**Lesson Plan Template**

**Modified 5/08/13 from** [**LEARN NC**](http://www.learnnc.org/) **(**[www.learnnc.org](http://www.learnnc.org))

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For LEARN NC partners

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| **Title (Required)** | Analysis of Biodiesel in the Chemistry Classroom |
| **Introduction (Required)** | In 2005, the United States established its first renewable fuel mandate. A renewable fuel is one that is derived from a non-petroleum source. Research currently focuses on producing fuel from various crops (soybean, sunflower, canola), animal waste (pig manure) or municipal solid waste from a landfill. Scientists estimate that fossil fuel supplies will be depleted in the next 50 – 120 years. Over the past 10 years, the US has spent $6.8 billion dollars on renewable energy research (Congressional Research Service report, Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D, March 2012).The lessons in this module are designed to teach thermochemistry to introductory chemistry students in the context of biodiesel production. The biodiesel link gives them an application of the thermochemical equations and calorimetry experiments that are typically taught during a first-year course. In addition, students will use environmental science, economics and energy analyses to determine whether biodiesel is sustainable and a good idea. This evaluation allows students to make an informed decision after studying the big picture. With petroleum fuel supplies running low, and the interest in greenhouse gases and global warming on the rise, alternative fuels are important for all people. The lessons in this module can each be completed independently of the others, making them appropriate for a physical science, chemistry, or environmental science class. Teachers can use the components of the unit that are most useful for a particular class. The assessments included are both formative and summative and can be used with the individual activities at the teacher’s discretion. |
| **Learning Outcomes (Required)** | **Students will*** Practice solving thermochemical problems.
* Produce biodiesel in a small-scale laboratory experiment.
* Analyze the quality of the prepared biodiesel.
* Compare and evaluate the usefulness of alternative fuel sources.
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| **Curriculum Alignment (Required)** | From the Next Generation Science Standards (<http://www.nextgenscience.org/>):

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| HS-PS3-1 | Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. |
| HS-PS3-4. | Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics). |
| HS-ETS1-3. | Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts. |

From the NC Essential Standards “unpacked” content for chemistry (<http://www.ncpublicschools.org/docs/acre/standards/support-tools/unpacking/science/chemistry.pdf>)* **2.1.1** Explain the energetic nature of phase changes (contrast heat and temperature, including temperature as a measure of average kinetic energy, and appropriately use the units Joule, Celsius, and Kelvin)
* **2.1.2** Explain heating and cooling curves (complete calculations of: q=mCT, q=mHf, q=mHv using heating/cooling curve data)
* **2.1.4** Infer simple calorimetric calculations based on the concepts of heat lost equals heat gained and specific heat.
* **2.2.1** Explain the energy content of a chemical reaction (interpret potential energy diagrams for endothermic and exothermic reactions including reactants, products, and activated complex-with and without the presence of a catalyst)
* **3.1.1** Explain the factors that affect the rate of a reaction (temperature, concentration, particle size and presence of a catalyst)
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| **Critical Vocabulary (Required)** | * Transesterification – a chemical reaction between an alcohol and a triglyceride to produce biodiesel and glycerin
* Triglyceride – oils or fats found in plants and animals; composed of a glycerol (3 carbon chain) backbone with three fatty acid chains (long straight chains of carbon atoms) attached
* Methyl ester – a compound formed from the reaction between an acid and an alcohol
* Biodiesel – a diesel fuel produced from organic sources, such as cooking oil, animal fat, or plant seeds (canola, sunflower, soybean)
* Catalyst – a substance used to speed up the rate of a chemical reaction without being used up during the process; similar to an enzyme in a biological system

