Fueling Chemical Engineering Concepts with Biodiesel Production: A Professional Development Experience for High School Pre-Service Teachers

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Abstract

This one-day workshop for pre-service teachers was aimed at implementing a uniquely designed and ready-to-implement chemical engineering curriculum in high school coursework. This educational and professional development opportunity introduced 1) chemical engineering curriculum and career opportunities, 2) basic industrial processes and flow diagrams, 3) the law of conservation of mass, and material balance, and 4) hands-on activity on biodiesel production through a variety of active learning exercises, group-based hands-on activities, and discussions. Additionally, the recruitment of female participants for this workshop was intended to prepare female ambassadors to encourage female students to pursue a career in engineering. The expected long-term outcomes of this workshop are 1) improved and advanced high school curriculum in local high schools, 2) establishment of ties between the university and local schools, 3) increased enrollment and retention in engineering fields to address the needs of local industries.

Introduction

There is a need for increased enrolment and retention in Science, Technology, Engineering, and Mathematics (STEM) fields for global economic growth. To address this, many strategies have been proposed that emphasize enhanced quality and quantity of K-12 STEM education (Denton et al., 1998). One of the key recommendations includes creating training and professional development opportunities for current practicing K-12 teachers and pre-service educators who are the students enrolled in a teacher education or training program. Many universities collaborate with local district schools to host summer programs for K-12 students and teachers that provide them engineering experience through a variety of hands-on activities. These programs are based on a combination of STEM content and strong pedagogical techniques to enable them to excite and motivate their students to pursue successful careers in STEM (Denton et al., 1998, Ejiwale et al., 2012, Golter et al., 2012, Goonatilake et al., 2012, Nadelson et al., 2012).

However, there are a very few initiatives for pre-service K-12 educators in the engineering disciplines, and many teacher preparation programs lack engineering and technological literacy (Mativo et al., 2012, Frank et al., 2004). This work committed to the advancement and diversification of engineering education in South Texas through a novel approach of creating a one-day workshop on "Chemical Engineering" as a part of the activities for secondary pre-service STEM teachers. The goal of the program was to fulfill the needs of industries in regions of South Texas serviced by Outreach Strategy Team's Pilot Program at Texas A&M International University (TAMIU). TAMIU serves a predominantly Hispanic population by providing academic services to a high number of economically disadvantaged and first-generation students, who, due to Laredo's isolated geographical location, have very limited access to higher education. The majority of the teachers in Laredo receive their education from TAMIU (Goonatilake et al., 2012). This workshop was based on the premise that targeting the pre-service teachers at TAMIU will expand our future teachers' knowledge of chemical engineering, and aid in Texas A&M University System's (TAMUS) Engineering recruitment program. This one-day workshop introduced the concepts of Chemical Engineering to fourteen participants (including 6 Females) enrolled in Grade 8-12 certification recruited though Departments of Mathematics and Education at TAMIU .

The objectives of this workshop were to:

1. Familiarize the chemical engineering curricula and career opportunities to a group of underrepresented, bilingual pre-service teachers.
2. Introduce the concepts of process flow diagrams, recycling, and mass balance of basic unit operations.
3. Demonstrate biodiesel production from waste oil and have the participants apply the concepts of flow diagrams and material balance.
4. Assist in professional development of pre-service teachers.
5. Prepare female ambassadors to encourage high school female students towards engineering careers.

