contained one open-ended question (see Appendix A). The instrument was administered to participants twice, once before participating in the training, and again after the training concluded. In addition to the original items, the deferred assessment (see Appendix B) contained four additional open-ended items, and are as follows:

- What aspects learned in the workshop do you utilize the most and why?
- Describe the bioenergy experiments you have performed and the lessons you have learned in the process.
- How did your participation in the workshop benefit you and your students?
- In what ways do you think the workshop can be improved for the next round of participants?

Data Collection

To collect the data, a pre-assessment was administered on Day One of the program prior to exposure of the bioenergy curriculum. On Day Five of the program, which was the last day of the workshop, the participants were administered the instrument again to determine the impact of the training. Approximately 11 months after participating in the bioenergy workshop, the educators were sent a modified version of the instrument as a follow-up to gauge their knowledge retention and determine which aspects of the content they were using with their students.

Data Analysis Plan

The data collected were analyzed using IBM 2015 statistical software SPSS version 23. To evaluate the overall impact of the program, grand means of the three data collection points were compared. The open-ended questions were used to make programmatic decisions.

Logic Model

Constructing a logic model is an important process for evaluators. We followed McLaughlin's and Jordan's (2015) five-stage process of developing a logic model, which included: 1) Collecting information germane to the program (Stage 1); 2) Defining the program's central problem (Stage 2); 3) Drawing meaning of the various elements central to the program

(Stage 3); 4) Creating the logic model to conceptualize the program and its intended impact (Stage 4); and 5) Validating the program's model with key stakeholders (Stage 5).

Figure 1 provides the logic model created to guide this evaluation. To accommodate McLaughlin's and Jordan's (2015) five-stage process, I (the lead evaluator) referred to the original grant team's goals and objectives and reviewed the information and rationale for the weeklong professional development sessions. I interacted, personally, with the research team as a graduate research assistant on a .50 FTE. Specifically, I examined the grant proposal and highlighted key information relevant to program. In addition, I collected, inputted, and examined the data from the program, all of which align with Stage 1. After collecting the necessary information, I highlighted the problem most germane to the program's needs (Stage 2). The problem centered on educators' (i.e., SBAE teachers, extension educators, and science teachers) lack of content knowledge related to bioenergy (see Figure 1). Although the program is a multi-year initiative, the evaluation conducted for this study is only meant for the first cohort of educators, who participated in Year 1 (Summer 2017). In Stage 3, after collecting the data, I organized statements and themes around the qualitative responses, which served to justify and explain educators' responses to the quantitative instrument at three separate stages: prior to and at the end of the weeklong training program, and 11 months after the program ended (i.e., deferred assessment). Understanding the relationships between these data at three different points in time helped the research team understand the various aspects associated with the program. In Stage 4, the research team, used the information collected to design the overall logic model for the study. This design consisted of inputs, activities, and outputs, as well as short-term, intermediate, and long-term goals (see Figure 1). Finally, in Stage 5, data were assessed to determine the practical application and validation of the logic model. In this stage, both quantitative and qualitative data were used to describe the performance of educators and their students regarding their bioenergy knowledge and interest in pursuing degrees in STEM and to determine why and how these levels of performance related to the program were achieved (McLaughlin & Jordan, 2015).

Program: Weeklong Professional Development Program for Educators on Bioenergy					
Goal: Increase the bioenergy content knowledge of school-based agricultural education teachers, extension educators, and science teachers.					
			Outcomes		
Inputs	**Activities**	**Outputs**	**Short-term**	**Intermediate**	**Long-term**
Need for increased bioenergy content knowledge	Weeklong professional development session	Trained educators and scientists	Middle and high school educators have the confidence needed to teach bioenergy curriculum	Educators accurately apply the evidence-based curriculum in their programming	An increased number of students participate in science fairs with bioenergy experiments
Evidence-based bioenergy curriculum	Educators teach students the content they learned in the PD sessions	Middle and high school students acquire greater science understanding	Middle and high school educators have the knowledge to teach bioenergy curriculum	Students elect to study bioenergy-related STEM degrees	An increased number of students graduate with STEM degrees and choose careers in bioenergy
NIFA funding necessary to provide training and training materials			Middle and high school educators use the bioenergy curricula to complement their existing lessons	Students participate in the scientific method and conduct experiments using bioenergy as the context	An increased number of students who understand advanced levels of science
Curricula necessary for teaching the lessons				Middle and high school educators increase their efficacy for teaching about bioenergy	Middle and high school educators return for supporting roles with future cohorts

Figure 1. Logic model for the impact of a weeklong training session on educators' bioenergy knowledge.

CHAPTER IV

Findings

Educators attended a session of the sustainable bioenergy workshop held at Oklahoma State University in Stillwater, OK June 18 through June 22, 2018. The educators were recruited through various outlets including word of mouth, social media, educational websites, and 4-H offices. The workshop was divided into classroom and laboratory sessions, led by Oklahoma State University scientists, and included offsite field tours and participant group discussions. Educators not only received technical science information, but also received training on statistics, experimental design, analyzing data, poster designs, and oral presentations. This program followed the train-the-trainer method with the hopes of increasing educators' bioenergy and STEM content knowledge.

Purpose of the Study and Objectives

The purpose of this program evaluation was to determine the changes in educators' content and pedagogical knowledge of bioenergy, after participating in a weeklong bio-based professional development workshop. The following objectives guided the study:

1. Determine the educator's knowledge of bioenergy and STEM concepts.
2. Determine the educator's pedagogical knowledge related to bioenergy and STEM concepts.

3. Determine if the educators applied the information presented to them in the workshop in their classrooms.
4. Determine if the educators retained the information presented to them at the workshop.
5. Describe participants' perceptions for improving the workshop for future cohorts of participants.

Participants

The 16 participants in the program evaluation consisted of SBAE teachers, secondary science teachers, and Extension educators. These individuals were recruited through social media, 4-H offices, word-of-mouth, and various educational websites.

Data Collection

To collect the data, a pre-assessment was administered to the educators on Day One of the program prior to exposure of the bioenergy curriculum. On Day Five of the program, which was the last day of the workshop, the participants were administered the same instrument again to determine the overall impact of the five-day training sessions. Then, approximately 11 months after participating in the workshop, the educators were provided a modified version of the instrument as a follow-up to gauge their knowledge retention.