The US Department of Energy maintains a full text glossary of terms related to the Biomass Program. The link is: <http://www1.eere.energy.gov/bioenergy/glossary_full_text.html> |
| **Classroom Time Required (Required)** | **Activity 1** - one 90 minute block.**Activity 2** - one 90 minute block. **Activity 3** – Two hours with overnight separation of reaction. To make the biodiesel, allow one 45 minute period to warm the oil and add the alcohol and catalyst. The reaction then needs to proceed for at least one hour, followed by separation in a funnel (overnight is ideal).**Activity 4** – 30-45 minutes**Activity 5** – one 90 minute block |
| **Materials Needed (Required)** | **Activity 1 Materials:**Teacher: computer with internet access, class monitor, power point software, 500 g calcium hydroxide, 32 g barium hydroxide, 11 g ammonium chloride, egg, frying pan, spatula, balsa wood board, water, 250 ml beaker, large porcelain dishStudents: computer with internet access, handouts or slides from power point (optional)**Activity 2 Materials:**Teacher: computer with internet access, class monitor, power point software, virtual calorimetry activity answer key, thermochemistry problem set answer keyStudents: computer with internet access, virtual calorimetry lab handout, Thermochemistry problem set worksheet**Activity 3 Materials:**Teacher: computer with internet access, class monitor, Biodiesel for the Global Environment handouts, Biodiesel preparation lab handout, goggles, gloves, apronStudents: Biodiesel for the Global Environment handout, Biodiesel preparation lab handout, goggles, gloves, apron (if students perform lab activity)Lab Materials (per lab group):* 300 mL soybean oil or canola oil
* 6 g potassium hydroxide
* 60 mL methanol
* Thermometer
* Hot plate/stirrer
* 500 mL beaker
* 250 mL Erlenmeyer flask with stopper
* Glass storage bottle with lid
* Stir bar
* Separatory funnel (optional)

**Activity 4 Materials:**Teacher: Quality Tests for Biodiesel answer keyStudents: Quality Tests for Biodiesel handout, Goggles, gloves and apron for labLab Materials (per lab group):* 15 mL sample of prepared biodiesel
* 10 mL methanol
* 10 mL deionized water
* Stirring rod
* Graduated cylinder
* Thermometer
* pH paper
* 3 test tubes with stoppers
* Balance

**Activity 5 Materials:**Teachers: Comparing Fuel Sources handout answer keyStudents: Comparing Fuel Sources handout, calculator, molecular modeling kit |
| **Pre-activities (Required)** | **Activity 1 – Introduction to Energy, Heat and Temperature**The teacher needs to prepare the chemicals and supplies for the endothermic and exothermic demonstration reactions before class begins.**Activity 2 – Heat problems and Calorimetry**The teacher needs to arrange computer access for students prior to this activity. If a bench calorimetry lab is to be conducted, the chemicals and equipment need to be set up before class begins.**Activity 3 – Biodiesel Basics and Production**Equipment and starting materials need to be set up before class begins. The teacher can pre-measure reactants and begin warming the vegetable oil before class begins if time is an issue. Once the reaction has started, the teacher may have students do other work because of the long wait time.**Activity 4 – Biodiesel Testing**Equipment and materials need to be set up before class begins. The teacher can collect the biodiesel from the separatory funnel and divide it into student samples if time is an issue.**Activity 5 – Fossil Fuel and Biofuel Comparison**The teacher should prepare the molecular modeling sets before class begins. If time is an issue, students can work in small groups and analyze one of the fuels and then share results with the rest of the class. |
| **Activities (Required)** | **Activity 1 – Introduction to Energy, Heat and Temperature**This activity gets students thinking about all the types of energy in the world, where it comes from and how it is used and studied. Students watch an introductory 30 second video in photopeach.com. The link is <http://photopeach.com/album/h5ew30?invitecode=93fb20d5df>The video contains 7 questions to engage student discussion.* What is energy?
* Where does it come from?
* What are some examples?
* Is it natural or manmade?
* How do we use energy?
* Are all types of energy good?
* How can we study it?