Designed Activities	Learning Objective
1. Draw the block diagrams for common processes showing the inlet and outlet streams	Apply the definitions of commonly known processes and law of conservation of mass to generate block diagrams
2. Draw the block diagrams (for activity 1) showing recycled streams	Apply the concept of recycling to the block diagrams to design green processes
3. Draw the process flow diagram for a detailed word problem	Combine the concepts of block diagram and recycling to generate process flow diagram
4.Identify the components of the given process flow diagram	Introduce the process flow diagrams symbols - vessels, tanks, pumps, compressors, stream ID's, temperature, pressure, flow rates
5. Write the material balance equation for the filtration and drying processes	Quantify the amounts of materials (emphasizing on mass) flowing in and out of a block diagram
6. Calculate the mass of recovered oil from an extractor	Apply the concept of mass balance to a numerical problem
7. Make biodiesel from waste TAMIU's diner oil and store bought soybean oil	Demonstrate a simple experiment that can be replicated by the participants at a K-12 institute to teach sustainability
8. Propose a process flow diagram for the biodiesel production (for activity 7)	Assess the ability to apply the concepts of flow diagram to the hands on experiment

Table 1. Workshop activities and the learning objectives

Course Organization

This one-day workshop was divided into two sessions: concepts and hands-on. The concepts session included a pre-workshop survey, introduction to the chemical engineering curriculum, and career opportunities. In addition to discussing the contents of the traditional sophomore and junior level chemical engineering courses, the participants were also exposed to a variety of senior design topics to demonstrate the multidisciplinary nature of the field supplemented by active learning exercises. The hands-on session involved production of biodiesel and proposing flow diagrams. Table 1 summarizes the chemical process diagrams based activities and their learning objectives.

Processes	Definitions	Commonly used example
Evaporation	Concentration of weak liquor to produce thick liquor by evaporating a portion of solvent	Making sugar syrup
Drying	removal of residual moisture or volatile liquids associate with wet solids with the help of hot air	Hair drying
Filtration	separation of solids from suspension in liquid	Filtering coffee
Mixing	to obtain a product of desired quality by mixing two streams	Making smoothie
Absorption	recovery/removal of solute gas component from its mixture with another component gas with the help of suitable liquid solvent in which solute gas absorbed	Blotting
Extraction	removal of water or other solvent from a solid/semi-solid	Oil extraction

Table 2 Basic chemical processes, definitions, and example

Active Learning Exercises

This workshop emphasized on basic unit operations, flow diagrams, and biodiesel production. Introductory material balance based on the law of conservation of mass that required basic algebra knowledge was also covered (Keith et al., 2009, Zheng et al., 2011).

Module 1: Introduction to process block and flow diagrams

In the first module, basic unit operations were discussed, followed by the generation of block diagrams. The operations were defined scientifically and relating to the examples from daily life. The concept of recycling was introduced, and the pre-service teachers modified the streams on their generated block diagrams to "avoid wastage". Activities included proposing a flow diagram of a simple two-step process, identifying the basic components of process flow diagrams and guessing the unknown process.

Activity 1: The participants were introduced to various important operations that are carried out in industry, and were expected to propose block diagrams representing and labeling the inlet and outlet streams. Table 2 summarizes the basic chemical processes that were discussed in Activity 1

Figure 1 demonstrates response of a participant of activity 1. For this process, the participant followed an example of hair drying, wherein the hot air is used to dry the wet hair. The diagram generated is for the wet soybean seeds that are prepared for making biodiesel. The sample block diagram indicates student's ability to organize the information of a process using boxes and lines with arrows to represent input and output.

Activity 2: In the second activity, the participants discussed the ways to improve the processes listed in Table 2 by proposing to re-use the products to make the processes more efficient. Figure 2 shows the recycled streams proposed by a participant following the example of making smoothies, and proposed that the mixture of milk, fruit, and ice cream if blended multiple times ensures better mixing of the ingredients.

Activity 3: The third activity involved suggesting a process flow diagram and identification of the inlet, outlets, and recycled streams for the production of methylene chloride process. A sample problem was assigned, and the participants were required to show the streams. Figure 3 shows the assigned problem and response of a participant indicating a clear understanding of process flow diagrams, and recycle streams.