Objective 1: Determine the Educator's Knowledge of Bioenergy and STEM Concepts

Objective one sought to assess the educator's knowledge of bioenergy and STEM concepts. The instrument items designed to assess the content knowledge were items 1 through 10 and 13. These had an alpha coefficient of .87, which suggests a relatively high level of internal consistency. Table 1 provides the breakdown of educators' confidence level changes related to teaching bioenergy and STEM content prior to and at the end of the weeklong training session. The content knowledge items educators were most confident to teach prior to the workshop were Energy (M = 2.77, SD = .73) and Sustainability (M = 2.77, SD = .73). In contrast, the content knowledge areas educators were least confident to teach prior to the workshop were Converting energy to usable form (*M* = 2.08, *SD* = 1.08) and Plant energy used as fuel (*M* = 2.08, *SD* = .95). Plant energy used as fuel (*Mean Difference* = 1.77), Converting energy to usable form (*Mean Difference* = 1.59), and Crop energy (*Mean Difference* = 1.55) were the three content items that educators displayed the greatest change in their perceived knowledge, as a result of the weeklong workshop (see Table 1). Only one item (Energy) received less than a 1-point growth in knowledge change in educators' confidence levels to teach (*Mean Difference* = .92). In all, educators experienced a 1.39 increase in their confidence levels to teach bioenergy and STEM-related concepts as a result of the weeklong training program (see Table 1).

Table 1

Bioenergy and STEM Concepts Confidence Levels

Items		*M*	*SD*	*Mean Difference*[a]
1.	What is the main idea behind bioenergy?			
	Prior to Training	2.23	.93	1.39
	After Training	3.62	.18	
2.	What are the relationships between plant based energy and the environment?			
	Prior to Training	2.15	.99	1.54
	After Training	3.69	.48	
3.	What is the basic idea of energy?			

	Prior to Training	2.77	.73	.92
	After Training	3.69	.63	
4.	How is plant energy used as fuel?			
	Prior to Training	2.08	.95	1.77
	After Training	3.85	.56	
5.	How do crops produce energy?			
	Prior to Training	2.23	1.01	1.55
	After Training	3.78	.44	
6.	Why do plants make a good energy source?			
	Prior to Training	2.39	.96	1.53
	After Training	3.92	.28	
7.	How is energy converted to a useable form?			
	Prior to Training	2.08	1.08	1.59
	After Training	3.67	.49	
8.	How is plant energy stored?			
	Prior to Training	2.39	1.04	1.46
	After Training	3.85	.55	
9.	How well do you understand sustainability?			
	Prior to Training	2.77	.73	1.08
	After Training	3.85	.36	
10.	How does crop breeding work?			
	Prior to Training	2.15	.90	1.16

	After Training	3.31	.63	
13.	How does plant energy help solve real world problems?			
	Prior to Training	2.62	.65	1.30
	After Training	3.92	.28	

Note. 0 = No Confidence, 1 = Little Confidence, 2 = Moderate Confidence, 3 = Good Confidence, 4 = Great Confidence, 5 = Not Applicable;

[a]*Mean Difference* = 1.39

Objective 2: Determine the educator's pedagogical knowledge related to bioenergy and STEM concepts

Objective two sought to assess the educators' pedagogical knowledge of bioenergy and STEM concepts. The instrument contained six items related to pedagogical knowledge. This section of the instrument had an alpha coefficient of .89, suggesting a relatively high level of internal consistency. The participants reported their confidence levels prior to and after the workshop for each of the six items (see Table 2). The items educators had the most knowledge of prior to the workshop was the Scientific Method (*M* = 3.62, *SD* = .65) and develop and test a hypothesis (*M* = 3.54, *SD* = .52), both ranging in the moderate to great knowledge category. The items, Relate new ideas to similar classes (*Mean Difference* = 1.00) and Relate new ideas to similar classes (*Mean Difference* = .92), were those that educators displayed the greatest change in their perceived knowledge, as a result of the weeklong workshop. Educators rated their confidence levels of their pedagogical knowledge in bioenergy and STEM concepts to be Great Confidence on all six items at the end of the weeklong training program (see Table 2)

Table 2

Educators' Confidence Levels of their Pedagogical Knowledge of Bioenergy and STEM Concepts

Items		*M*	*SD*	*Mean Difference*[a]
11.	Relate new ideas to similar classes			
	Prior to Training	3.08	.76	.92
	After Training	4.00	.00	
12.	Relate new ideas to cross curricular classes			
	Prior to Training	3.00	.71	1.00
	After Training	4.00	.41	
14.	The scientific method			
	Prior to Training	3.62	.65	.38
	After Training	4.00	.00	
15.	Setting up an experiment			
	Prior to Training	3.46	.88	.46
	After Training	3.92	.28	
16.	Develop and test a hypothesis			
	Prior to Training	3.54	.52	.38
	After Training	3.92	.28	
17.	Making conclusions based on relevant information			
	Prior to Training	3.33	.66	.59
	After Training	3.92	.28	

Note. 0 = No Confidence 1 = Little Confidence, 2 = Moderate Confidence, 3 = Good Confidence, 4 = Great Confidence, 5 = Not Applicable

[a]*Mean Difference* = .62

Objective 3: Determine how educators applied the information presented to them in the workshop in their classrooms.

Objective three sought to assess if the educators applied the content of the workshop in their classrooms. The deferred assessment (see Appendix B) contained two qualitative questions asking if the educators utilized what they learned in the weeklong training session. In response to the question, "What aspects learned in the workshop do you utilize the most and why?", participants reported they had indeed incorporated the laboratory lessons into their curriculum. One of the participants responded: "My students learn better with hands-on activities." Another participant said he chose to incorporate the labs because it is a "different way to include agriculture in my class easily." When asked specifically about which laboratory experiences they chose to perform and why, the participants responded with a variety of answers. One participant responded the bioplastics laboratory provided her students with a "wow" moment. Another participant responded: "The yeast experiment gave them knowledge about how the result was a gas and can be used for energy", and "students love to learn through a hands-on process, and I enjoy teaching that way."

Objective 4: Determine if the educators retained the information presented to them at the workshop.

Objective four sought to assess if the educators retained the information presented to them at the workshop. This was accomplished by sending out a modified version of the instrument (see Appendix B) 11 months after the workshop was completed. All of the following confidence levels are reported from the post assessment (i.e., last day of the training session) to the deferred post assessment (11 months after the training session ended). Fortunately, educators' confidence levels regarding their ability to teach items related to bioenergy and STEM ranged between moderate and great 11 months after the training concluded (see Table 3). The items in which educators lost the greatest amount of confidence to teach were relate new ideas to similar classes (*Mean Difference* = -.58) and crop energy (*Mean Difference* = -.57), respectively. Energy was the item educators felt most confident to teach 11 months after the conclusion of the training program, as indicated by a *Mean Difference* of -.14).

