5-2019

Evaluating Michigan's Food, Agriculture, and Resources in Motion (FARM) Science Lab as a Modality for Agricultural Literacy

Amelia J. Miller
Utah State University

EVALUATING MICHIGAN'S FOOD, AGRICULTURE, AND RESOURCES IN

MOTION (FARM) SCIENCE LAB AS A MODALITY

FOR AGRICULTURAL LITERACY

by

Amelia J. Miller

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Agricultural Extension and Education

Approved:

Debra Spielmaker, Ph.D. Major Professor	Kelsey Hall, Ed.D. Committee Member
Rebecca Lawver, Ph.D. Committee Member	Denise Stewardson, M.S. Committee Member

Richard S. Inouye, Ph.D.
Vice-Provost for Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2019

ABSTRACT

Evaluating Michigan's Food, Agriculture, and Resources in Motion (FARM) Science Lab as a Modality for Agricultural Literacy

by

Amelia J. Miller, Master of Science

Utah State University, 2019

Major Professor: Debra M. Spielmaker, Ph.D.
Department: Applied Sciences, Technology, and Education

Michigan's Food, Agriculture, and Resources in Motion (FARM) Science Lab is a 40-foot mobile classroom outfitted with 10 learning stations including scientific equipment and iPads. This quasi-experimental study evaluated preexisting data from Michigan Agriculture in the Classroom to evaluate the effectiveness of the FARM Science Lab mobile classroom as a method of teaching agriculture-themed, standards-based lessons to third- through fifth-grade students in order to increase their understanding of agriculture. From January through June 2018, more than 1,258 students participated in these lessons and completed the pretest and posttest and 72 teachers completed the post survey. Research questions not only addressed student learning but also teacher's perceptions of the mobile classroom program and measured differences between rural, suburban and urban student populations.

(187 pages)

PUBLIC ABSTRACT

Evaluating Michigan's Food, Agriculture, and Resources in Motion (FARM) Science Lab as a Modality for Agricultural Literacy

Amelia J. Miller

Michigan's Food, Agriculture, and Resources in Motion (FARM) Science Lab is a 40-foot mobile classroom outfitted with 10 learning stations including scientific equipment and iPads. This quasi-experimental study analyzed preexisting data provided by Michigan Agriculture in the Classroom to evaluate the effectiveness of the FARM Science Lab mobile classroom as a method of teaching agriculture-themed, standards-based lessons to third- through fifth-grade students in order to increase their understanding of agriculture. From January through June 2018, more than 1,258 students participated in these lessons and completed the pretest and posttest and 72 teachers completed the post survey. Research questions not only addressed student learning but also teacher's perceptions of the mobile classroom program and measured differences between rural, suburban and urban student populations.

Four lessons were offered to students in third through fifth grade during the time of this study. Each lesson had a unique pretest and posttest provided to each school by Michigan Agriculture in the Classroom using Google Forms. Students and teachers participated in the agricultural lessons within existing classroom groups; therefore, this was not a random sample of either population. During the timeframe of this study, all sections of each grade level for each participating school were engaging in FARM

Science Lab programming; therefore, no control groups were used in this research. The student and teacher data were analyzed using standard statistical tools including *t*-tests and Cohen's *d*. Difficulty and item discrimination values provided more confidence in the reliability of the question as a measure of knowledge change after participation in the FARM Science Lab intervention.

Results indicated there were statistically significant differences in knowledge between pretest and posttest scores for nearly all grade level/lesson groups. Each individual question was analyzed for statistically significant change in addition to overall test scores. Some questions did not see statistically significant changes from pretest to posttest for each group. These results suggested the FARM Science Lab was making a difference in students' agricultural understanding, at a basic knowledge level, after a short intervention. The assessment questions tested the recall of facts rather than an understanding of a whole concept about science or agriculture. Teacher surveys indicated the FARM Science lab did address appropriate educational standards for their respective grade levels. Teachers also believed agriculture could be very effectively used to contextualize science concepts. The final research question addressed differences in rural, suburban and urban student gains from pretest to posttest. The FARM Science Lab did not visit any urban schools during the time of this study. Of the grade/lesson groups which did have a rural and suburban population to compare, there were some differences in scores between students' responses in each geographic location. These populations were small therefore these differences may not be generalized to the larger population.

ACKNOWLEDGMENTS

The completion of this research and degree would not have been possible without the support, mentorship, and advisement of many. I would like to extend the utmost gratitude to Dr. Debra Spielmaker for recruiting me to attend Utah State University, her guidance as my committee chair, and her mentorship. Dr. Spielmaker's inspiration to think critically extends learning far beyond this research and my degree program. I am thankful for her willingness to share her unrivaled knowledge of agricultural literacy research and practice. Her innovation in teaching and flexibility afforded me the opportunity to conduct this project at a distance yet feel a part of the Utah State University community. Dr. Spielmaker's mentorship and friendship are invaluable outcomes of my graduate school endeavors.

To my research committee, Dr. Kelsey Hall, Dr. Becki Lawver, and Denise Stewardson, thank you for your time, shared knowledge, and encouragement. Your dedication to agricultural education, formal and non-formal, is inspiring. I am grateful for your feedback and the unique angle each of you bring to help me learn and build a successful research project. Thank you to Dr. Hall for nominating my thesis proposal to the Association of Communication Excellence in Agriculture, Natural Resources and Life and Human Sciences. I am honored you found enough merit in my writing to warrant this nomination and award.

I would like to express my appreciation to the National Agriculture in the Classroom Organization and National Center for Agricultural Literacy Research for supporting and encouraging research to further our field. I am thankful for the network of

peers I have built across the country through involvement in these organizations. This network's shared resources and ideas motivate me to continue my work in this area. I am extremely grateful to Michigan Farm Bureau for the support of employee development through continuing education and for allowing me access to data collected through the FARM Science Lab program. To my management and peers, thank you for your support throughout this project. The assistance, flexibility, and excel wizardry has not gone unnoticed.

I could not have completed this project without the love and care of my family and friends who are like family. To Nicole, Kate, Emily, Renee, and Jillian who made sure I took breaks to maintain my sanity, thank you. Aaron, Aunt Traci, Julie, and Joe, thank you for your words of encouragement, check-ins, and listening ears. Grandpa, you are the reason I set out on this agricultural path. Mom and Dad, I am grateful beyond words for your unwavering love, encouragement to further my learning, and inspiration to conquer any challenge I set out to take on. Thank you too, for your willingness to help with everyday tasks—giving me the time to dedicate to this project. To Grandma, Aunt Lori, and Uncle Philip—your way with words, encouragement to read, and your editing tutelage laid the foundation for my writing many years ago. Though you are not here to see this research, I credit the skills you instilled in me for my academic success.

Amelia J. Miller

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The logic model for agricultural literacy programs defines an agriculturally literate person as someone who "understands and can communicate the source and value of agriculture as it affects our quality of life" (Spielmaker, Pastor, & Stewardson, 2014, p. 2). This logic model suggests increased education for influential groups—including educators, students, and policy makers—will lead to more consumer-based information that may increase agricultural literacy in the U.S. (Appendix A). Agriculture in the Classroom programs in the 56 U.S. and territories work to implement programming to increase agricultural literacy among teachers and their students at the pre-school through 12th-grade levels (National Agriculture in the Classroom, n.d.).

Most notably defined by David Kolb, experiential learning creates knowledge through the transformation of experience. Experiential learning helps students to solve practical problems by drawing upon abstract concepts and previous knowledge (Kolb, 1984). Agriculture in the Classroom programs are using real-world agricultural concepts as the context for teaching science, social studies, language arts or math content required by state and national educational standards (National Agriculture in the Classroom, n.d.).

Today, most Americans are at least three generations removed from the farm (American Farm Bureau Federation, n.d.). As the distance between farm and fork increases, society's interaction with agriculture continues to change (Center for Food Integrity, 2015). The theory of situated cognition provides a framework for educators to bring together knowledge, experience, and society in a learning environment. Through

educational content paired with an appropriate real-world context, students learn the what, the how, and the why to transfer an abstract idea to functional application (Brown, Collins, & Duguid, 1989). As Agriculture in the Classroom programs work toward developing a more agriculturally literate society, these lessons are bringing together sociocultural ideals with educational content (National Agriculture in the Classroom, n.d.). Michigan's Food, Agriculture and Resources in Motion (FARM) Science Lab is the state's newest tool to address agricultural literacy. The 40-foot trailer can host up to 30 students at a time at its 10 lab stations, each equipped with an iPad and scientific tools for each lesson. Qualified teachers are employed to travel the state with the lab, teaching standards-based lessons tying curriculum concepts to applications in agriculture (L. Grasman, personal communication, May 22, 2017). To date, no data has been analyzed to determine the effectiveness of the FARM Science Lab as a means for increasing agricultural literacy.

Problem Statement

The American Association for Agricultural Education's National Research Agenda establishes seven priorities to address current and emerging challenges to bridge the gap between agriculture and the general public. Research Priority 1 asks, "What methods, models and programs are effective for informing public opinions about agricultural and natural resources issues?" (Roberts, Harder, & Brashears, 2016, p. 10).