Activity 4: A brief introduction to process flow diagram symbols was given. For this activity, the participants were given the list of commonly encountered process symbols and were asked to identify them on a complex process flow diagram (Figure 4). The participant could en-

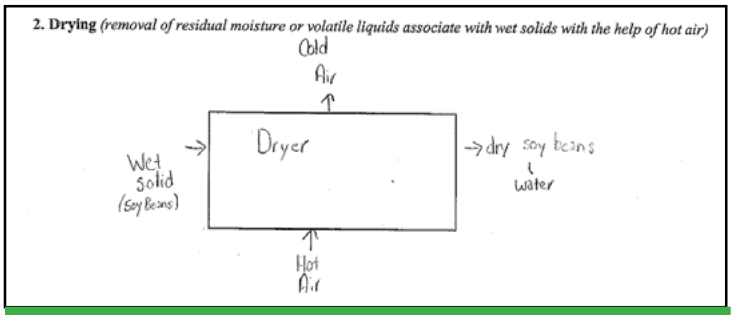

Fig 1. Block diagram of basic operation demonstrating inlet and outlet streams (Participant response of Activity 1)

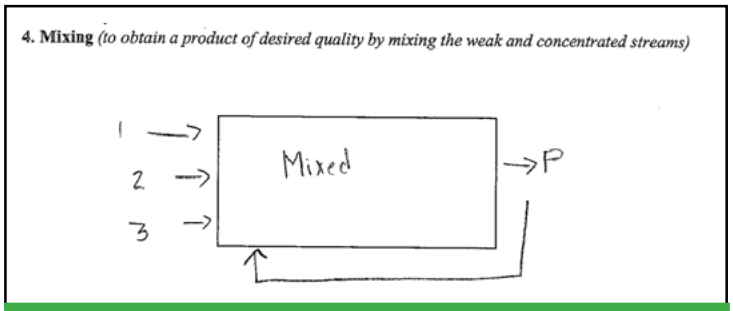

Fig 2. Block diagram of basic operation demonstrating recycled stream (Participant response of Activity 2)

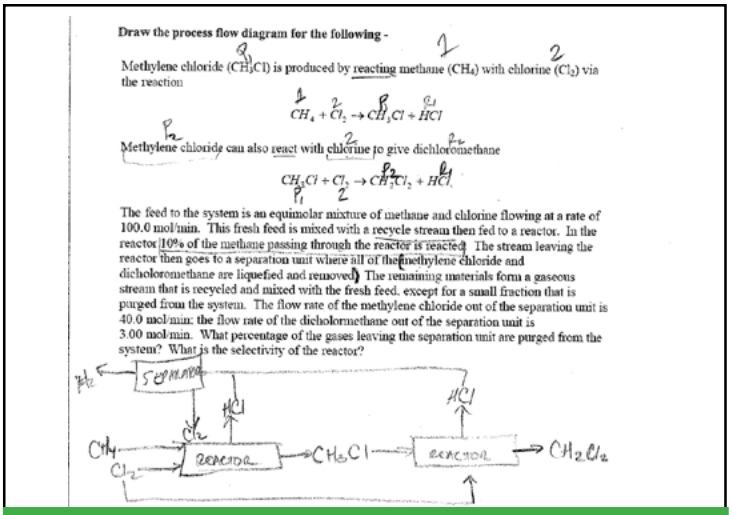

Fig 3. Process flow diagram for methylene chloride production process (Participant response of Activity 3)