Table 3

Bioenergy and STEM Content and Pedagogical Confidence Levels 11 months after the workshop

Items		*M*	*SD*	*Mean Difference*[a]
1.	What is the main idea behind bioenergy?			
	After Training	3.71	.49	-.42
	11 months later	3.29	.95	
2.	What are the relationships between plant-based energy and the environment?			
	After Training	3.71	.49	-.42
	11 months later	3.29	.95	
3.	What is the basic idea of energy?			
	After Training	3.71	.29	-.14
	11 months later	3.57	.53	
4.	How is plant energy used as fuel?			
	After Training	3.71	.76	-.42
	11 months later	3.29	.95	
5.	How do crops produce energy?			
	After Training	3.86	.38	-.57
	11 months later	3.29	.95	
6.	Why do plants make a good energy source?			
	After Training	3.86	.38	-.29

	11 months later	3.57	.54	
7.	How is energy converted energy to a useable form?			
	After Training	3.83	.41	-.33
	11 months later	3.50	.55	
8.	How is plant energy stored?			
	After Training	3.71	.76	-.42
	11 months later	3.29	1.11	
9.	How well do you understand sustainability?			
	After Training	3.86	.38	-.43
	11 months later	3.43	.79	
10.	How does crop breeding work?			
	After Training	3.57	.79	-.43
	11 months later	3.14	.90	
11.	Relate new ideas to similar classes			
	After Training	4.00	.00	-.58
	11 months later	3.42	.53	
12.	Relate new ideas to cross curricular classes			
	After Training	3.86	.38	-.29
	11 months later	3.57	.53	
13.	How does plant energy solve real world problems?			
	After training	3.86	.38	-.29
	11 months later	3.57	.79	
14.	Scientific method			

	After Training	4.00	.00	-.29
	11 months later	3.71	.95	
15.	Setting up an experiment			
	After Training	3.86	.38	-.29
	11 months later	3.57	.53	
16.	Develop and test a hypothesis			
	After Training	3.86	.38	-.29
	11 months later	3.57	.79	
17.	Making conclusions based on relevant information			
	After Training	3.86	.38	-.29
	11 months later	3.57	.79	

Note. 0 = No Confidence 1 = Little Confidence, 2 = Moderate Confidence, 3 = Good Confidence, 4 = Great Confidence, 5 = Not Applicable

[a]*Mean Difference* = -.36

Objective 5: Describe the ways the workshop can be improved for the next cohort of participants.

Objective five sought to discover any suggestions for improvements that would enhance the workshop experience for the next cohort of participants. When asked about improvements to the workshop, an overwhelming number of participants reported they did not have any suggestions for improvement. However, one participant reported he or she would have liked to receive more follow-up support throughout the year. Another participant said he or she would have liked a more in-depth curriculum that would "better serve their students."

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS, RECOMMENDATIONS, AND DISCUSSION,

Educators attended a session of the sustainable bioenergy workshop held at Oklahoma State University in Stillwater, OK June 18 through June 22, 2018. The educators were recruited through various outlets including word-of-mouth, social media, educational websites, and 4-H offices. The workshop was divided into classroom and laboratory sessions, led by Oklahoma State University scientists, and included offsite field tours and participant group discussions. Educators not only received technical science information, but also received training on statistics, experimental design, analyzing data, poster designs, and oral presentations. This program followed the train-the-trainer method with the hopes of increasing teacher biofuel content efficacy.

Purpose of the Study and Objectives

The purpose of this program evaluation was to determine the changes in educators' content and pedagogical knowledge of bioenergy, after participating in a weeklong bio-based professional development workshop. The following objectives guided the study:

1. Determine the educator's knowledge of bioenergy and STEM concepts.

2. Determine the educator's pedagogical knowledge related to bioenergy and STEM concepts.
3. Determine if the educator applied the content knowledge presented to them in the workshop in their classrooms.
4. Determine if the educators retained the content and pedagogical knowledge presented to them at the workshop.
5. Describe participants' perceptions for improving the workshop for future cohorts of participants

Methods and procedures

The study was conducted over an intense weeklong professional development session for bioenergy content and pedagogical knowledge of 16 educators, which consisted of SBAE teachers, science teachers, and extension educators. Over the course of the week, the educators attended classroom and laboratory sessions where they learned about bioenergy content and pedagogical strategies. They were provided with reflection and group discussion time at the conclusion of session every day. Additionally, they attended several field tours where they received an up-close look of research being conducting in the bioenergy field.

Data Collection and Analysis

To gauge the effectiveness of the workshop the educators were administered a 17-item Likert-type 5-point assessment prior to and after the workshop. The instrument was developed by a graduate student, who operated under the guidance of two faculty members in plant and soil science. Each of these individuals has experiences teaching and researching bioenergy. To assess knowledge retention long-term, a deferred post assessment was administrated to those educators who participated 11 months after the conclusion of the workshop. The data were analyzed using

IBM 2015 statistical software SPSS version 23. The means and standard deviations were used to make comparisons between the three data collection points.

Conclusions

Educators who participated in the weeklong training program experienced substantial increases in their confidence as related to their content and pedagogical content knowledge in the area of bioenergy. This conclusion relates to the importance of investing in one's human capital (Becker, 1993; Shultz, 1961). When done, positive changes can occur. Specifically, educators' confidence related to bioenergy and STEM increased in excess of one full point as a result of the training (see Table 1). The data show the workshop was effective in increasing the content confidence levels among the educators. Item four, which pertained to using plant energy as fuel, received the greatest increase in confidence level as reported by the educators. In addition, the pedagogical knowledge confidence levels also increased across all items on the instrument. However, item 12, Relating new ideas to cross-curricular classes, received the sharpest increase in confidence levels.

The laboratory experiences where educators incorporated the information into their classrooms were due to their ability to provide students with a unique hands-on learning experience. The fact that these educators implemented the curriculum at all is a testament to their comfort with and understanding of the material, a concept deemed vital to implementation (Schneider & Plasman, 2011).

The deferred post assessment was designed to gauge if the educators retained any of the content and pedagogical knowledge presented at the workshop. Educators perceived their confidence with bioenergy content to range between good to moderate prior to the workshop. Each item on the instrument had a mean score of moderate knowledge. However, the workshop provided increased confidence in educators' ability to know and be able to teach bioenergy. The weeklong professional development workshop devoted to bioenergy impacted their confidence positively, which aligns with findings by Darling-Hammond et al. (2007) who stated for professional development to make a lasting impact, it needs to be intense and prolonged.

Although educators noticed substantial gains in content knowledge as a result of the one-week professional development sessions, their confidence in the material decreased 11 months later. This conclusion aligns with Shulman's (1986) PCK Theory, which states that educators need to possess a knowledge of content specific for teaching, which is even more extensive than just a basic understanding of the subjects they teach. Although the data revealed educators failed to retain the information at the level they had acquired originally, it was encouraging the information retained 11 months after the program ended was substantially higher than that prior to the workshop. Specifically, item 11, relating new ideas to similar classes, had a particularly sharp decline in the confidence levels for educators. What is more, even 11 months after the conclusion of the program, educators' confidence levels with the content ranged from Good Confidence to Great Confidence.