A Google search of "mobile + agriculture + classroom" returned 3,950,000 results, surfacing 17 mobile agriculture classroom programs, in as many states, teaching agricultural lessons as a method to address the gap between agriculture and the public.

Previous studies have tested the effectiveness of agricultural literacy programs. In a synthesis of the literature, Kovar and Ball (2013) analyzed 49 studies conducted over 23 years of agricultural literacy research. Of these studies, 19 focused on the effectiveness of agricultural literacy programs, all showing participants to have an increased understanding of agriculture but with varying levels of effectiveness (Kovar & Ball, 2013). However, despite these promising results, no research has investigated the experiential learning in mobile classrooms as it relates to agricultural literacy. For this reason, additional research is necessary to evaluate the treatment effect of non-traditional experiential learning approaches such as mobile science labs on agricultural literacy among primary school students.

Purpose of the Study

The purpose of this quasi-experimental study was to evaluate the effectiveness of Michigan’s FARM Science Lab mobile classroom as a method of teaching agriculture-themed, standards-based lessons to third- through fifth-grade students in order to increase their understanding of agriculture. This research will expand our understanding of the impact of non-traditional experiential learning approaches in a formal traditional setting on agricultural literacy, thereby addressing the American Association for Agricultural Education National Research Agenda Priority 1 concerning “what methods, models and programs are effective for informing public opinions about agricultural and natural resources issues?” (Roberts et al., 2016, p. 10). The results of this research may also be used to improve curriculum, teaching pedagogy, and experiential learning opportunities for youth in non-traditional settings. The results of this research could also provide

options for agricultural literacy organizations to build new, effective and financially efficient programming.

Research Questions

1. What is the difference in student agricultural literacy before and after participation in the FARM Science Lab mobile classroom?

2. What are teacher perceptions of the FARM Science Lab mobile classroom model regarding increased academic and agricultural literacy understandings?

3. What are the differences between urban, suburban, and rural student gains from pretest to posttest?

Limitations

1. This study evaluates the pretest and posttest results within a single state.
2. This study is limited to the students and teachers who participate in the FARM Science Lab program, so results should not be generalized beyond similar populations.
3. The testing technology available for administering the pretest and posttest may vary between schools.
4. The FARM Science Lab has little control over when students are provided posttests after participation. Posttest results may be collected at various intervals after each session in the lab between one hour and one month after participation.
5. The FARM Science Lab teaches the same lessons to students throughout the school year, so the natural developmental and intellectual progress (maturation) of students throughout the year may affect results.

6. The FARM Science Lab program has no control over what the classroom teacher has or has not taught prior to participation in the mobile classroom program.

7. This study will not be able to measure student or teacher behavioral changes related to concepts taught, as defined by the Logic Model for Agricultural Literacy Programming (Spielmaker, Pastor, & Stewardson, 2014).

8. Students may be apprehensive about taking the pretest as it evaluates material they have not yet covered in class.

9. All FARM Science Lab third through fifth-grade lessons are 50 minutes in length.

Assumptions

1. All students in each grade level are similar in cognitive abilities.
2. Respondents will answer truthfully and completely.
3. All teachers are searching for additional science-based lessons or experiences for their students.
4. Pretest and posttest assessments are not graded assignments; therefore, it is assumed students will still be motivated to do their best work.

Significance

Michigan's FARM Science Lab affected just over 4,000 students from February to June 2018 at 22 schools holding reservations. This evaluation will determine the effect this program is having on student learning, beyond the visible recognition of the FARM Science Lab. This study will provide recommendations for Michigan and other

agricultural literacy programs using mobile labs for agricultural literacy outreach efforts and informing public understanding about agriculture.

Theoretical Framework

Experiential learning is widely accepted as a structure for student-centered instructional design and lesson development (Kolb, 2014). Kolb's model of experiential learning indicates students move through four phases; concrete experience, reflective observation, abstract conceptualization and active experimentation to solve problems by drawing upon abstract concepts and previous knowledge (Kolb, 1984). John Dewey discussed teachers directing student experiences as a way to provide accurate learning while allowing students to be actively engaged in the learning process (Dewey, 1938). In the context of the FARM Science Lab program, experiential learning is the theoretical framework. The Logic Model for Agricultural Literacy was used to operationalize Kolb and Dewey's experiential learning theory through interventions (inputs) leading to desired agricultural literacy outcomes (Spielmaker et al., 2014). This model indicates inputs such as the human, program, and financial resources (e.g., the FARM Science Lab program), that reach teachers and students should produce changes in knowledge, attitudes, skills, behaviors and practices relating to the connection of agriculture to daily life. This study measured changes in student knowledge of the agricultural and science content the FARM Science Lab lessons.

Definition of Terms

Agricultural literacy: An agriculturally literate person is someone who

understands and can communicate the source and value of agriculture as it affects our quality of life (Spielmaker et al., 2014)

Effectiveness: For the purposes of this research, effectiveness is defined as the value of the program related to positive outcomes, favorable teacher attitudes and program cost.

Experiential learning: Creates knowledge through the transformation of experience (Kolb, 1984)

Mobile dairy classroom: Any sort of vehicle or trailer that hauls a cow and milking equipment for the purpose of education

Mobile display: any sort of educational material hauled in a trailer, but taken out for presentation. No students enter the trailer for programming.

Mobile classroom: For the purposes of this research, a mobile classroom refers to any size trailer or vehicle in which students participate in educational programming inside the vehicle.

Situated cognition: brings together the what, the how and the why of learning to provide for the transfer of this learning from abstract concept to functional application, including the sociocultural ideals surrounding this application (Brown, Collins & Duguid, 1989)

Summary

The logic model for agricultural literacy provides a road map for building programs that work toward increased agricultural literacy among students, teachers, consumers, and policymakers (Spielmaker et al., 2014, p. 2). Michigan's FARM Science

Lab and other agricultural mobile classroom programs operationalize this model through teacher-directed, experiential learning. The American Association for Agricultural Education’s research agenda prioritizes investigating modalities for informing the public’s opinion of agriculture (Roberts et al., 2016, p. 10). The purpose of this study was to evaluate the FARM Science Lab as a modality for increasing agricultural literacy. As with any research, there are limitations to this study, assumptions made about the student population reached, and terms to define providing clarity to the readers and other researchers.

CHAPTER II

LITERATURE REVIEW

Much of the research on agricultural literacy has been conducted at the primary grade levels and focused on assessing agricultural literacy, testing a program, or the development of a framework or guide (Kovar & Ball, 2013). However, no research has been conducted on mobile agricultural classrooms. For these reasons, additional research is needed to determine the efficacy of different agriculture-based learning environments, such as a mobile classroom. The purpose of this literature review is to synthesize previous research on the definitions of agricultural literacy, evaluate the depth of information about mobile agriculture classrooms available, examine experiential and situated cognition, and define novelty as a motivation for learning. Due to the pertinent history of these topics, works published more than 10 years ago were included in this review. Searches of Google Scholar, JSTOR, and EBSCO host education collections along with some personal communication were used to conduct this research. In addition, the National Center for Agricultural Literacy's website contained a large collection of previous research. Search terms included *agricultural literacy, mobile agriculture classroom, experiential learning, experiential learning science, situated cognition, situated learning, learning novelty, and novelty as a motivation for learning.*

Agricultural Literacy

Initial definitions envision "an agriculturally literate person's understanding of the food and fiber system would include its history and its current economic, social, and

environmental significance to all Americans" (National Research Council, 1988, p. 8). Martin Frick built upon this definition through a survey of panelists from 48 land-grant institutions. This collective definition incorporated the ability to "synthesize, analyze, and communicate basic information about agriculture" as well as categorized the scope of agricultural literacy into 11 subject areas (Frick, 1990). More recently, the logic model for agricultural literacy programs updated the definition of an agriculturally literate person as someone who "understands and can communicate the source and value of agriculture as it affects our quality of life" (Spielmaker et al., 2014, p. 2). This logic model suggests increased education for influential groups including educators, students, and policy makers will lead to more consumer-based information that may increase agricultural literacy in the U.S.

To work toward increasing agricultural literacy, the National Research Council's Committee on Agricultural Education in Secondary Schools recommended all students in kindergarten through 12th-grade should receive some agriculture instruction. The committee suggested agriculture be incorporated into existing lessons rather than separately taught (National Research Council, 1988). However, it was nearly 10 years before a framework for this integration was organized (Leising, 1994). The Food and Fiber Systems Literacy Standards (FFSLS) align agricultural concepts with national educational standards. The FFSLS divide these agricultural education objectives into five categories: understanding food and fiber systems; history, geography, and culture; science, technology, and environment; business and economics; and food, nutrition, and health. In addition to these standards, the FFSLS program included student assessments

to evaluate learning for each benchmark.

The FFSLS have been used to evaluate student knowledge about agriculture topics. Using the benchmarks as a guide, researchers set up treatment and control groups to test knowledge before and after agricultural instruction at elementary grade levels. Across all grade levels, the treatment and control groups scored similarly on the pretests. The treatment group posttest scores showed increase in agricultural knowledge overall. Students did gain knowledge in each of the five FFSLS themes; however, different grade levels appeared to have larger increases in understanding of different themes, supporting previous conclusions found (Leising, Pense, & Igo, 2000; Pense, Leising, Portillo, & Igo, 2005). These studies provided recommendations for state-level Agriculture in the Classroom resource development to address the knowledge gaps shown in the states participating.