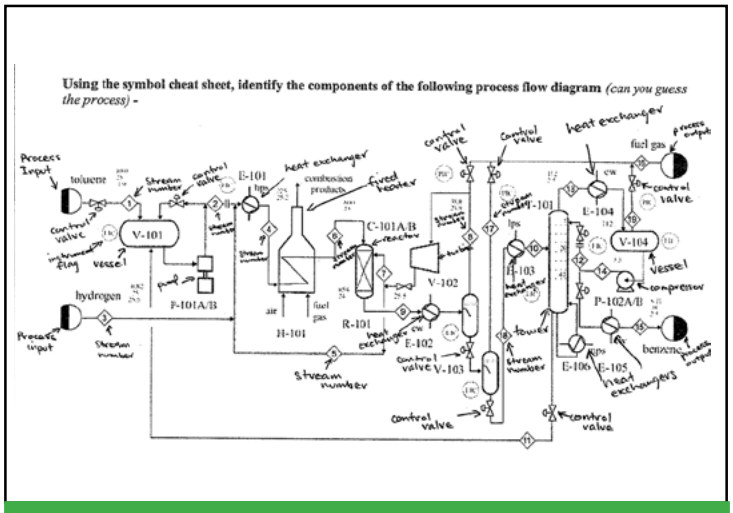

Fig 4. Identification of symbols on a process flow diagram (Participant response of Activity 4)

thusiastically identify the process equipment, valves, and streams.

Module 2: Material balance

The second module covered the basic material balance of the processes listed in Table 2. The concept of conservation of mass was introduced to write the material balance equations, which was further applied to a filtration and drying operation problem using the block diagram generated in the first module. A simple extraction numerical problem based on block diagram (Activity 1) and conservation of mass (Module 2) was also discussed.

Activity 5: The participants performed overall and individual material balances on the block diagrams generated in activities 1 and 2. The response of the participant demonstrated in Figure 5 shows the understanding of law of conservation of mass.

Activity 6: A simple material balance oil extraction from seeds problem requiring basic algebra was assigned. Figure 6 shows that the participant could easily perform the mass balance for an extractor by solving the equations using simple algebra that were derived from the description of the process.

Module 3: Sustainability: Biodiesel Production

The third laboratory module provided an overview of the scientific and engineering aspects of biodiesel production supplemented with a hands-on activity on the biodiesel production using soybean and waste vegetable oil obtained from the TAMIU diner. The participants were given a brief introduction to laboratory safety practices, list of materials, and detailed experimental procedure (Kulkarni et al, 2006, Pecen et al., 2012, Hillion et al., 2003) (Table 3).

The hands-on activities were conducted in the groups of two. Figure 7a-c shows a sample laboratory assessment sheet. The participants were able to identify the products (Figure 7a), propose the block diagrams showing the inlet and outlet labeled streams (Figure 7b), and identify the process requirements to treat waste oil and store-bought oil. The participants also addressed the issue of presence of water in waste oil by proposing in the process diagram to heat the oil and getting rid of the water by evaporation (Figure 7c).

Professional Development of Pre-Service High School Teachers

The workshop provided professional development opportunity for pre-service high school teachers by increasing their knowledge of chemical engineering, with an application in the exciting area of biodiesel production. This workshop was aimed at designing and developing