Lastly, when educators were asked what aspects of the workshop needed improvement, the overwhelming response was that the participants were satisfied with their experience and that no improvements were needed. However, one educator suggested the need for follow-up support throughout the year. Another suggested more rigorous curriculum be developed, as they felt a deeper curriculum would suit the needs of their students better. Such follow-up over time has the potential to improve the overall human capital of educators, making them more valuable employees in their formal and informal teaching positions (Becker, 1993; Shultz, 1961).

Recommendations

Research has suggested that professional development can help educators increase their knowledge of and confidence to teach the content they are held accountable for delivering (Bates

& Morgan, 2018). However, affording teachers adequate time and resources to share and collaborate is vital to ensuring learning and adoption occurs once the workshop ends (Wenger, 1998). The one-week duration of this workshop is not sufficient for lasting change. Rather, a more sustained and prolonged effort over time is warranted (Darling-Hammond et al., 2017). Therefore, it is recommended educators continue to participate and engage regularly in professional development on topics related to bioenergy and STEM content knowledge. Further, the professional development coordinators of this session should provide ongoing support to participating educators after the conclusion of the workshop. Doing so will likely increase educators' retention of the material and confidence for teaching bioenergy long-term. In addition to face-to-face training, online modules and communities should be established for the educators who participated in the training and are teaching the content.

In addition to ongoing support, a CoP should be set up for the participants to join (Wenger, 1998). Communities of practice have been shown to increase the knowledge and skills for groups of people (Wenger, 2006). An online CoP where the participants can share their thoughts, lessons, struggles, and experiences, as well as seek out mentorship and interact with one another regularly could greatly enhance the educators' experience by extending their learning after the workshop has concluded. Another welcomed benefit would be the potential increase in the number of educators who incorporate the bioenergy material into their classrooms. Van As (2018), found that when teacher professional development implemented a CoP approach, the teachers reported a higher level of efficacy related to instructional strategies and pedagogy. Therefore, once implemented, the CoP should be tracked longitudinally to determine its impact on student learning and educator efficacy.

As the program continues, it is important stakeholders increase the intensity of the evaluation. Future evaluations should be conducted around and framed using Stufflebeam's (2007) Context, Input, Process, and Product (CIPP) Model. For instance, the school's culture of these participating educators should be studied to determine if any changes have occurred as a result of this training. For instance, do the facilities include evidence that these experiments have been conducted and are being used frequently (Process), or are the materials boxed away on a shelf in storage? Assuming educators are using the materials, is their physical layout design in the learning environment conducive to student learning (Context)?

The purpose of teaching is student learning. Pil and Leana (2009) found that human capital related to specific setting, i.e., teaching bioenergy-related concepts, had more impact on student achievement than general education levels. Therefore, it is recommended the students of these educators be studied to determine how their knowledge of and interest in bioenergy and STEM changed as a result of their educator encountering the training and teaching the curriculum. Specifically, students should be assessed prior to and at the end of each experiment their educator introduces. In addition to knowledge changes, attitudinal changes should be assessed if any, have occurred in educators and students based on the lessons taught? Are students more interested in bioenergy, specifically, and STEM, generally, after completing aspects of the curriculum in class (Product)? Students of these educators should be followed longitudinally and compared over time to determine the learning skills that have been gained (Input).

A long-term goal in the logic model is to have past participants return in a supporting role for future cohorts. One avenue for this support would be for educators from Cohort 1 to host their own professional development sessions for other educators in their respective disciplines. In a true train-the-trainer fashion, if the participants trained other members of their professions, the dissemination of the information would be exponential in developing and sustaining human capital (Becker, 1993; Shultz, 1961) necessary to effect positive, long-term change. Another goal in the logic model is to have an increased number of students participate in science fairs with a bioenergy project. However, for unknown reasons past cohorts have not been engaging in science fairs. The goal of the professional development session would be to increase teacher efficacy and content knowledge related to coaching students into performing science fair projects related to the topic. Therefore, the professional development coordinators of this work should assist educators and hold them accountable for following through with this goal.

Because the Oklahoma Extension service is dedicated to increasing science literacy by performing trainings and camps throughout the year (Branscum & Sallee, 2019), the content and resources from this professional development session should be shared with Extension educators and specialists to enhance their programs and trainings. In addition, the results of this study should be shared with the state STEM specialist to contribute to future STEM programs and inform future professional development sessions. With Extension educators stationed in every county across the state, the potential exists for bioenergy education to impact youth statewide.

Finally, this study assessed educators' perceptions. Perceptions and actual ability to teach content, especially that related to science, can be two very different things (Scales, Terry, Jr., & Torres, 2009). Therefore, assessing educators' perceptions along with their actual knowledge of bioenergy is needed. To accomplish this, the instrument needs to be enhanced by crosswalking it with the National Science Education Standards (NSES) and the Agriculture, Food, and Natural Resources (AFNR) standards. By cross referencing both sets of standards and including items that overlap, participants' actual ability to teach the standards could be assessed.

Discussion

The results of the pre-assessment and post assessment indicate the workshop was effective in increasing the content and pedagogical knowledge confidence levels in the educators who attended. This is congruent with previous research studies on the impact professional development makes of teachers' knowledge (Bates & Morgan, 2018). The educators reported they perceived the workshop greatly enhanced their teaching, and the learning of their students. The educators reported their students enjoyed learning about bioenergy with the hands-on opportunities provided by the laboratory activities. They reported they enjoyed using the hands-on instructional strategy they learned in the workshop. Although the participants reported a multitude of benefits, the scores declining slightly after 11 months had passed suggests the educators may not have retained all the information presented in the workshop.

Although the findings are encouraging, the small population warrants further investigation. Having only 16 subjects limits the study's generalizability. In addition, demographic data (i.e., personal and professional characteristics) of the participants were not collected, which exacerbates the issue of generalizability. Another limitation of the study was that the instrument was entirely self-reported perceptions, and as such, is subject to personal bias. Finally, attrition existed between the three assessments. With about one-half of the participants choosing not to participate in the 11-month deferred assessment, the attrition rate was relatively high, and should be taken into consideration when examining the findings of the study.

REFERENCE

Abernathy, T. V., & Vineyard, R. N. (2001). Academic competitions in science: What are the rewards for students? *The Clearing House, 74*(5), 269–276. doi:10.1080/00098650109599206

Ahearn, M. C., Yee, J., & Bottum, J. S. (2003). *Regional trends in extension system resources* (No. 1474-2016-120822).