The National Agricultural Literacy Outcomes (NALOs) provide an updated road map for educators to incorporate grade-level appropriate agricultural connections that pair with the required national educational standards (Spielmaker & Leising, 2013). Using the logic model for agricultural literacy programs as a guiding definition, the creation of the NALOs was influenced by previous research and agriculture literacy frameworks, including the Food and Fiber Systems Literacy Standards. Similar to the FFSLS, the NALOs are organized into five categories: agriculture and the environment; plants and animals for food, fiber & energy; food, health, and lifestyle; science, technology, engineering, & mathematics; and culture, society, economy, & geography. These five themes align agriculture, food, and natural resources concepts with national

educational standards in science, social studies, and health content areas. This alignment to standards and agricultural literacy significance was reviewed by members of the National Agriculture in the Classroom Organization and invited educators. As with the Food and Fiber Systems Literacy Standards, these NALOs have then been utilized as a framework to assess students' knowledge of agriculture and environmental topics. Evaluations indicated upper elementary students are more knowledgeable about STEM topics than agricultural or environmental topics. Of the agricultural and environmental topics, students were most knowledgeable about ways technology helps farmers, recognition of natural resources used in agricultural practices and the interaction of sun, soil, water and weather in plant and animal growth (Brandt, 2016). Brandt (2016), Leising et al. (2000), and Pense et al. (2005) and have shown these agricultural education frameworks can provide the structure for creating evaluation tools to measure student knowledge about agricultural concepts and to provide recommendations for future agricultural education resources. Based upon these findings, the NALOs could be used as a basis for the evaluation of learning in mobile agricultural classrooms.

Existing Mobile Agricultural Classrooms

The concept of mobile educational endeavors is not new. George Washington Carver established a "movable school" in 1906 at the then Tuskegee Institute as a way to take practical trainings to rural, minority farmers who could not otherwise attend university courses. From 1906 to 1944, this program grew to include veterinary practices, sewing, childcare, harvesting techniques, and more. It is credited as the basis for some of today's cooperative extension programming, mobile veterinary units, and school outreach

programs (Zabawa, 2012).

Today, the Mobile Laboratory Coalition seeks to organize traveling science-based educational programs as a membership organization for the staff and management of these programs. Established in 2010, the coalition meets annually to build this network of professionals, to share ideas, problem solve and support the development of new enterprises with the same mission. The membership of this group includes staff of children's hospitals, science centers, museums, non-profits, universities, private organizations and for-profit businesses—all who operate mobile outreach programs to students in K-12 classrooms to enhance science education (Mobile Laboratory Coalition, 2016).

For the purpose of this research, mobile agricultural classrooms are defined as traveling units available to a state or region, solely teaching about agriculture, food, and natural resources (AFNR: agriculture, food, and natural resources) topics. The programs are operated by agricultural foundations, state departments of agriculture, farm bureaus, cooperative extensions, conservation districts, commodity organizations, or agribusinesses. A Google search of "mobile + agriculture + classroom" returned 3,950,000 results, surfacing 17 mobile agriculture learning programs fitting the aforementioned definition**.** Of those results, nine mobile agriculture classroom programs were identified. In addition, five mobile displays and three mobile dairy classrooms were identified. To further understand the structure of these existing mobile agricultural programs, a survey was sent to the staff contact listed on each program's website. Distributed using Qualtrics, this survey asked questions about program management,

staffing, source and content of lesson materials, and evaluation methods used for student learning and teacher perceptions of the program. This research provided context for evaluating Michigan's FARM Science Lab program (Miller & Spielmaker, 2018). Pennsylvania operated the largest program with six mobile classrooms and one mobile display traveling their state. Georgia and Arkansas both operate mobile dairy classrooms, hauling a dairy cow and milking equipment to teach audiences about animal science and the nutritional value of dairy products. Nine states responded to an email inquiry about their program. On average, each of these mobile educational units reaches more than 40,000 students annually. Three programs staff their mobile units with part-time staff, while the remainder hire full-time employees to run the programming. In total, 50 staff members work full or part-time for the mobile agricultural classroom programs. Nearly all of these programs solely focus on primary grade levels, with second through fifth-grade being the most common grades taught. Only one program is available through the twelfth grade, and four programs service the seventh and eighth grades. All nine programs indicate agricultural subjects taught align with NALO categories. Only two states conducted pre/post testing of student participants, and two programs conducted post-visit teacher surveys. The remaining programs cite returning reservations as their largest indicator of success. No program indicated formally publishing the results of these evaluations. While these agricultural and other science-focused mobile laboratory programs exist, very little published literature about their effectiveness or impacts exists (Jones & Stapleton, 2017).

Michigan's FARM Science Lab is a 40-foot mobile classroom. Technology is

incorporated into the unit through 10 iPad learning stations and lab equipment as well as a teacher station with a projection microscope, document camera, and large television screen. The FARM Science Lab began traveling to schools in February 2017, reaching nearly 7,600 students at 25 schools across three counties in Michigan through June 2017 (T. Ritter, personal communication, December 4, 2017). Lessons taught to kindergarten through fifth-grade students were compiled by Michigan Agriculture in the Classroom staff, utilizing existing lessons available from the National Agriculture in the Classroom Matrix. These lessons were all linked to NALOs. The seven lessons offered teach agriculture concepts within the five NALO themes, including agriculture and the environment; plants and animals for food, fiber and energy; food, health, and lifestyle; science, technology, engineering & mathematics; and culture, society, economy, and geography. The lessons are aligned with appropriate Next Generation Science Standards. Instructional methods bring together science, technology, engineering, and math (STEM) incorporating the use of technology and relevant science laboratory practices through hands-on learning. These lessons draw upon students' previous experiences with agriculture, food, and the natural resources around them to build understanding of scientific theory and real-world career awareness. Though the FARM Science Lab is available to kindergarten through fifth grades, this study focuses on third through fifth grade students. For reservations, one main contact from the school serves as the liaison between Michigan Agriculture in the Classroom staff and the school. Schools select dates in advance and pay a daily fee of $425 or $1,925 for five consecutive days, with a preferred minimum 2-day reservation. This use fee is often sponsored by county Farm

Bureau organizations, agricultural businesses, individual farms, parent teacher organizations, or other community entities. The initial investment of the lab and equipment was $110,000 in 2016. Annual operating costs average $89,000 including lesson supplies, fuel for the generator, maintenance, hauler and regional educator payroll and travel expenses. This annual operating cost does not reflect the salary of the Michigan Agriculture in the Classroom program manager and one support staff as their roles do support other programming as well. The school fees do not cover all lab operating expenses. Donors provided all support for the initial investment and additional financial support for operating the lab through the Michigan Foundation for Agriculture (T. Ritter, personal communication, June 14, 2017).

Experiential Learning

The concept of learning through experience has been defined and studied for more than 100 years. William James, considered to be one of the greatest American psychologists, believed that knowing is to experience and that experience is knowing. Though not all philosophers or psychologists agreed with this theory, John Dewey did and went on to pen many works about progressive education (Taylor & Wozniak, 1996). Dewey's *Experience and Education* further defines this idea of experience is knowing by adding not all experiences may be educational. Some experiences may, in fact, be wrong or misinformed (Dewey, 1938). Dewey added the element of teachers directing student experiences to ensure accurate learning is taking place. While other psychologists have gone on to add to these early definitions, David Kolb continues to define experiential learning in the context of formal education. This updated definition, "learning is a

process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38) led to Kolb's model of experiential learning which defines four phases in the learning cycle (see Figure 1).

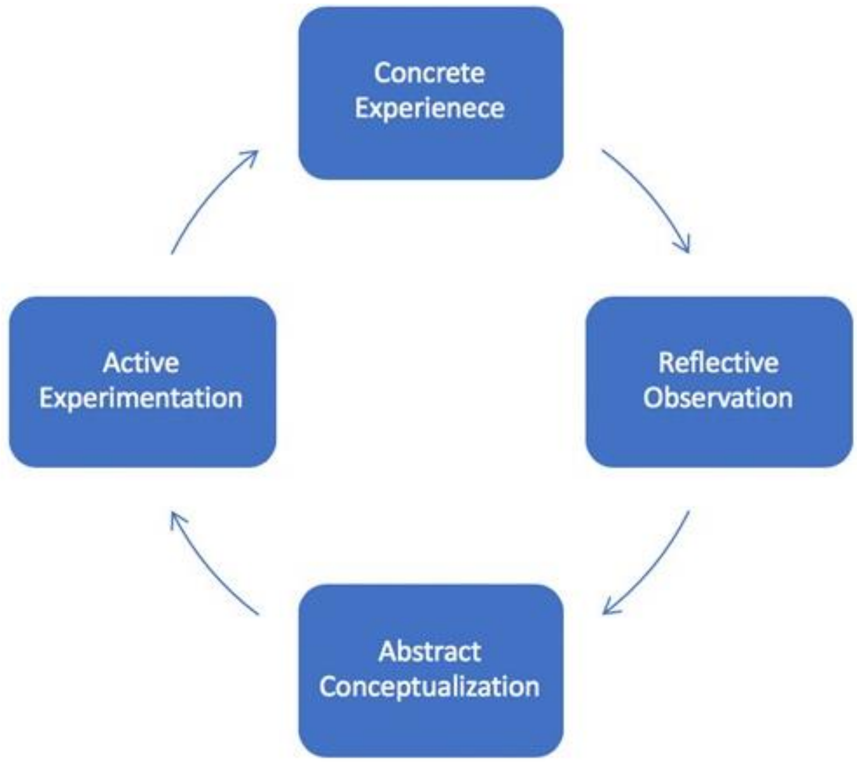


Figure 1. Kolb's model of experiential learning.