It may be useful to type the questions for students on a handout or either on a separate slide. Once they watch the video clip, give them time to brainstorm the questions. This may be done in small groups or as individuals, followed by a grouping activity, such as “think-pair-share.” The idea is to get students thinking about a broad definition of energy with many examples and viewpoints. For example, some students will only think of electricity as energy, while another will initially think of the food we eat. This activity can lead to a class discussion on the following topics, depending on what the teacher wants to include in the unit. There are some weblinks for these topics at the end of the lesson plan.* Sources of energy
* Forms of energy
* Conservation of energy
* Heat, temperature, catalyst, calorimetry
* Renewable and nonrenewable resources
* Advantages and disadvantages of various forms of energy
* Current research on energy
* Careers associated with energy and fuel

Students are not likely to list biofuel or biodiesel as a form of energy during this discussion. The teacher will introduce it with a few 30-second public service/commercial clips from the National Biodiesel Board’s video library. The links are <http://bcove.me/r6k4gt36> and <http://bcove.me/rwararju>. For other appropriate video links, use the National Biodiesel Board website at [www.biodiesel.org](http://www.biodiesel.org). The video links are under the “News” tab in a video library. It is interesting to ask students “How did researchers figure out this technology?” or “Why are these products being used?” The idea, again, is to broaden their thinking about energy and the issues we face by using petroleum-based products.Students will begin learning how energy is studied. Using their knowledge of prefixes, students can infer that thermochemistry is the study of heat changes associated with a chemical reaction. A power point and class demonstration will show students that some chemical reactions release energy while some absorb it. A picture of a hot pack and a cold pack allows them to predict the differences between the two products. The first reaction is calcium oxide and water, which is exothermic and releases enough energy to cook an egg. The second reaction is barium hydroxide and ammonium chloride, which is endothermic and absorbs enough energy to freeze a beaker to a wet balsa board. Students will predict the products of the demonstration reactions. If the chemicals used in the power point file are not available, the teacher may use a hot pack and a cold pack purchased at any local drug store. Another low-cost option is to use rubbing alcohol on students’ hands to demonstrate an endothermic process and steel wool soaked in vinegar closed in a jar with a thermometer to demonstrate an exothermic process. The demonstration shows how an exothermic reaction releases heat to its surroundings and an endothermic reaction absorbs heat. Students can then check their predictions and include heat in both balanced equations. The teacher needs to explain the reaction diagram to students. Point out the location of products, reactants, activation energy and the change in energy between products and reactants. Make sure students recognize that the graphs are opposites of one another. Encourage students to think of other examples of endothermic and exothermic processes.Finally, heat and temperature are compared and the equation Q = CmT is developed with teacher instruction. Students typically understand that matter and the temperature change affects the amount of heat energy involved in a process, but most will not understand specific heat. A power point file is included. The experimental set up for calorimetry can be introduced as well as conservation of energy and heat lost = heat gained. Explain that this is the process scientists use to determine heat content of the foods we eat and the fuel we burn. Use this to preview the lab procedure that will be completed in Activity 2. For the remainder of the period or for homework, ask students to reflect and begin filling out a modified KWL chart for the unit. As the unit continues, they may continue to add and answer questions they think of. The entire class will create a KWL study guide at the end of the unit.**Activity 2 – Heat problems and Calorimetry**In this activity, students will perform a virtual calorimetry experiment and practice using Q = CmT to calculate amounts of heat in various situations. Students will also use the concept of heat lost = heat gained for problem-solving.Begin this class by discussing the KWL charts the students worked on during Activity 1. The teacher can assess if there are any questions about heat and temperature or biofuels before beginning Activity 2.Students will perform the activity “Heat Transfer between a Metal and Water” using the Iowa State University simulation (<http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/thermochem/heat_metal.html>). If the classroom has equipment, students may perform a lab using Styrofoam cups as calorimeters and various metal objects with hot water. If there is not enough equipment for students to perform this lab, it can be completed as a whole class with the teacher. A handout is included where students write their own procedure. If students are having trouble writing their own procedure, it can be filled in for them or the teacher can remind them about the calorimetry set up from the notes in Activity 1. Alternatively, there are many online videos and procedures for various reactions involving calorimetry.Students will complete the Thermochemistry Problem set questions. These problems may be completed during class and shared on whiteboards or for homework, depending on what the teacher determines is best for their students. If there are students who need more explanation, The Physics Classroom website has a good review with some sample problems. The link is <http://www.physicsclassroom.com/Class/thermalP/u18l2c.cfm>.Complete this activity by once again reviewing the KWL chart and adding to it.