Anderson, J. R., & Feder, G. (2004). Agricultural extension: Good intentions and hard realities. *The World Bank Research Observer, 19*(1), 41–60. doi:10.1093/wbro/lkh013

As, F. (2018) Communities of practice as a tool for continuing professional development of technology teachers' professional knowledge. *International Journal of Technology and Design Education, 28*(2), 417– 430. doi:10.1007/s10798-017-9401-8

Avraamidou, L., & Zembal□Saul, C. (2010). In search of well□started beginning science teachers: Insights from two first□year elementary teachers. *Journal of Research in Science Teaching, 47*(6), 661–686. doi:10.1002/tea.20359

Balschweid, M. A. (2002). Teaching biology using agriculture as the context: Perceptions of high school students. *Journal of Agricultural Education, 43*(2), 56–67. doi:10.5032/jae.2002.02056

Balschweid, M., Thompson, G., & Cole, R. (1998). The effects of an agricultural literacy treatment on participating K-12 teachers and their curricula. *Journal of Agricultural Education, 39*(4), 1–10. doi:10.5032/jae.1998.04001

Bates, C. C., & Morgan, D. N. (2018). Seven elements of effective professional development. *The Reading Teacher, 71*(5), 623–626. doi:10.1002/trtr.1674

Barbieri, A. F., Domingues, E., Queiroz, B. L., Ruiz, R. M., Rigotti, J. I., Carvalho, J. A., & Resende, M. F. (2010). Climate change and population migration in Brazil's Northeast: Scenarios for 2025–2050. *Population and Environment, 31*(5), 344–370. doi:10.1007/s11111-010-0105-1

Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., ... & Martinez, N. D. (2012). Approaching a state shift in Earth's biosphere. *Nature, 486*(7401), 52. doi:10.1038/nature11018

Becker, G. (1993). *Human capital: A theoretical and empirical analysis, with special reference to education* (3rd ed.). Chicago, IL: The University of Chicago Press.

Birkenholz, R. J. (December, 1993). *Pilot study of agricultural literacy – Final report.* U.S. Department of Agriculture, Cooperative States Research Service: Washington, DC.

Bowling, C. J., & Brahm, B. A. (2002). Shaping communities through extension programs. *Journal of Extension, 40*(3).

Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and Teacher Education, 26*(3), 599–607. doi:10.1016./j.tate.2009.09.006

Branscum, H., & Sallee, J. (2019). Addressing scientific literacy in Oklahoma: The stemist program. *Journal of Extension, 57*(3).

Brinkley, A. (2009). Half a mind is a terrible thing to waste. *Newsweek, 154*(21), 48.

Camp, W. G. (2017). Smith, Hughes, Page, and Prosser. *The Agricultural Education Magazine, 89*(4), 10.

Campbell, B. T., Wilkinson, C. A., Shepherd, P. J., & Gray, P. (2015). Industry and extension partnership to enhance STEM and agricultural education. *Journal of Extension, 53*(4).

Chiasson, T.C., & Burnett, M. F. (2001). The influence of enrollment in agriscience courses on the science achievement of high school students. *Journal of Agricultural Education, 42*(1), 61–71. doi:10.5032/jae.2001.01061

Carolan, M. (2009). A sociological look at biofuels: Ethanol in the early decades of the twentieth century and lessons for today. *Rural Sociology, 74*(1), 86–112. doi:10.1526/003601109787524034

Chumbley, S. B., Haynes, J. C., & Stofer, K. A. (2015). A measure of students' motivation to learn science through agricultural STEM emphasis. *Journal of Agricultural Education, 56*(4), 107–122. doi:10.5032/jae.2015.04107

Coale, A. J. (1974). The history of the human population. *Scientific American, 231*(3), 40–51.

Colbert, J. A., Brown, R. S., Choi, S., & Thomas, S. (2008). An investigation of the impacts of teacher-driven professional development on pedagogy and student learning. *Teacher Education Quarterly, 35*(2), 135–154.

Dale, B. E., Bals, B. D., Kim, S., & Eranki, P. (2010). Biofuels done right: Land efficient animal feeds enable large environmental and energy benefits, *Environmental Science Technology, 44*(22), 8385–8389. doi:10.1021/es101864b

Dale, C., Robinson, J. S., & Edwards, M. C. (2017). An assessment of the agricultural literacy of incoming freshmen at a land-grant university. *NACTA Journal, 61*(1), 7–13.

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Learning Policy Institute. Retrieved from https://static1.squarespace.com/static/56b90cb101dbae64ff707585/t/5ade348e70a6ad624d417339/1524511888739/NO_LIF%7E1.PDF

Demirbas, A. (2009). Political, economic and environmental impacts of biofuels: A review. *Applied Energy, 86,* S108–S117. doi:10.1016/j.apemergy.2009.04.036

Dragoş, V., & Mih, V. 2015). Scientific literacy in school. *Procedia – Social and Behavioral Sciences, 209*(C), 167–172. doi:10.1016/j.sbspro.2015.11.273

Environmental Protection Agency. (2012). *Demographics.* Retrieved from http://www.epa.gov/agriculture/ag101/demographics.html

Finlay, M. R. (2003). Old efforts at new uses: A brief history of chemurgy and the American search for biobased materials. *Journal of Industrial Ecology, 7*(3□4), 33–46.

Escobar, J. C., Lora, E. S., Venturini, O. J., Yáñez, E. E., Castillo, E. F., & Almazan, O. (2009). Biofuels: Environment, technology and food security. *Renewable and Sustainable Energy Reviews, 13*(6-7), 1275–1287. doi:10.1016/j.rser.2008.08.014

Graham, R. C., Burgoyne, N., Cantrell, P., Smith, L., St. Clair, L., & Harris, R. (2009). Measuring the TPACK confidence of inservice science teachers. *TechTrends, 53*(5), 70–79. doi:10.1007/s11528-009-0328-0

Gray, J. S., Dautel, H., Estrada-Peña, A., Kahl, O., & Lindgren, E. (2009). Effects of climate change on ticks and tick-borne diseases in Europe. *Interdisciplinary Perspectives on Infectious Diseases, 2009.* doi:10.1155/2009/593232

Haynes, J. C., Robinson, J. S., Edwards, M. C., & Key, J. P. (2012). Assessing the effect of using a science-enhanced curriculum to improve agriculture students' science scores: A causal comparative study. *Journal of Agricultural Education, 5*3(2), 15–27. doi:10.5032/jae.2012.02015

Harker-Schuch, I., & Bugge-Henriksen, C. (2013). Opinions and knowledge about climate change science in high school students. *Ambio, 42*(6), 755–766. doi:10.1007/s13280-013-0388-4

Hill, J., Nelson, E., Tilman, D., Polasky, S., & Tiffany, D. (2006). Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proceedings of the National Academy of Sciences, 103*(30), 11206–11210. doi:10.1073/pnas.0604600103

Herren, R. (1986). Controversy and unification: The passage of the Smith-Hughes Act. *Journal of the American Association of Teacher Educators in Agriculture, 27*(1), 39–44. doi:10.5032/jaatea.1986.01039

Hess, A. J., & Trexler, C. J. (2011). A qualitative study of agricultural literacy in urban youth: What do elementary students understand about the agri-food system? *Journal of Agricultural Education, 52*(4), 1–12. doi:10.5032/jae.2011.04001

Hubert, D., Frank, A., & Igo, C. (2000). Environmental and agricultural literacy education. *In Environmental Challenges* (pp. 525-532). Springer, Dordrecht.