This model includes four stages. A concrete experience is an active learning engagement where learners must be involved in doing something. During reflective observation, learners reflect on actions to determine what has been observed. Abstract conceptualization is for understanding existing theories, diagrams, or lectures to connect the previous two stages with previously studied theory. Finally, active experimentation allows learners to practice what has been learned (Kolb, 1984). This process helps students to solve practical problems by drawing upon abstract concepts and previous

knowledge (Kolb, 1984). This theory of experiential learning is widely accepted as a structure for student-centered instructional design and lesson development. Experiential learning brings together job demands and educational objectives to connect the classroom and the real world. In classrooms with successful implementation of experiential learning, students have become intrinsically motivated to learn (Kolb, 2014). In science education, a challenge for teachers is to bring together students' experiences in the everyday world and scientific theory to make some sense of these processes to increase scientific knowledge (Duschl, Schweingruber, & Shouse, 2007). The idea of building on these explanations of observed phenomena is captured in today's Next Generation Science Standards (NGSS). The NGSS standards serve as a guiding framework to build upon these experiences, gaining complexity as a student progresses through grade levels (National Research Council, 2012).

Situated Cognition

Educational models often teach vocabulary, definitions, or abstract theories in a silo, expecting rote memorization without context for the practical practice of these concepts (Brown et al., 1989). The theory of situated cognition brings together the what, the how, and the why of learning to provide for the transfer of this learning from abstract concept to functional application, including the sociocultural ideals surrounding this application. These learning situations provide for a twofold knowledge gain: first, the understanding of the definition or theory, and second, an explanation of the real-world context in which it is used (Brown et al., 1989). Bednar, Cunningham, Duffy, and Perry (1992) suggested school learning is both quantitatively and qualitatively different than

the real-world environment of the subject matter. Maintaining an authentic complexity of the subject matter within the scope of the learner's knowledge and prior experience will help students to understand concepts (Bednar et al., 1992). It is the content of the learning that drives this authenticity (Choi & Hannafin, 1995). The context provides the framework for learning. These problem-based contexts with authentic content provide students the opportunity to sense when and how to use the acquired knowledge (Choi & Hannafin, 1995). Young (1993) further applies the psychological theory of situated cognition to classroom learning by outlining four imperative pieces of instructional design. First, an educator must select the real-world context to match the content. Then, the appropriate scaffolding is necessary to adjust the complexity of content and context to match the grade level or ability of the students. The third step is to develop the situation, knowledge to be acquired, cooperation between students, and other necessary elements of learning. Finally, a form of assessment must be determined (Young, 1993). Similar to the theory of experiential learning, situated cognition and learning promote learning by doing; however, situated cognition often provides a stronger tie to the sociocultural world of the real-world problem (Quay, 2003). In part, the American Association for Agricultural Education's National Research Agenda works to address the sociocultural connections to agriculture in the U.S. While all seven of the research priorities play a role, Research Priority 1 specifically focuses on the societal connections and disconnections of agriculture (Roberts et al., 2016, p. 10). Agricultural literacy is a focus on this priority, working to bridge the gap between consumers and the farm. Situated cognition combined with experiential learning provides a framework for introducing

students to the cultural connections to agriculture as well as the ability to gain real-world exposure to agriculture content.

Novelty as a Motivation for Learning

The Oxford Advanced Learner's Dictionary defines novelty as "the quality of being new, different, and interesting" (Hornby, 2015). Neuroscientists are finding novelty can increase learning. The middle region of the brain responsible for controlling motivation and reward processing has been found to respond better to new experiences and things than familiar items (Bunzeck & Düzel, 2006). This neuroscience, as the basis of brain function, leads to learning when a person experiences something new; each of the five senses matches this new experience with a previously stored memory, thus increasing these memories (Willis, 2007). Willis goes on to explain when classroom experiences are positive, new, and exciting to students, the brain stimulates memory centers thus increasing focused attention and learning. She suggests learning should be relevant; students should be able to answer "why are we learning about this?" at any point during the lesson (p. 3). Lessons should connect theories with known topics and allow for students to explore solutions on their own (Willis, 2007). *Education Week*, a periodical for K-12 educators, cites Duzel's neuroscience research, encouraging educators to overcome fear of changing methods to allow for increased novelty experiences in their classrooms (Laurent, 2011). These early experiences increasing motivation for learning can have long-term implications for students. Professionals working in science-related careers have indicated their interest in science careers started well before high school (Maltese & Tai, 2010). Those indicating interest in science

beginning early in life or in elementary school cited science exploration led by teachers such as demonstrations, laboratory experiments, science projects or other enrichment experiences as motivators for their career choices.

Summary

Agricultural literacy goes deeper than simply knowing milk comes from cows, and field corn is not the same as sweet corn. An agriculturally literate person has an understanding of agriculture and its necessary daily role in society (Spielmaker et al., 2014). For more than 30 years the National Agriculture in the Classroom Organization and its state affiliates have been working toward increasing agricultural literacy among teachers, students and ultimately the future leaders of society (National Agriculture in the Classroom, n.d.). The Food and Fiber Systems Literacy Standards served as the first framework for this educational effort (Leising, 1994). Derived in part from the FFSLS, the National Agricultural Literacy Outcomes provide updated direction for agricultural literacy objectives standards (Spielmaker & Leising 2013). Mobile agricultural classrooms are potentially one mode of delivering effective agricultural lessons to elementary school students. By using agriculture as the real-world context of learning, teachers can bring together students' previous knowledge with scientific theory. Building on this model of experiential learning, the theory of situated cognition adds the sociocultural element to learning by doing (Brown et al., 1989). It is this combination of agricultural knowledge, experiences, and society, which could influence increases in agricultural literacy through the novel learning experiences of mobile agricultural classrooms.

CHAPTER III

METHODOLOGY

The purpose of this study was to evaluate the effectiveness of Michigan's FARM Science Lab mobile classroom as a modality for teaching agriculture-themed, standards-based lessons to third- through fifth-grade students to increase their understanding of agriculture.

Research Questions

1. What was the difference in student agricultural literacy before and after participation in the FARM Science Lab mobile classroom?

2. What were teacher perceptions of the FARM Science Lab mobile classroom model regarding increased academic and agricultural literacy understandings?

3. What were the differences between urban, suburban, and rural student gains from pretest to posttest?

Research Hypotheses

1. As a result of participating in the mobile classroom lessons taught in the mobile science classroom, student knowledge of agriculture, food, and natural resources topics (agricultural literacy) will show an increase.

2. After participating in a mobile science classroom lesson, teachers will have a positive perception related to the contextualization of science in agriculture, food, and natural resources content.

3. Students in suburban and urban areas will show more gain in knowledge than those in rural locations.

Research Design

This quasi-experimental study used a one-group pretest-posttest design. Logic models can be used as a tool for designing and evaluating many types of programs. In this context, a program was an intentional use of specific resources put into specific activities to produce a desired outcome within a specific context (McLaughlin & Jordan, 2004). Using the Logic Model for Agricultural Literacy (Spielmaker et al., 2014), an intervention, such as the FARM Science Lab lessons, based on specific outcomes should result in changes in knowledge, attitudes, skills, behaviors, and practices. This research was testing the short-term gain of knowledge through a pretest and a posttest design. The theory of situated cognition also influenced this research design, assembling the what, the how, and the why of learning (Brown et al., 1989). The grade level-specific, agricultural learning objectives contextualized scientific concepts by providing an agricultural application (Spielmaker & Leising, 2013). This real-world application provided the "why of learning" Brown discussed, while the partnering science concepts provide "the what" and "the how." FARM Science Lab lessons brought scientific principles and content to life by applying students' previous science learning to the real-world context of agriculture, food, and natural resources. The pretest and posttest questions used NALO objectives to assess students' abilities to apply the "what" and the "how" of this learning to the "why." Teachers and students participating in the FARM Science Lab program were the target population of this research. As with all human subject research, it was not

possible to control all potentially confounding variables of each participant. Pretesting was used to establish the baseline for each classroom group. The posttest results were compared to the pretest results, noting any significant differences. It is this comparison of the baseline to the posttest, after treatment, which provided the statistical strength for this design (Bonate, 2000). Students and teachers participated in the agricultural lessons within existing classroom groups; therefore, this was not a random sample of either population. When random sampling is not possible, a quasi-experimental design is an appropriate design method (Johnson & Christensen, 2014). Treatment was the participation in an agricultural lesson in the FARM Science Lab. During the timeframe of this study, all sections of each grade level for each participating school were engaging in FARM Science Lab programming; therefore, no control groups were used in this research.