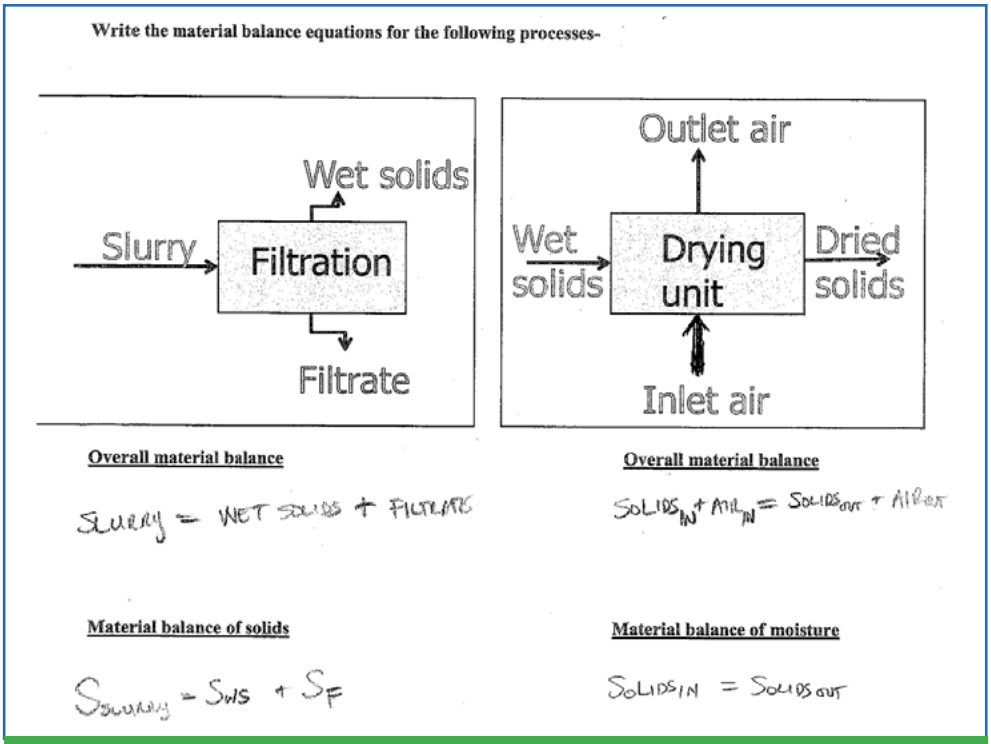

Fig 5. Overall and individual component material balance (Participant response of Activity 5)

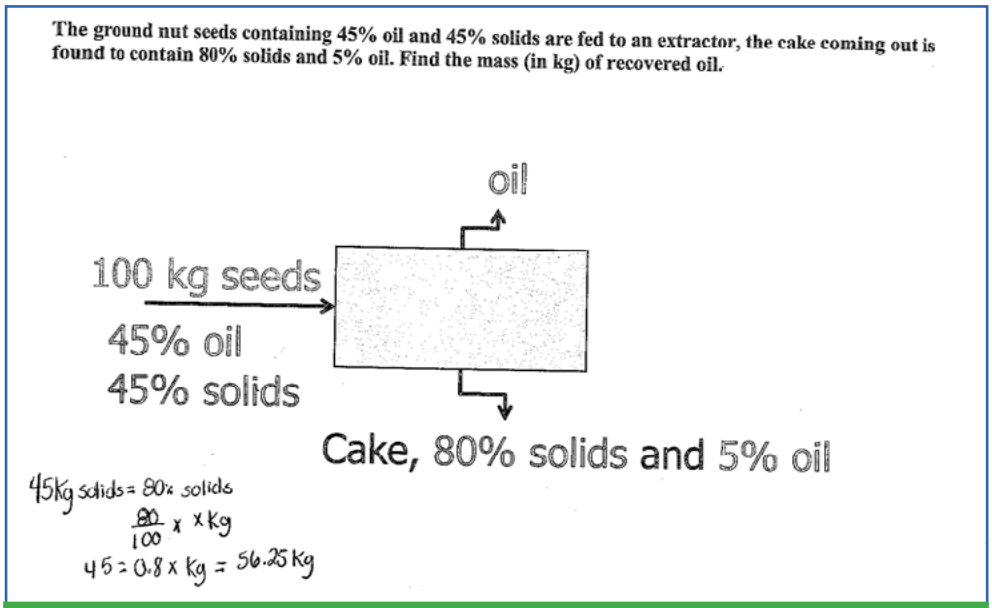

Fig 6. Mass balance calculation of an extractor (Participant response of Activity 6)

Materials	Procedure (for waste oil)
Two 250mL plastic bottles	Weigh out 0.525 g of sodium hydroxide (NaOH) pellet and place in 250 mL bottle
One 100mL graduated cylinder	Measure 30 mL of methanol in graduated cylinder, and pour into sodium hydroxide bottle. Shake the bottle until NaOH is dissolved
1 funnel	Measure 150mL of waste oil and pass it through the sieve to remove solid food particles
Two 250 mL beakers	Pour the waste oil into the bottle containing NaOH and methanol. Tape the bottle and shake vigorously (Activity 2)
Laboratory sieve	Allow the oil and glycerin to settle and observe the separated layers (Activities 1 and 5)