Hurd, P. D. (1958). Science literacy: Its meaning for American schools. *Educational Leadership, 16*(1), 13–16.

Impey, C., Buxner, S., Antonellis, J., Johnson, E., & King, C. (2011). A twenty-year survey of science literacy among college undergraduates. *Journal of College Science Teaching, 40*(4), 31–37.

Ingvarson, L., Meiers, M., & Beavis, A. (2005). Factors affecting the impact of professional development programs on teachers' knowledge, practice, student outcomes & efficacy. *Education Policy Analysis Archives 13*(10), 1–20.

Jayaratne, K. S. U., Bradley, L. K., & Driscoll, E. A. (2009). Impact evaluation of integrated Extension programs: Lessons learned from the community gardening program. *Journal of Extension, 47*(3).

Jiang, L., & Hardee, K. (2011). How do recent population trends matter to climate change? *Population Research and Policy Review, 30*(2), 287–312. doi:10.1007/s11113-010-9189-7

Karl, T. R., & Trenberth, K. E. (2003). Modern global climate change. *Science, 302*(5651), 1719–1723.

Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. *Studies in Science Education, 45*(2), 169–204. doi:10.1126/science.1090228

Koetse, M. J., & Rietveld, P. (2009). The impact of climate change and weather on transport: An overview of empirical findings. *Transportation Research Part D: Transport and Environment, 14*(3), 205–221. doi:10.1016/j.trd.2008.12.004

Kovar, K. A., & Ball, A. L. (2013). Two decades of agricultural literacy research: A synthesis of the literature. *Journal of Agricultural Education, 54*(1), 167–178. doi:10.5032/jae.2013.01167

Kovarik, B. (1998). Henry Ford, Charles F. Kettering and the fuel of the future. *Automotive History Review, 32*, 7–27.

Lakshmanan, A., Heath, B. P., Perlmutter, A., & Elder, M. (2011). The impact of science content and professional learning communities on science teaching efficacy and standards□based instruction. *Journal of Research in Science Teaching, 48*(5), 534–551. doi:10.1002/tea.20404

Liaquat, A. M., Kalam, M. A., Masjuki, H. H., & Jayed, M. H. (2010). Potential emissions reduction in road transport sector using biofuel in developing countries. *Atmospheric Environment, 44*(32), 3869–3877. doi:10.1016/j.atmosenv.2010.07.003

Lieberman, A., & Pointer Mace, D. (2010). Making practice public: Teacher learning in the 21st Century. *Journal of Teacher Education, 61*(1-2), 77–88. doi:10.1177/0022487109347319

Liu, X. (2009). Beyond science literacy: Science and the public. *International Journal of Environmental and Science Education, 4*(3), 301–311.

Loewenberg-Ball, D., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407. doi:10.1177/0022482108324554

Matthews, H. S., Hendrickson, C. T., & Weber, C. L. (2008). The importance of carbon footprint estimation boundaries. *Environmental Science & Technology 42*(16), 5839–5842. doi:10.1021/es703112w

McKim, A. J., Velez, J. J., Lambert, M. D., & Balschweid, M. A. (2017). A philosophical review of science and society within agricultural education. *Journal of Agricultural Education, 58*(2), 98–110. doi:10.5032/jae.2017.02098

McLaughlin, J. A., & Jordan, G. B. (2015). Using logic models. In K. E. Newcomer, H. P. Hatry, and J. S. Wholey. *Handbook of practical program evaluation* (4th ed.). Hoboken, NJ: Jossey-Bass.

Meischen, D. L., & Trexler, C. J. (2003). Rural elementary students' understanding of science and agricultural education benchmarks related to meat and livestock. *Journal of Agricultural Education, 44*(1), 43–55. doi:10.5032/jae.2003.01043

Menetrez, M. Y. (2012). An overview of algae biofuel production and potential environmental impact. *Environmental Science & Technology, 46*(13), 7073–7085. doi:10.1021/es300917r

Moser, S., & Ekstrom, J. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America, 107*(51), 22026–22031. doi:10.1073/pnas.1007887107

Myers, B. E., & Thompson, G. W. (2009). Integrating academics into agriculture programs: A Delphi study to determine perceptions of the national agriscience teacher ambassador academy participants. *Journal of Agricultural Education, 50*(2), 75–86. doi:10.5032/jae.2009.02075

National Research Council. (1988). *Understanding agriculture: New directions for education.* Washington, DC: National Academy Press.

Ndlovu, M. (2014). Investigating some background factors affecting student participation in science fairs: A case study of a regional expo for young scientists. *ICERI2014 Proceedings*, 2381–2388.

Newcomber, K. E., Hatry, H. P., & Wholey, J. S. (2015). *Handbook of practical program evaluation* (4th ed.). Hoboken, NJ: Jossey-Bass.

Page, T., Iwata, B., & Reid, D. (1982). Pryamidal training: A large-scale application with institutional staff. *Journal of Applied Behavior Analysis, 15*(3), 335–351. doi:10.1901/jaba.1982.15-335

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science*, *328*(5977), 459–463. dio:10.1126/science.1182595

Pil, F. K., & Leana, C. (2009). Applying organizational research to public school reform: The effects of teacher human and social capital on student performance. *Academy of Management Journal, 52*(6), 1101–1124.

Piloto-Rodríguez, R., Sánchez-Borroto, Y., Melo-Espinosa, E. A., & Verhelst, S. (2017). Assessment of diesel engine performance when fueled with biodiesel from algae and microalgae: An overview. *Renewable and Sustainable Energy Reviews, 69*, 833–842. doi:10.1016/j.rser.2016.11.015

Ragauskas, A. J., Williams, C. K., Davison, B. H., Britovsek, G., Cairney, J., Eckert, C. A., ... & Mielenz, J. R. (2006). The path forward for biofuels and biomaterials. *Science, 311*(5760), 484–489. doi:10.1126/science.1114736

Ramos, J., Valdivia, M., García□Lorente, F., & Segura, A. (2016). Benefits and perspectives on the use of biofuels. *Microbial Biotechnology, 9*(4), 436–440. doi:10.1111/1751-7915.12356

Ricketts, J. C., Duncan, D. W., & Peake, J. B. (2006). Science achievement of high school students in complete programs of agriscience education. *Journal of Agricultural Education, 47*(2), 48–55. doi:10.5032/jae.2006.02048

Rivera, W. M. (2011). Public sector agricultural extension system reform and the challenges ahead. *Journal of Agricultural Education and Extension, 17*(2), 165–180. doi:10.1080/1389224x.2011.544457

Roberts, L. (2011) (n.d.). 9 billion? *Science, 333*(6042), 540–543. doi:10.1126/science.333.6042.540

Robinson, K., Westfall-Rudd, D., Drape, T., & Scherer, H. (2018). Conceptualizing integrative agricultural education: Introductory framework for integrating mathematics in agricultural curriculum. *Journal of Agricultural Education, 59*(4), 253–269. doi:10.5032/jae.2018.04253

Robinson, W. (2011). That great educational experiment: The city of London vacation course in education 1922–1938: A forgotten story in the history of teacher professional development. *History of Education, 40*(5), 557–575. doi:10.1080/0046760X2011.563756

Rodionova, M. V., Poudyal, R. S., Tiwari, I., Voloshin, R. A., Zharmukhamedov, S. K., Nam, H. G., ... & Allakhverdiev, S. I. (2017). Biofuel production: Challenges and opportunities. *International Journal of Hydrogen Energy, 42*(12), 8450–8461. doi:10.1016/j.ijhydene.2016.11.125

Sayers, I. (2011, July). New approaches to feeding the world's population. *In International Trade Forum* (No. 3, p. 30). International Trade Centre.