**Activity 3 – Biodiesel Basics and Production**In this activity, students will learn basic information about biodiesel production and will perform a transesterification reaction to produce biodiesel. Factors that affect reaction rate and the effect of a catalyst on the energy diagram will be discussed.A Prezi presentation will guide students through biodiesel basic information. Each student needs to keep their KWL chart for additions. This activity begins with a slide that asks “Where does biodiesel come from?” The teacher can define biodiesel (see Critical Vocabulary section) and get students thinking about how it is different from petroleum-based fuels. The teacher can ask students which perception they have from the slide – do they just know it comes from the gas pump, do they picture a scientist in a messy garage lab, or do they think of the starting biomass materials? The second slide shows the transesterification reaction and begins the lab. Explain that the triglyceride and methanol are the reactants and that the potassium hydroxide is a catalyst. Review the energy diagram to point out activation energy and the effect of the catalyst on this graph. The teacher can also point out that this reaction uses heat and stirring to increase the rate of reaction by mixing reactants together more effectively than would occur if reactants were simply combined and left to sit at room temperature. Connections to biology can be made by reviewing that triglycerides are fats found in our blood and that cholesterol testing also tests the levels of triglycerides. We metabolize these triglycerides for energy, just like this reaction will use it to produce a fuel for energy. Also, glycerol is used in skin and hair care products, toothpaste and soap. It is also used to produce nitroglycerin, which is a component of dynamite and cordite.The teacher will have to determine how many lab set ups to have in each class. If safety concerns or lack of equipment are issues, the biodiesel production can be done as a teacher demonstration. Once the reactants are all added and the reaction is started, students can then go back to finish the Prezi presentation.Slide 3 asks “Why is this a good idea?” The image of the biodiesel cycle will begin a class discussion on economics, health concerns and global warming issues associated with both petroleum and biodiesel. A few thinking points are included and students can read the “Biodiesel for the Global Environment” handout. The teacher should point out some of the advantages and disadvantages from the handout. Remind students to continue to add their questions to the KWL chart they have been keeping for the unit. The final slide is a site map of the Catawba County landfill site and a link for a video clip with images from the site. Catawba County uses buffer land around its landfill to grow fuel crops for biodiesel. They harvest the seeds and press the oil out on site. The oil is then converted to biodiesel on site and is blended into diesel fuel to run the landfill machinery. The landfill also uses its methane to produce electricity and to heat water for the buildings and to power approximately 1500 homes in Catawba County. The Ecocomplex is a great example of a profitable waste management system. The link for more information on the site is <http://www.catawbacountync.gov/ecocomplex/index.asp>The remainder of the class will be for students to begin researching advantages and disadvantages of biodiesel. A list of student resources is included. Students will use their research to answer questions remaining on the KWL chart and to prepare their final assessment product. *Optional Community engagement:* The class may visit a biodiesel production facility if one is nearby. Locally, there are often small-scale facilities that may be available for a tour.**Activity 4 – Biodiesel Testing**In this activity, students will test the quality of the biodiesel prepared in Activity 3. The tests use physical properties and can be done with small samples (20 mL) of biodiesel.Each student will need the Quality Analysis of Biodiesel handout. There are five tests that students will run on their sample of biodiesel and a data table for them to complete as the tests are run. In the end, students will decide if their biodiesel could be sold for fuel.*Optional Community engagement:* If the class has access to a university/college chemistry lab, the teacher can arrange a field trip for students to test their biodiesel with a calorimeter and to visit a college-level laboratory. Other possible tests include viscosity, cloud point, or GC/MS.**Activity 5 – Fossil Fuel and Biofuel Comparison**In this activity, students will compare the energy content of four fuels – methane, ethanol, octane and biodiesel. This activity uses molecular models to demonstrate the combustion of the fuels to produce carbon dioxide and water. Students then compare the energy content of the reactants to products. The teacher may point out that a good fuel releases a great deal of energy and that the net energy output is high. However, students also get a chance to consider how much carbon dioxide each fuel produces. The teacher can ask them to consider the trade off, energy versus global warming CO2. At the conclusion of the activity, students are asked to make a recommendation of the best fuel source, based on both the energy and emissions data.Each student can build models with a molecular modeling kit. If there are not enough kits, students may work in small groups. A low-cost option is to purchase soft candy (jelly beans or marshmallows work well) and toothpicks for building the models.The information students study in this activity can be used to continue their research for their summative assessment product. If Activity 3 has not been used, students will need some of the resources listed in this module for information on global warming and the economic impact of biodiesel comparisons with other fuels. |
| **Assessment (Required)** | Teachers can use a variety of formative assessments that are not graded, but will inform instruction after each activity. The following are some suggestions for these informal assessments.* Entrance/exit tickets – each student fills out a small ticket. The teacher can ask a content question, such as “Name two things you have learned about energy” or an open-ended question, such as “Write one question that you still have about calorimetry.” The teacher can then use the responses to guide future instruction.
* Starter question – The teacher can make a quick power point slide with a heat problem for students to work out.
* Thumbs up/thumbs down – A quick poll of understanding by a show of “thumbs up” or “thumbs down” can let the teacher know if students are confused. If students are not likely to give responses in this way, polleverywhere.com or gosoapbox.com are websites that have similar functions.
* Whiteboarding – students may work in small groups. The teacher assigns one problem from the homework sheet and the group puts the solution on the board and explains it to the rest of the class. This provides an easy way to uncover misconceptions.
* Electronic feedback – padlet.com allows teachers to build a wall and students to post comments. In this unit, a padlet could be created to post student questions or student feedback from each activity. Gosoapbox.com is a student management site where students can post questions, teachers can give quizzes or polls, and students can post discussion comments during class.