Population and Sample

Using pre-existing data (as collected by Michigan Agriculture in the Classroom staff, see Appendix G), students and teachers who participated in the FARM Science Lab program during the months of February through June 2018 were analyzed. As a part of existing FARM Science Lab programming, all students were asked to complete the student pretest and posttest. All teachers (n = 150) bringing their classrooms to the FARM Science Lab were asked to complete a teacher evaluation of the program. From February to June 2018, the FARM Science Lab visited 22 schools in the following counties: Clinton, Grand Traverse, Hillsdale, Ingham, Leelanau, Midland, Missaukee, Monroe, Newaygo, Saginaw, Sanilac, Tuscola, Wexford, and Wayne. At these schools,

approximately 91 teachers brought 4,077 students in the following grades: 1,090 third graders, 1,781 fourth graders, and 1,206 fifth graders. Public, private and charter schools participated and were located in both rural and urban areas. The curriculum, pretest/ posttest, and teacher evaluation were reviewed by the researcher, industry experts, and university professors to ensure content curricular validity and criterion-related validity between the student agricultural literacy outcomes and the teacher perceptions.

Intervention and Instrumentation

Four different FARM Science Lab lessons were available to third through fifth-grade students. Each lesson was 50 minutes in length. Lesson titles, descriptions, and objectives are shown in Table 1. Michigan Agriculture in the Classroom employed several part-time employees to facilitate these lessons, across different regions of the state. At one school, one of the FARM Science Lab educators taught all of the lab's lessons, accommodating up to five 50-minute lessons per day. The regular classroom teacher was required to remain in the lab for the duration of the lesson. The FARM Science Lab can hold up to 30 students at a time; therefore, most often each classroom had its own timeslot for participation. Classes rotated through in 50-minute intervals throughout the day, with a short break for clean-up between (T. Ritter, personal communication, June 14, 2017).

Each assessment contained a mixture of multiple choice or true and false style questions. The assessments were unique to the specific objectives of each lesson, while all lessons had components connecting agricultural careers to the lesson content as well as drawing conclusions about Michigan-specific agricultural production. All lesson

Table 1

FARM Science Lab Lesson Descriptions and Objectives

Title	Description	Objectives
"Extraction of Life" (Appendix A)	Students will unravel plant genetics by identifying structures within a plant cell, discovering the location of DNA inside each cell. Using wheat as an example, students will follow a procedure to extract plant DNA. Throughout the guided discussion and experiment, students will explore careers related to plant science and facts about Michigan agriculture.	1. Identify components of DNA including phosphates, sugars, nitrogen bases (adenine, thymine, cytosine, and guanine), and double-helix twisting structure. 2. Explain the function of the cell wall, cytoplasm, nucleus and chromosomes of a plant cell, recognizing cells are too small to be seen with the naked eye. 3. Name one career related to the study of genetics.
Field Plastic (Appendix B)	Students will describe how plant-based products are used in daily life. Then, students will make observations, predictions and write a hypothesis while investigating the differences between a biodegradable packing peanut and a petroleum-based packing peanut. In groups, students will make corn-based plastic to take home.	1. Identify renewable and nonrenewable resources and define "biodegradable." 2. Compare petroleum and plant based-Styrofoam by running a series of tests and comparing the results. 3. Identify types of physical properties. 4. Describe how plants can be used in everyday products such as food, fuel and fiber.
Parts Per What (Appendix C)	Students will demonstrate water flow through a watershed, identifying landforms and possible sources of water contamination. Then, students will explore ways farmers work to protect the environment, including watersheds, by planting buffers strips, using precision technologies to apply fertilizers or manage water use on their farms. Finally, students will dilute a "contaminant" in a water sample to demonstrate water clarifying practices. Lesson includes division of fractions and decimals starting with 1/10 and progressing to 1/1,000,000.	1. Identify possible sources of surface and ground water contamination. 2. Recognize how water is used in agricultural production and the conservation practices employed by farmers to maintain or improve the quality of our water. 3. Measure the dilution of a contaminant in water by dividing fractions of the contaminant in a water sample. 4. Name two careers related to water quality.
Resourceful Bean (Appendix D)	Explore renewable and nonrenewable resources through an investigation of soy-based materials. First, students will learn the steps a soybean takes from farm to final product. Then, students will carry out a test to observe differences between a soy crayon and a petroleum-based crayon. Finally, students will assist in making their own soy-based lip balm. Throughout the lesson, agricultural career connections are made and Michigan agriculture facts are shared.	1. Arrange the processing steps of a soybean from farm to final product. 2. Compare petroleum- and plant-based crayons by running a series of tests and comparing the results. 3. Identify renewable and nonrenewable resources. 4. Name two careers involved in the making of soy-based materials. 5. Predict changes in states of matter when a solid is heated or cooled.

objectives and assessment questions were aligned with the objectives laid out in the Next Generation Science Standards as well as the National Agricultural Literacy Outcomes as a guiding framework. The pretest and the posttest for each lesson asked the same questions for comparison. To help with the error of students guessing on the pretest multiple-choice assessment questions, the pre-existing assessments were modified for a second group of students (Group 2) taking the assessment. Students had the additional option of selecting “I don’t know.” All Group 2 students participated in the assessments and FARM Science Lab experience after March 26, 2018. Also at this time, two opinion-based questions were added to all student assessments. All pretests included a yes or no question, “I am excited to learn more about science on the farm.” The question added to the posttest asked students to rank their experience by finishing the sentence “I thought the FARM Science Lab ______” with the multiple-choice options: “was awesome,” “was good,” “was just okay,” “could have been better,” and “was bad.” This question helped Michigan Agriculture in the Classroom staff collect the students’ opinion of the FARM Science Lab in addition to evaluating their learning. The teacher evaluation (Appendix E) consisted of 10 questions; 5 Likert scale, 4 yes or no, and 1 long-answer comment box—all evaluating the appropriateness of the lesson, connection to classroom learning, and overall quality of the presentation. Other questions asked teachers’ perceptions of student learning during the lab session, effectiveness of agriculture as an example to contextualize science principles, and the likelihood of teachers to use Agriculture in the Classroom materials in the future. All assessments were pilot-tested using Google Forms as the collection tool during January 2018. Access to Google platforms, ease of student

use, pairing of pretest and posttest responses and timing of emailed links were all tested during the pilot phase. All questions in the pilot instrument were developed by Michigan Agriculture in the Classroom staff. After the pilot, the test was reviewed and revised by Michigan Agriculture in the Classroom staff, the researcher, and a university professor. Due to the few items in each of the preexisting assessments and small sample size neither a Cronbach's alpha or Kuder-Richardson 20 were appropriate to calculate instrument reliability. Alternatively, a difficulty and item discrimination score (Matlock-Hetzel, 1997) were calculated for each pretest and posttest within each lesson and grade level groups. The item difficulty designation categorizes a question as very difficult (0-20%), difficult (21-60%), moderately difficult (61-90%), or easy (91-100%) using the percent of students in a given population who correctly answered the question. It is considered that an assessment should include a mix of difficulties; however "very easy" and "very difficult" items are not an effective means of discriminating between students who know the content and those who do not. Item discrimination could also be considered item effect, or the question's effectiveness at discerning between students who know the content and students who do not. This calculation separates the students into the top and bottom scoring thirds for comparison. The minimum item discrimination value is 0.2; however, values could range from -1.0 to 1.0. Matlock-Hetzel explained a negative discrimination index indicates a test question might be written in such a way that it is possible to correctly answer without a true understanding of the content being assessed. This would result in a student easily guessing the correct response or a student finding the question too easy and overcomplicating the question thus ending up with an incorrect

answer. Evaluating a question's difficulty and discrimination assist the test developer in determining problems with individual items (Matlock-Hetzel, 1997).

While the goal of this study is not to discriminate between questions for difficulty, using the discrimination value provides for more confidence in the reliability of the question as a measure of knowledge change after participation in the FARM Science Lab intervention. If a question has a low discrimination score and most students got the answer correct on the pretest and posttest, this could indicate the question was too easy meaning they brought prior experience to the test and really nothing was learned. A low discrimination score on the posttest where most students who were doing well got the question wrong indicates that item may not have been addressed in the lesson resulting in student guessing, or the question was poorly written and not a reliable measure.

All participants were asked to take the mobile lab lesson assessment, and teachers were asked to confirm that all participating students took the pretest and posttest. Time and date stamps as well as counts of responses from Google Forms were used to ensure the expected number of students completed both assessments.