Scales, J., Terry, R., Jr., & Torres, R. M. (2009). Are teachers ready to integrate science concepts into secondary agriculture programs? *Journal of Agricultural Education, 50*(2), 100–111. doi:10.5032/jae.2009.02100

Schmidt, K. M., & Kelter, P. (2017). Science fairs: A qualitative study of their impact on student science inquiry learning and attitudes toward STEM. *Science Educator, 25*(2), 126–132.

Schneider, R., & Plasman, K. (2011). Science teacher learning progressions: A review of science teachers' pedagogical content knowledge development. *Review of Educational Research, 81*(4), 530–565. doi:10.3102/0034654311423382

Schultz, T. W. (1961). Investment in human capital. *The American Economic Review*, 1–17.

Schwartz, R. A., & Bryan, W. A. (1998). What is professional development? *New Directions for Student Services, 1998*(84), 3–13.

Semenza, J. C., Hall, D. E., Wilson, D. J., Bontempo, B. D., Sailor, D. J., & George, L. A. (2008). Public perception of climate change: Voluntary mitigation and barriers to behavior change. *American Journal of Preventive Medicine, 35*(5), 479–487. doi:10.1016/j.amepre.2008.08.020

Shen, B. S. (1975). Views: Science literacy: Public understanding of science is becoming vitally needed in developing and industrialized countries alike. *American Scientist, 63*(3), 265–268.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. doi:10.3102/0013189X015002004

Smith, K. L., Rayfield, J., & McKim, B. R. (2015). Effective practices in STEM integration: Describing teacher perceptions and instructional method use. *Journal of Agricultural Education, 56*(4), 183–203. doi:10.5032/jae.2015.04183

Songstad, D. D., Lakshmanan, P., Chen, J., Gibbons, W., Hughes, S., & Nelson, R. (2009). Historical perspective of biofuels: Learning from the past to rediscover the future. *In Vitro Cellular & Developmental Biology-Plant, 45*(3), 189–192. doi:10.1007/s1167-009-9218-6

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Folke, C. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855. doi:10.1126/science.1259855

Stephenson, L. G., Warnick, B. K., & Tarpley, R. S. (2008). Collaboration between science and agriculture teachers. *Journal of Agricultural Education, 49*(4), 106–119. doi:10.5032/jae.2008.04106

Stufflebeam, D. L. (2007). *CIPP evaluation model checklist: A tool for applying the CIPP model to assess long-term enterprises* (2nd ed.). Retrieved from https://kwschochconsulting.com/wp-content/uploads/2017/04/cippchecklist_mar07.pdf

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 37*(9), 963–980. doi:10.1111/j.1949-8594.2006.tb18172.x

Swafford, M. (2018). STEM education at the nexus of the 3-circle model. *Journal of Agricultural Education, 59*(1), 297–315. https://doi.org/10.5032/jae.2018.01297

Vallera, F. L., & Bodzin, A. M. (2016). Knowledge, skills, or attitudes/beliefs: The contexts of agricultural literacy in upper-elementary science curricula. *Journal of Agricultural Education, 57*(4), 101–117. doi:10.5032/jae.2016.04101

Wang, H., & Knobloch, N. (2018). Levels of STEM integration through agriculture, food, and natural resources. *Journal of Agricultural Education, 59*(3), 258–277. doi:10.5032/jae.2018.03258

Weidema, B. P., Thrane, M., Christensen, P., Schmidt, J., & Løkke, S. (2008). Carbon footprint: A catalyst for life cycle assessment? *Journal of Industrial Ecology, 12*(1), 3–6. doi:10.1111/j.1530-9290.2008.00005.x

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. New York, NY: Cambridge University Press.

Wenger, E. (2006). *Communities of practice: A brief introduction*. Retrieved from https://pdfs.semanticscholar.org/84d6/e4deccf799fbc18c6a2b7a86911e62cbe78d.pdf?_ga=2.187614696.1708399113.1575298638-1626206043.1566354625

Wilson, S. M. (2013). Professional development for science teachers. *Science, 340*(6130), 310–313. doi:10.1126/science.1230725

Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International, 86*, 14–23. doi:10.1016/j.envint.2015.09.007

Zhang, D. D., Lee, H. F., Wang, C., Li, B., Pei, Q., Zhang, J., & An, Y. (2011). The causality analysis of climate change and large-scale human crisis. *Proceedings of the National Academy of Sciences, 108*(42), 17296–17301. doi:10.1073/pnas.1104268108

Zidanšek, A., Blinc, R., Jeglič, A., Kabashi, S., Bekteshi, S., & Šlaus, I. (2009). Climate changes, biofuels and the sustainable future. *International Journal of Hydrogen Energy, 34*(16), 6980–6983. doi:10.1016/j.ihydene.2008.11.004

APPENDICES

Appendix A:
Pre Assessment and Post Assessment Instrument

First two letters of last name and first two letters of first name followed by random number.