Summative assessments are more formal and are graded. A number of suggested assessments are listed below. Teachers may select work that is appropriate for their classes.* Heat Practice Problems – a power point with four heat problems with answers worked out on the last slide. Can be used as a quiz after Activity 2.
* Quiz – a short quiz can be given after Activity 3.
* Class summary – the entire class can create a KWL-type chart once the activity is complete. Padlet.com is one option to do this electronically. A low-tech option is to create whiteboards. Students can use this as a study guide before the test.
* Written test – a test with multiple choice, heat problems, graphs and short answer questions has been included. This test is best given once the entire unit has been completed.
* Lab report – students can write up formal lab reports for Activities 3 and 4. A suggested format can be found on a prezi. The link is <http://prezi.com/lxl9c0rw81mv/?utm_campaign=share&utm_medium=copy>
* Student presentations – students can create a presentation to support or oppose biodiesel production in the United States. Options for formats include: power point; prezi.com; piktochart.com. Students can also make videos, posters or skits. This will be most effective after Activity 5.
* Class debate – students can be assigned roles (environmentalist, farmer, scientist, congressman, etc.) to help them focus research for the debate. The debate will be most productive if it is held after the completion of the unit.
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| **Community Engagement (Required)** | In North Carolina, there are several sites involved in biofuel production or research. These operations offer education outreach by offering tours or guest speakers to school groups. Teachers should brainstorm.* Piedmont Biofuels – Pittsboro, NC – free public tours on Sunday afternoons and the first Friday of each month
* Patriot Biofuels – Greensboro, NC
* Biofuels Center of North Carolina – Oxford, NC – tours are available or guest speakers can visit schools
* Catawba County landfill site – Newton, NC – free tours can be scheduled
* Guest speakers – North Carolina A&T bioenergy center, Greensboro; North Carolina Biotechnology Center, Research Triangle Park.
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| **Websites (Optional)** | **Introductory Articles** – these have basic information that you will want to read before you start looking at other aspectsA list of common FAQs* http://biodiesel.org/what-is-biodiesel/biodiesel-faq's
* http://www.patriotbiodiesel.com/category\_s/1820.htm

A great introduction to biodiesel* <http://biodiesel.org/what-is-biodiesel/biodiesel-basics>