Data Collection

This study was conducted using pre-existing data provided by Michigan Agriculture in the Classroom (Appendix G). The data were analyzed and served as one measure to determine the effectiveness of the FARM Science Lab. Michigan Agriculture in the Classroom staff established a process for collecting pretest and posttest data from classes participating in the FARM Science Lab program through the program's pilot phase. Program scheduling staff sent out links to the appropriate Google Form pretest to

the schools' contact person two weeks in advance of the FARM Science Lab visit. It was the responsibility of this school contact to distribute the assessment links to all participating teachers or students. If the pretest was not completed within one week prior to the visit, a reminder was sent to the school contact person. The following procedures were used for data collection. Teachers used school computer labs or student tablets to administer the pretest prior to the arrival of the FARM Science Lab. Teachers were instructed to administer the test as any other classroom assessment, asking the students to take the questions seriously and answer to the best of their ability. Teachers were asked not to explain the meaning of questions but were permitted to read questions to students if necessary. The only identifying information collected by the instruments included the school name, teacher's name, and grade level. Teachers were asked to randomly assign a number to students for use in matching pretest and posttest responses. Students were required to input this number as the first question on both the pretest and posttest for the sole purpose of matching test responses; no personal information was associated with this number. No demographic questions were asked, and student names were not collected. School names were later used to determine geographic locations for sorting by urban, suburban and rural locations. Posttests were administered in a similar manner. To collect data about teachers' perceptions of the FARM Science Lab program, an electronic survey was distributed to teachers via email following the program. As with the student assessments, a link to the teacher survey was sent to the school contact who was asked to distribute the survey link to all participating teachers.

Validity

The curriculum and testing instruments were developed by the Michigan Agriculture in the Classroom staff and reviewed by the researcher and university professors for content validity. The researcher and university professor compared the assessment questions to the lesson plan objectives to ensure content curricular validity.

Data Analysis

To compare findings across grade levels and across lesson content student pretest and posttest responses were exported from Google Forms into Microsoft Excel then separated by grade level and by lesson plan taught. Due to a technical challenge, 126 students at two elementary schools took the pretest and posttest on paper copy. Teachers copied the Google Form assessments for their own students, as these students could not individually have access to a computer during the necessary timeframe. The paper assessments were entered into Google Forms by the researcher to be sorted with the digitally collected data. Using the date stamp provided by Google Forms, assessments completed prior to March 26, 2018 (Group 1) were kept separate from assessments completed after March 26, 2018 (Group 2). Individual responses were compared using the numbers assigned to students as the identifier, pairing each pretest response with its respective posttest response. For the purpose of this research, unmatched pairs were not considered for analysis. Variables were coded in Microsoft Excel using the VLookUp formula to change words to numbers for statistical analysis. Once responses were sorted and grouped in Microsoft Excel, coded data were transferred to the Statistical Package for

Social Sciences (SPSS). Descriptive statistics were calculated and analyzed using the SPSS. A paired-samples *t* test was conducted to determine statistical significance. A Cohen's *d* was calculated to determine the effect size of the FARM Science Lab learning on agriculture, food, and natural resources knowledge amongst students. Because text responses were coded to numeric values for analysis, the absolute value of the *t* value and Cohen's *d* were used to interpret the data. To interpret the effect size for Cohen's *d* the following values were used: 0.2 = small effect, 0.5 = medium effect, and 0.8 = large effect (Cohen, 2013).

Teacher surveys (Appendix F) were downloaded from Google Forms then organized in Microsoft Excel for ease of sorting. This data were coded in Microsoft Excel then transferred to SPSS for statistical analysis. Descriptive statistics were used to analyze the teachers' responses. Teacher survey data were separated by grade level in order to better evaluate perceptions of student learning.

To address research Question 3, schools that participated in the FARM Science Lab were separated into rural, suburban and urban categories and student data was stratified to compare differences in mean pretest and posttest score in these locations. The National Center for Education Statistics (NCES) is located within the U.S. Department of Education with responsibility to collect, analyze, and report statistics about education in the U.S. (NCES, n.d.a.). NCES maintains a database of all public schools in the U.S. including demographic and geographic information. This database segments school locales into 12 categories from large cities to remote rural locations. Census data are used to define the parameters of each of the 12 categories (NCES Glossary, n.d.b.). For the

purpose of this study, the categories of “rural remote,” “rural fringe,” “town remote,” “town distant,” and “rural distant” were combined to be considered rural. Also, “suburban large,” “suburban midsize,” “suburban small,” and “city small” were combined to be considered suburban. “Large City,” “midsize city,” and “city small” were combined to be considered urban. Each FARM Science Lab school was found in the database to define its category. Then, mean scores were separated by grade, lesson and location from the previously analyzed data sets.

Summary

Using existing data provided by Michigan Agriculture in the Classroom, student assessments were compared to evaluate change in knowledge between pretests and posttest. Teacher surveys provided by MIAITC were also be evaluated. These assessments were written by Michigan Agriculture in the Classroom staff to align with the four lessons available to third through fifth grade students. Data was collected February through June 2018. For evaluation, data were segmented into lesson/grade level groups. A *t* test was used to determine the significance of differences between pretest and posttest scores. Effect size was measured using Cohen’s *d* calculation. Due to the low number of items per assessment and low populations in each lesson/grade group, item difficulty and discrimination values were calculated to help provide confidence in each question as a measure of knowledge. Geographic segmentation was also used to separate student responses into urban, suburban, and rural groups for further evaluation. Teacher survey data were evaluated using descriptive statistics.

CHAPTER IV

RESULTS

The purpose of this study was to evaluate the effectiveness of Michigan's FARM Science Lab mobile classroom as a method of teaching agriculture-themed, standards-based lessons to third through fifth-grade students in order to increase their understanding of agriculture. This research expands on to the body of agricultural literacy research to provide researchers with greater insight into the impact of nontraditional experiential learning approaches in formal traditional settings on agricultural literacy. The results provide educators and agricultural literacy leaders with information to improve curriculum, teaching pedagogy, and influence the selection of experiential learning opportunities for youth in nontraditional settings.

Research Question 1

What is the difference in student agricultural literacy before and after participation in the FARM Science Lab mobile classroom?

From February through June 2018, 4,077 students in grades three through five participated in FARM Science Lab lessons and all were provided pretests and posttests. Of those students, 1,258 (31%) completed both the respective pretests and posttests for their lessons. While the intent was that all students participating in the FARM Science Lab would take the pretest and posttest, some had technical challenges or in some cases, the primary school contact did not appropriately disseminate the assessment links to all teachers in their school. Participation in the assessments was not required by Michigan

Agriculture in the Classroom prior to beginning the FARM Science Lab lessons. Four lessons were offered to these grade levels during this time frame: “Extraction of Life,” “Field Plastic,” “Parts Per What” and “Resourceful Bean.” The number of students who participated in each individual lesson is identified within each lesson’s summary.

To help with the error of students guessing on the multiple-choice assessment questions, the pre-existing assessments were modified for a second group of students (Group 2). These students had the additional option of selecting “I don’t know.” Group 1 represents assessments given prior to the “I don’t know” being added. The results presented in Table 2 show an increase in mean score from pretest to posttest on each group’s assessments. Total score for each assessment is listed in the “Lesson” column. Each lesson’s data is summarized in separate sections following Table 2.

Extraction of Life Lesson

From February through June 2018, 537 students in third through fifth grades participated in the “Extraction of Life” lesson (Appendix A). The breakdown of each grade level was as follows: 19 third-grade students, 70 fourth-grade students, 448 fifth-grade. Of those students, 30% completed both the pretest and posttest: 0 third-grade students, 10 fourth-grade students (14%), and 155 fifth-grade students (33%). The pretest and posttest included the same seven questions. To reduce error from guessing, after March 26, 2018, “I don’t know” was added as an option to all pretest multiple choice answers. In addition, one question was added to each pretest and the posttest asking students to rate their excitement about and experience in the FARM Science Lab. All responses after March 26 are named Group 2. Mean scores in Table 3 are out of seven

Table 2

Mean Pretest and Posttest Differences for all FARM Science Lab Lessons

			Pretest		Posttest				
Lesson	Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Extraction of life (score out of 7)	Third, Group 1	-	-	-	-	-	-	-	-
	Third, Group 2	-	-	-	-	-	-	-	-
	Fourth, Group 1[a]	10	5.70	0.48	6.30	0.48	-0.6	-3.67*	1.64
	Fourth, Group 2	-	-	-	-	-	-	-	-
	Fifth, Group 1	109	5.04	1.21	5.65	1.00	-0.62	-5.49*	-0.66
	Fifth, Group 2	46	4.35	1.58	5.22	1.26	-0.87	-4.29*	0.90
Field plastic (score out of 5)	Third, Group 1[a]	45	1.31	0.87	2.27	1.03	-0.96	-5.59*	1.18
	Third, Group 2	-	-	-	-	-	-	-	-
	Fourth, Group 1		-	-	-	-	-	-	-
	Fourth, Group 2[a]	53	1.83	1.19	4.00	1.07	-2.17	-10.09*	1.96
	Fifth, Group 1	18	1.28	0.96	4.39	0.7	-0.19	-13.53*	4.89
	Fifth, Group 2	27	1.59	1.05	3.52	1.12	-1.93	-7.53*	2.05
Parts per what (score out of 5)	Third, Group 1	-	-	-	-	-	-	-	-
	Third, Group 2[a]	150	1.61	1.13	4.05	1.05	-2.43	-20.18*	2.33
	Fourth, Group 1	-	-	-	-	-	-	-	-
	Fourth, Group 2[a]	130	2.73	1.29	4.26	0.95	-1.53	-11.67*	1.45
	Fifth, Group 1	130	3.31	1.08	3.48	1.08	-0.17	-1.51	-
	Fifth, Group 2	13	3.46	1.56	3.54	1.61	-0.08	-0.13	-
Resourceful bean" (score out of 5)	Third, Group 1	133	3.26	1.22	4.06	1.01	-0.81	-6.84*	0.84
	Third, Group 2	82	2.56	1.34	3.34	1.36	-0.78	-4.45*	0.70
	Fourth, Group 1	148	3.55	1.21	4.20	0.95	-0.64	-5.90*	0.69
	Fourth, Group 2	71	2.97	1.22	2.90	0.42	-0.66	-3.84*	0.64
	Fifth, Group 1	34	3.32	1.07	4.65	0.54	-1.32	-6.73*	1.63
	Fifth, Group 2	67	2.15	1.49	4.51	0.68	-2.36	-12.75*	2.20

[a] Only one group per grade level.