Code:_______________

			No Knowledge		Little Knowledge		Moderate Knowledge		Good Knowledge		Great Knowledge		Not Applicable
1		The main idea behind bioenergy	0		1		2		3		4		5
2		The relationship between plant-based energy and the environment	0		1		2		3		4		5
3		The basic idea of energy	0		1		2		3		4		5
4		Plant-based energy used as fuel	0		1		2		3		4		5
5		How crops produce energy	0		1		2		3		4		5
6		Plants as energy sources	0		1		2		3		4		5
7		Converting energy to a useable form	0		1		2		3		4		5
8		The storing of plant energy	0		1		2		3		4		5
9		Sustainability	0		1		2		3		4		5
10		Crop breeding	0		1		2		3		4		5
11		Relate new ideas to similar classes in your teaching	0		1		2		3		4		5
12		Relate new ideas to cross curricular classes in your teaching	0		1		2		3		4		5
13		Using plant energy to help solve real world problems	0		1		2		3		4		5
14		The scientific method	0		1		2		3		4		5
15		Setting up an experiment	0		1		2		3		4		5
16		Developing and Testing a hypothesis	0		1		2		3		4		5
17		Making a conclusion based on relevant information	0		1		2		3		4		5
18		How would you describe bioenergy to someone else? (comment below)											

Appendix B

Deferred Post Assessment Instrument

First two letters of last name and first two letters of first name followed by random number.
Code:_______________

			No Knowledge		Little Knowledge		Moderate Knowledge		Good Knowledge		Great Knowledge		Not Applicable
1		The main idea behind bioenergy	0		1		2		3		4		5
2		The relationship between plant-based energy and the environment	0		1		2		3		4		5
3		The basic idea of energy	0		1		2		3		4		5
4		Plant-based energy used as fuel	0		1		2		3		4		5
5		How crops produce energy	0		1		2		3		4		5
6		Plants as energy sources	0		1		2		3		4		5
7		Converting energy to a useable form	0		1		2		3		4		5
8		The storing of plant energy	0		1		2		3		4		5
9		Sustainability	0		1		2		3		4		5
10		Crop breeding	0		1		2		3		4		5
11		Relate new ideas to similar classes in your teaching	0		1		2		3		4		5
12		Relate new ideas to cross curricular classes in your teaching	0		1		2		3		4		5
13		Using plant energy to help solve real world problems	0		1		2		3		4		5
14		The scientific method	0		1		2		3		4		5
15		Setting up an experiment	0		1		2		3		4		5
16		Developing and Testing a hypothesis	0		1		2		3		4		5
17		Making a conclusion based on relevant information	0		1		2		3		4		5
18		How would you describe bioenergy to someone else? (comment below)											
19		What aspects learned in the workshop do you utilize the most and why? (comment below)											

20		Describe the bio-energy experiments you have performed and the lessons you have learned in the process. (comment below)
21		How did your participation in the workshop benefit you and your students? (comment below)
22		In what ways do you think the workshop can be improved for the next round of participants? (comment below)

Appendix C

IRB Content Letter

Division of Agricultural Sciences and Natural Resources

Department of Plant and Soil Sciences
371 Agricultural Hall
Stillwater, Oklahoma 74078-6028
Phone: 405-744-9586
Fax: 405-744-0354
Web: www.pss.okstate.edu

Study Title: Sustainable Bioenergy Workshop

As a past participant of the study that was conducted by Oklahoma State University, we are seeking additional information from you about the effectiveness of the workshop. If you have any questions about the study or the follow up procedure, please do not hesitate to ask.

If you decide to participate in the study, you will be asked to complete a post-post survey that goes along with what was discussed in the workshop. The surveys should take no more than 15 minutes to complete.

There are no risks from participating in this post-post survey. By participating in this survey, you will allow us to develop better training for future attendees. In order to keep your identity confidential, we will use a pseudo code that will be attached to every survey. You will go through the questions on the sheet and place that code on your surveys. This allows us to compare survey data changes over time, but still keeps your answers confidential.

If you have any questions right now, please ask them before completing the survey. If you have questions later, please contact Katie Monroe with the below information.

Katie Monroe
(918) 231-8505
kathabm@okstate.edu

Additionally, you may contact IRB with any questions about participating in this study.

The Institutional Review Board (IRB) for the protection of human research participants at Oklahoma State University has reviewed and approved this study. If you have questions about the research study itself, please contact the Principal Investigator at beatrix.haggard@okstate.edu. If you have questions about your rights as a research volunteer or would simply like to speak with someone other than the research team about concerns regarding this study, please contact the IRB at (405) 744-3377 or irb@okstate.edu. All reports or correspondence will be kept confidential.

By completing the survey, you consent to your non-identifiable survey data being used in research publications.

Appendix D

Workshop Weekly Schedule

SUSTAINABLE BIOENERGY WORKSHOP

OKLAHOMA STATE UNIVERSITY

Schedule

MONDAY

REGISTRATION 12:45-1:15 PM

OPENING REMARKS 1:15-2:15 PM
Beatrix Haggard, Plant and Soil Sci

BREAK 2:15-2:30 PM

BIOMASS 2:30-4:15 PM
GOPAL KAKANI - PLANT AND SOIL SCI

DISCUSSION IN GROUPS
4:30-5:30 PM

DINNER - STUDENT UNION 450
6:10 - 8:00 PM

Tuesday

Bioplastics and Ethanol- Group A & B
9:00-11:45 AM 401 AG HALL

BREAK 10:15-10:30 AM

ALGAE & PLANT GROWTH - GROUPS C & D
9:00-11:45 AM

LUNCH - SIGNIFICANT DIFFERENCES
MARSHALL BAKER, AGRICULTURAL EDUCATION
12:00- 1:00

BIOPLASTICS & ETHANOL - GROUPS C & D
1:15-3:30 PM

BREAK 2:15-2:30 PM

ALGAE & PLANT GROWTH - GROUP A & B
1:15-3:30 PM

WEDNESDAY

FIELD TOURS
9:00-12:00

LUNCH - COMMUNICATION
SHANE ROBINSON, AGRICULTURAL EDUCATION
11:45-1:00 PM

BIODIESEL - ALL GROUPS
1:15-2:15 PM

BREAK 2:15-2:30 PM

BIODIESEL - ALL GROUPS
2:30-3:30 PM

DISCUSSION IN GROUPS
3:45-4:15 PM

THURSDAY

Field Tour Noble Research Center
Ardmore, OK

FRIDAY

COMPOSING A SCIENCE FAIR PROJECT

8:00-10:30 Student Union 450

11:00 AM PICK UP SUPPLIES

West of AGH

VITA

Katharine Brooke Monroe

Candidate for the Degree of

Master of Science

Thesis: AN EXPLORATORY EVALUATION OF A SUSTAINABLE BIOENERGY EDUCATION PROGRAM

Major Field: Agricultural Education

Biographical:

Personal Data: Born in Oklahoma City, OK on December 1, 1994. Daughter of Terry and Tammara Monroe. Married to Robert Honeyman on July 13, 2019.

Education: Masters of Science in Agricultural Education

Completed the requirements for the Master of Science in Agricultural Education at Oklahoma State University, Stillwater, Oklahoma in December, 2019.

Completed the requirements for the Bachelor of Science in your Animal Science Oklahoma State University, Stillwater, Oklahoma in 2017.

Experience:

Research Assistant
Department of Agricultural Education, Communications, and Leadership, Oklahoma State University, **January 2018-August 2019**

Assistant General Superintendent
Department of Agricultural Education, Communications, and Leadership, Oklahoma State University, **January 2019-April 2019**

Animal Technician
E. Kika de la Garza American Institute for Goat Research, Langston University, **May 2019-October 2017.**

Professional Memberships:

- NAAE- National Association for Agricultural Educator