Table 3 Materials and experimental procedure for biodiesel production hands-on activity

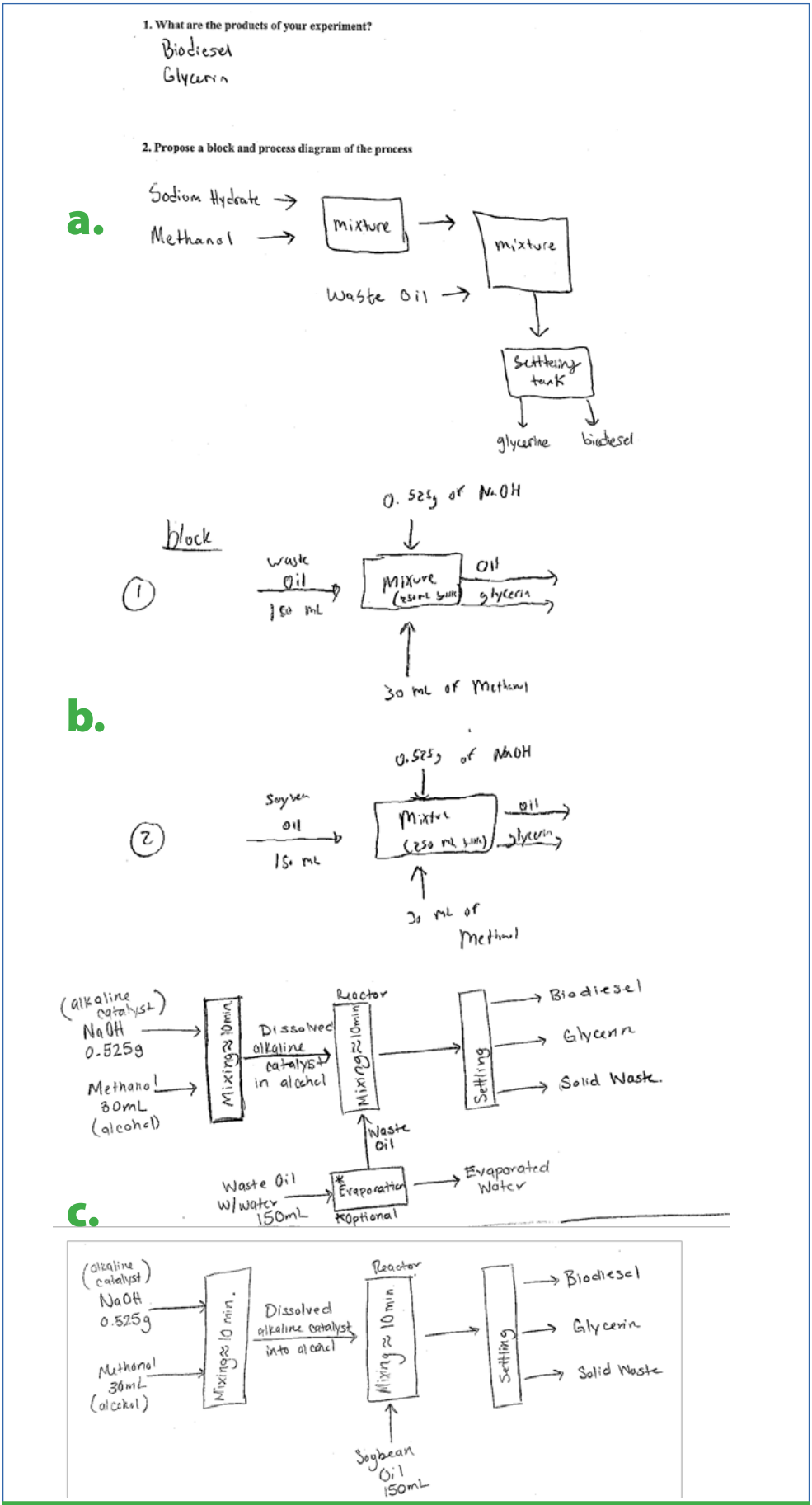

Fig 7. Hands-on activity on biodiesel production from waste and store bought oil a) identification of the products, b) block diagrams showing inlet and outlet streams, c) proposed process flow diagram of the chemical process of conversion of oil to biodiesel (Participant response of Activity 7)

a new curriculum that can be easily supplemented to an existing pre-engineering course, or any other science and mathematics high school course. Team-based and in class discussions, active learning exercises, and group based hands-on activity were the featured tools of this workshop to promote active and collaborative learning.