*$p < .05$.

points as the excitement and experience questions were not included in the test score as no wrong or right answer was appropriate.

No third-grade students participated in the "Extraction of Life" lesson during the

time of this study. No fourth-grade students participated in the “Extraction of Life” lesson during the latter portion of this study when Group 2 was added. Therefore, these groups are absent from Table 3. All the fourth-grade students who participated in the “Extraction of Life” lesson are in Group 1. These students are all from one school with a very small population (*n* = 10) and show a nearly 1-point increase in mean score from pretest to posttest (Table 3). To make a comparison between the pretest and posttest a paired-sample *t* test was conducted was set a priori $\alpha = .05$. There was a statistically significant difference found between the pretest scores (*M* = 5.70, *SD* = 0.48) to the posttest scores (*M* = 6.30, *SD* = 0.48, $t(9) = -3.67$, $p < .05$ (two-tailed)). The mean increase in the fourth-grade Extraction on Life test scores was 0.6 with a 95% confidence interval ranging from -0.97 to -0.23. Cohen’s *d* (1.64) indicated a large effect size.

Group 1 (*n* = 109) fifth-grade students had a statistically significant difference in mean score from pretest (*M* = 5.04, *SD* = 1.21) to posttest (*M* = 5.65, *SD* =1.00, $t(103) = 5.49$, $p < 0.05$ (two-tailed). The mean increase in fifth-grade Group 1 was 0.62 with a 95% confidence interval ranging from -0.86 to -0.37. The Cohen’s *d* (0.69) indicated a medium effect size. Fifth-grade Group 2 also had a statistically significant difference in mean score from pretest (*M* = 4.35, *SD* = 1.21) to posttest (*M* = 5.22, *SD* = 1.263), $t(45) = -4.29$, $p < 0.05$ (two-tailed). The mean increase in fifth-grade Group 2 test scores was 0.87 points with a 95% confidence interval ranging from -1.28 to -0.46. Cohen’s *d* (0.85) indicated a large effect size.

Question 1 of the “Extraction of Life” assessment asked students to fill in the blank, “____contains DNA.” This multiple-choice option offered “living things” (coded

Table 3

"Extraction of Life" Pretest and Posttest Differences

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Fourth, group 1[a]	10	5.70	0.48	6.30	0.48	-0.6	-3.67*	1.64
Fifth, group 1	109	5.04	1.21	5.65	1.00	-0.615	-5.49*	-0.66
Fifth, group 2	46	4.35	1.58	5.22	1.26	-0.87	-4.29*	0.89

Note. Perfect score = 7.

[a] Only one group of fourth-grade students.

*$p < .05$.

as 1) or "non-living things" (coded as 2) as the responses. After March 26, 2018, "I don't know" was added to the pretest only. Assessment data collected after this time made up Group 2. Table 4 indicated fifth-grade Group 1 saw more students correctly answer "_______ contains DNA" on the pretest than on the posttest. This group of fifth-grade students had a statistically significant 0.06 difference in mean between the pretest (M = 1.01, SD = 0.42) and posttest (M = 1.06, SD = 0.21), $t(107) = -2.157$, $p < 0.05$ (two-tailed). The 95% confidence interval ranged from -0.11 to -0.01, and the Cohen's *d* indicated a small effect size. Fourth-grade Group 1 and fifth-grade Group 2 did not see statistically significant differences between pretest and posttest responses.

A difficulty index calculation was conducted to determine the percent of students (n) who answered this question correctly and item discrimination was calculated to indicate the degree to which high scoring students also got this particular question correct (Matlock-Hetzel, 1997). As outlined in Table 5, all groups of fourth- and fifth-grade students had a high percent of students correctly answering "_______contains DNA" on

Table 4

Descriptive Statistics for Question 1: "__________Contains DNA"

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Fourth, group 1[a]	10	1.00	0.00	1.10	0.32	0.10	-1.00	-
Fifth, group 1	108	1.01	0.10	1.06	0.21	0.06	-2.16*	-0.29
Fifth, group 2	46	1.04	0.42	1.09	0.29	0.04	-4.29	-

Note. 1 = correct response.

[a] Only one group of students.

*$p < .05$.

the pretest and posttest. These high percentages indicate moderately difficult to easy categories on the item difficulty designation scale. Item discrimination is the degree to which students with high overall scores also got this question correct (Matlock-Hetzel, 1997.). An ideal item discrimination is 0.20 or higher. In instances where a high percentage of students correctly answered the question, including fourth-grade Group 1 posttest and fifth-grade Group 1 pretest and posttest, the discrimination number was 0. On the "Extraction of Life" pretest Question 1, fourth-grade Group 1 students had a negative discrimination number, which indicates students who generally performed well overall on the assessment got this question wrong, or students who performed poorly overall got this question correct. The goal of this research is was not to separate the high achieving students from the low achieving students. This negative item discrimination value supported by the high percentage of students correctly answering the pretest question indicate students may have already known this content prior to participation in the FARM Science Lab. Table 4 indicates fourth-grade Group 1 had a pretest mean of 1.0 with 0.00 standard deviation indicating all students (*n* = 10) correctly answered the

question, further indicating students were familiar with this content prior to participation in the intervention. Fifth-grade students in Group 2 (“I don’t know” was added as a multiple-choice item) saw a decrease in discrimination from pretest to posttest. This indicates that Question 1 was easy for most fourth- and fifth-grade students.

Table 5

Question 1: “_______Contains DNA.” Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (*n* = 10)		Group 1 (*n* = 109)		Group 2 (*n* = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	80	100	98	93	83	91
Discrimination index	-0.3	0	0	0	0.33	0.13

Question 2 of the “Extraction of Life” assessment presented students with three different diagrams of scientific objects in a multiple-choice format. All images were the same colors and digitally similar in appearance. The images included an atom (coded as 1), a molecule (coded as 3) and a strand of DNA (coded as 2; Appendix A). Table 6 illustrates fourth-grade students in Group 1 saw a 0.5 difference in mean response from pretest (M = 1.5, SD = 0.53) to posttest (M = 2.0, SD = 0.00), $t(9) = -3.0$, $p < 0.05$ (two-tailed). The mean difference was statistically significant with a 95% confidence interval ranging from -0.88 to -0.12. Cohen’s d (d = -1.34) indicated a large effect size for this small student population (n = 10). The increased mean from pretest to posttest indicated fourth-grade students in Group 1 were changing their response as a result of participating in the FARM Science Lab, with more students selecting the correct response in the

posttest (coded as 2). While fifth-grade Group 1 saw the largest population (*n* = 109), this group did not have a statistically significant difference in means from pretest to posttest (Table 6). Fifth-grade Group 2 students also did not have a statistical difference in the mean response.

Table 6

Descriptive Statistics for Question 2: Which photo shows the structure of DNA?

Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Fourth, group 1[a]	10	1.50	0.53	2.00	0.00	-0.5	-3.00*	-1.34
Fifth, group 1	108	1.95	0.42	2.01	0.1	-0.06	-1.35	-
Fifth, group 2	46	1.89	0.38	2.00	0.21	-0.11	-1.95	-

Note. 2 = correct response.

[a] Only one group of students.

**p* < .05.

Difficulty scores indicated the pretest was moderately difficult for all students whereas the posttest was easy, based on the item difficulty designation index. Both fifth-grade pretests in Table 7 have the minimum indicator of discrimination, greater than 0.02; however, the fourth-grade assessments show no discrimination score. The item discrimination value indicates fifth-grade students who correctly identified the structure of the DNA diagram in the pretest generally scored well on the pretest overall. All group's posttests do not meet the minimum indicator of discrimination. The students' item discrimination combined with the "easy" difficulty designation indicates both high and low performing students answered this question correctly following the intervention of the "Extraction of Life" lesson.

Table 7

Question 2: Which Photo Shows the Structure of DNA? Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (*n* = 10)		Group 1 (*n* = 109)		Group 2 (*n* = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	80	100	84	99	85	91
Discrimination index	0	0	0.23	0	0.33	0.2

Question 3 was a true/false question asking students to evaluate the statement "A plant scientist would need to know DNA's base pairs always have the same partners, A-T and C-G." True was coded as 1 and false was coded as 2. Fourth- and fifth-grade Group 1 did not have statistically significant differences between pretest and posttest (Table 8). For fourth-grade Group 1, the standard deviation of 0 on the posttest indicates all fourth-grade Group 1 students (n = 10) provided the same answer on the posttest. This group's posttest mean (M = 1.0) indicated all students correctly answered this question as true after participating in the "Extraction of Life" lesson. Table 8 indicates the smaller group of fifth-grade students (n = 46), Group 2, had a statistically significant difference in mean of 0.39 from pretest (M = 0.79, SD = 0.66) to posttest (M = 1.09, SD = 0.29), $t(46)$ = -3.89, p < .05 (two-tailed). The 95% confidence interval ranged from -0.59 to -0.19 and the Cohen's d (d = -0.81) indicated a large effect size.