History of Biofuels* <http://blog.hemmings.com/index.php/2013/07/10/a-brief-history-of-biofuels-from-the-civil-war-to-today/>

A basic dictionary of terms* http://www1.eere.energy.gov/bioenergy/glossary\_full\_text.html

NC State Energy report 2010 – overview of policies, regulations and energy statistics for NC* http://www.energync.net/Portals/14/Documents/Publications/ANNUAL%20NC%20ENERGY%20REPORT%20final%20feb%202010%20v2-1.pdf

**Biodiesel Production**A one-page schematic of how biodiesel is produced* http://biodiesel.org/docs/ffs-production/production-fact-sheet.pdf?sfvrsn=4

US Dept of Energy data – current prices of fuel in different areas of the country* http://www.eia.gov/petroleum/gasdiesel/

**Advantages and Disadvantages**Biodiesel Myths v. Facts brochure (pro-biodiesel)* http://biodiesel.org/docs/default-source/ffs-basics/biodiesel-myths-vs-facts.pdf?sfvrsn=10

Alternative Fuels Data Center – you can compare various types of fuel* http://www.afdc.energy.gov/

Create your own comparison chart for various fuels* http://www.afdc.energy.gov/fuels/fuel\_properties.php

A short article on renewable v. nonrenewable sources of energy* http://www.ecology.com/2011/09/06/fossil-fuels-vs-renewable-energy-resources/

Crunching the Numbers on Alternative Fuels – Popular Mechanics articles* http://www.popularmechanics.com/cars/alternative-fuel/news/2690341
* http://www.popularmechanics.com/cars/how-to/4314657?click=main\_sr

Ending the Food vs. Fuel Debate* http://www.renewableenergyworld.com/rea/news/article/2012/10/ending-the-food-v-fueldebate-researchers-define-surplus-land

Food vs. Fuel Debate – CNBC article* <http://www.cnbc.com/id/48477352>

CDC report on human exposure to fuel oil* <http://www.atsdr.cdc.gov/toxprofiles/tp75-c1.pdf>

**Video Resources –** Each video clip has the time listed at the end of the titleInvention Nation: Biodiesel video (3:38)* http://videos.howstuffworks.com/science-channel/5044-invention-nation-biodiesel-video.htm

Public service announcement – introduces the use of fuel from organic materials (0:30)* http://bcove.me/r6k4gt36

“Here, Now” commercial – use of biodiesel in Dallas (0:37)* http://bcove.me/rwararju

“Fast Track” commercial – a biodiesel truck breaks a land speed record (0:37)* http://bcove.me/9cdwh71s

Jay Leno’s Garage – Jay talks to a scientist about using biodiesel in some of his cars (1:31)* http://bcove.me/316xk1ki

Motorweek segment – interviews farmers and various industries using biodiesel (7:55)* http://bcove.me/3yzusjn6

Biofuel lesson from National Defense Education Program – brief description of how organic materials are being developed into gasoline, biodiesel, and jet fuel* http://www.ndep.us/Biofuel

CNN Story on the Catawba County landfill site* http://www.cnn.com/video/?/video/tech/2009/08/20/wolf.green.town.cnn

**Careers in Biofuels**A US Bureau of Labor Statistics report on biofuel associated careers with salaries and credentials* <http://www.bls.gov/green/biofuels/biofuels.pdf>

Biofuel and Biodiesel product development careers – lists job outlook, salaries, personality traits and has links to other related careers* <http://myfootpath.com/careers/science-careers/biofuel-and-biodiesel-product-developer-careers/>

Green Career Guide – basic information about school and expectations for various biofuel jobs* <http://www.greencareersguide.com/Cellulosic-Biofuels.html>
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| **Author Info (Required)** | Marci Harvey is a chemistry and physics teacher at West Forsyth High School in Clemmons, NC. She has been teaching in NC for 17 years. She has a BS in chemistry from the College of Charleston and a MS in chemistry from the University of South Carolina. Marci earned National Board certification in 2008. This lesson is part of a Kenan Fellowship “Pump New Life into the Classroom with Biofuels” completed at North Carolina A&T University. |