To assess the effectiveness of the workshop, and to test their knowledge, surveys of the participants were conducted at pre and post-workshop stages. Pre-workshop survey indicated that the participants had limited knowledge of the field which was solely based on the employment trends in Laredo. For instance, Laredo has very few industries, and water treatment plants are the largest of them. The most common response for employment sectors was working for the water plant and the city, which is where the majority of engineers of Laredo work. The responses from the post-workshop surveys suggested an improved understanding of 1) chemical engineering curriculum and career, 2) process flow diagrams and material balance, 3) biodiesel production. Following are a few comments from the survey:

- *The information given during the presentations was really good. It helped me understand what chemical engineering is and what chemical engineers do. The activities were the things that helped me the most to understand this discipline of engineering. The hands on activity were also really interesting. It helped me understand how several things, such as waste oil, can be recycled*
- *Lecture: Lecture was very informative in the areas that chemical engineering is used and how it is used. Information was useful for us as future teachers to see what topics are discussed in each college year (freshmen-senior),*
  Lab activity: Excellent activity to show the block diagram and process diagrams usefulness in chemical engineering a small example of what chemical engineers do
- *I have a much better understanding of chemical engineers*
- *Overall it was a very productive and education opportunity*
- *"Fun", " great", " interesting", " appealing"*

Conclusions

This workshop introduced chemical engineering curriculum and career opportunities to pre-service high school teachers. The in-class and laboratory activities were tailored in the form of a ready-to-use curriculum that can be implemented into the existing high school coursework. Based on surveys and assessments, by the end of the workshop, the pre-service teachers were able to define basic chemical processes, generate flow diagrams, conduct material balances using the law of conservation of mass, produce biodiesel from waste oil, and

Survey Questions	Pre-workshop response	Post-workshop response
Expectations from the workshop	Basic understanding of the field, preparing to discuss with the future students- prerequisites, classes to take, career opportunities, applications and usefulness in daily life	-
What is chemical engineering	Studying chemicals- mixing, different types like acid, experiment with liquids for humans, ecosystem, and environment	"They take a chemist's vision of a product and create a production plant complete with towers, pumps, compressors, pipes etc to mass produce new product" "universal engineering because they use branches of engineering to improve and recycle, manufacture, transport" "concerned with the efficiency of the mass production of products"
Topics in Chemical Engineering	Oil field, environment, chemistry, water supply	Thermodynamics, Mass transfer, Kinetics, Heat transfer, Biofuel, Biotechnology, Distillation
Employment sectors	Manufacturing, State government, Oil, fuel, engine, water plant, NASA, research, chemist, City	All sectors of engineering, Pharmaceuticals, Information technology, Petroleum, Finance, Law, FDA, Education, Environmental protection
What is Biodiesel	Type of oil, biodegradable diesel, environment-related, plant product, making of petroleum, organic gasoline, alternate fuel resource, life/body related, synthetic, renewable oil	A type of biofuel, cheap alternative to gas,
What is Process diagram	Diagram that explains how a process works	"more detailed diagram describing the process of production" "very specific diagram that comes from the block diagram and elaborating what was done on the block diagram with symbols" "it shows the process, you get information to guide through a process"

Table 4. Pre and post-workshop survey responses

propose a reasonable process flow diagram for the bio-diesel production. It is expected that the local engineering magnet schools will incorporate some of these activities in the future.

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