The difficulty index score of 100 (Table 9) indicates this question was easy for fourth-grade students in Group, 1 and the negative item discrimination is in alignment with the difficulty score; further indicating all students correctly answered Question 3.

Table 8

Question 3: A Plant Scientist Would Need to Know DNA's Base Pairs Always Have the Same Partners, A-T and C-G

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Fourth, group 1[a]	10	1.10	0.32	1.0	0.00	0.10	1.00	-
Fifth, group 1	108	1.31	0.47	1.11	0.32	0.20	3.78	-
Fifth, group 2	46	0.79	0.66	1.09	0.29	-0.39	-3.89*	-0.81

Note. 1 = correct response.

[a] Only one group of students.

*p < .05.

Both fifth-grade groups' difficulty index score signifies the true/false statement "A plant scientist would need to know DNA's base pairs always have the same partners, A-T and C-G" was difficult to moderately difficult on the pretest. However, after participating in the FARM Science Lab "Extraction of Life" lesson, these groups' difficulty index score indicates this question became moderately difficult to easy for both fifth-grade groups. Fifth-grade Group 1 has an item discrimination score of 0.26, just over the minimum score of 0.2. Fifth-grade Group 2 also has a high item discrimination score (0.78) on the pretest. Both groups of fifth-grade students have decreased discrimination scores (0.0 and 0.2) on the posttest as anticipated after participating in the intervention of the "Extraction of Life" lesson, indicating more students were correctly responding after the intervention.

"A person who studies wheat genetics is a ______" was the fourth "Extraction of Life" assessment question—a fill-in-the-blank, multiple-choice question. This offered the responses "plant scientist," "account manager," "veterinarian" or "water conservationist" as the multiple-choice options with plant scientist (coded as 1) being the correct response.

Table 9

Question 3: "A Plant Scientist Would Need to Know DNA's Base Pairs Always Have the Same Partners, A-T and C-G Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (n = 10)		Group 1 (n = 109)		Group 2 (n = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	100	100	68	88	47	91
Discrimination index	-0.30	0	0.26	0	0.78	0.20

No group of students had a statistically significant difference in means on this question (Table 10). Each of the three grade level groups saw an increase in score mean from pretest to posttest. The correct answer was coded as 1; therefore, an increase in mean indicates some students were selecting an answer, coded as a higher number, not the correct answer, on the posttest.

Table 10

Question 4: A Person Who Studies Wheat Genetics Is a _________

		Pretest		Posttest				
Grade level group	n	M	SD	M	SD	Mean differences	t	Cohen's d
Fourth, group 1**	10	1.30	0.95	1.40	0.84	-0.10	-0.43	-
Fifth, group 1	108	1.22	0.71	1.27	0.77	-0.05	-0.51	-
Fifth, group 2	46	1.13	0.65	1.35	0.77	-0.22	-1.46	-

Note. 1 = correct response.

[a] Only one group of students.

*p < .05.

Based on the item difficulty index, difficulty scores of 80-100 fall in the moderately difficult to easy categories (Table 11). Each group's increase in difficulty

score value from pretest to posttest indicates more students were selecting the correct response after participating in the FARM Science Lab's "Extraction of Life" lesson. The item discrimination value of 0 for fourth-grade Group 1 pretest and posttest indicates this question is not effective in separating the higher achieving students from the lower achieving students. This could indicate "A person who studies wheat genetics is a _______" was an easy question for this fourth-grade population. Fifth-grade Group 1 and 2 saw a decrease in the item discrimination values from pretest to posttest. This decrease in item discrimination values does indicate students were correctly answering Question 4 following participation in the FARM Science Lab "Extraction of Life" lesson.

Table 11

Question 4: A Person Who Studies Wheat Genetics is a _________. Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (*n* = 10)		Group 1 (*n* = 109)		Group 2 (*n* = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	90	100	89.4	88	85	97
Discrimination index	0	0	0.12	0	0.33	0.1

Question 5 presented students with the statement "Farmers and plant scientists need to know about inherited traits to _____." The multiple-choice options provided included "increase yield" (coded as 1), "select for flower color" (coded as 2), "predict fruit size," (coded as 3), "determine plant height" (coded as 4), and "all of the above" (coded as 5). The correct answer was "all of the above." No groups had a statistically significant difference in mean between the pretest and posttest (Table 12).

Table 12

Question 5: Farmers and Plant Scientists Need to Know About Inherited Traits to _____

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Fourth, group 1[a]	10	2.30	1.42	2.0	1.7	-0.3	-1.96	-
Fifth, group 1	108	4.14	1.42	4.17	1.44	-0.03	-0.18	-
Fifth, group 2	46	3.46	2.1	3.83	1.77	0.37	-1.36	-

Note. 5 = correct response.

[a] Only one group of students.

$*p < .05$.

All three pretest groups of the "Extraction of Life" lesson had scores that indicated a moderately difficult test (Table 13). Although each group of students saw an increase in difficulty in the percent of students answering correctly, from pretest to posttest, all posttest values also fell in the moderately difficult range of the difficulty index (Matlock-Hetzel, 1997). Fourth-grade Group 1 had a value of 0 for both pretest and posttest item difficulty. The two fifth-grade groups saw a significant item discrimination value on the respective pretests indicating this question was a good assessment of student knowledge for those groups. Fifth-grade Group 1 saw less ability to discern the top and bottom segments of students on the posttest with an item discrimination value of 0. Fifth-grade Group 2 item discrimination value did not change from pretest to posttest, remaining within the recommended range for effectively discerning between the top and bottom segments of students. Though the goal of this study was not to find effective item discrimination values, groups with item discrimination within the effective range build confidence in the reliability of the question as a measure of student knowledge.

Table 14 outlines responses to "Extraction of Life" assessment Question 6, a

Table 13

Question 5: Farmers and Plant Scientists Need To Know About Inherited Traits to _________. Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (*n* = 10)		Group 1 (*n* = 109)		Group 2 (*n* = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	70	80	64	68	61	63
Discrimination index	0	0	0.55	0	0.65	0.65

multiple-choice question asking students the location of the genetic information in the cell. Response options included cell wall, cytoplasm, nucleus or chloroplast. The correct response—nucleus—was coded as three. Fourth and fifth-grade students in Group 1 did not have a statistically significant change in mean from pretest to posttest. Fifth-grade Group 2 was the only group with a statistically significant difference in means on Question 6 of the "Extraction of Life" assessment (Table 14). Fifth-grade Group 2 saw an increase in mean from pretest (M = 1.48, SD = 1.38) to posttest (M = 2.15, SD = 1.05), $t(45) = -3.05$, $p < .05$ (two-tailed). The 95% confidence interval ranged from -1.13 to -0.22 and the Cohen's d (d = -0.63) value indicated a large effect size.

Table 14

Question 6: Where is the Genetic Information of the Cell?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Fourth, group 1[a]	10	1.56	0.88	2.00	1.00	-0.44	-1.08	-
Fifth, group 1	108	2.40	0.95	2.29	1.04	0.11	1.04	-
Fifth, group 2	46	1.48	1.38	2.15	1.05	-0.37	-3.05*	-0.63

Note. 3 = correct response.

[a] Only one group of students.

*p < .05.

Question 6 of the “Extraction of Life” assessment proved to be more challenging for all groups of students. With 60% and 64% of fourth and fifth-grade Group 1 students, respectively, correctly answering “Where is the genetic information of the cell?,” this pretest question falls in difficult range of the item difficulty designation index (Table 15). Only 24% of fifth-grade Group 2 correctly answered Question 6, also falling into the difficult range of the item difficulty designation index. This group of students did not find this question easier following participation in the FARM Science Lab’s “Extraction of Life” lesson. With 60%, 48%, and 30% of the fourth and fifth-grade students correctly answering the posttest “Where is the genetic information of the cell?” this question remained designated as difficult. The discrimination value indicated the degree of effectiveness the question has in separating the high achieving students from the lower achieving students on each individual question. Table 15 indicates fourth-grade Group 1 had a discrimination value of 0, which indicated the students guessed, the content had not been thoroughly learned, or the questions was poorly written. Because this is a pretest, it was possible the students had not yet learned any of this content. However, this changes on the posttest with a discrimination value of 0.5, which is higher than the minimum item discrimination of 0.2 (Matlock-Hetzel, 1997). Both Group 1 and Group 2 of fifth-grade students have discrimination values above the 0.2 minimum and, therefore, Question 6 on the pretest and the posttest for these groups is effectively discerning students who know this content from those who do not.

Question 7 presented students with true (coded as 1) and false (coded as 2) options for the statement “The food we eat contains DNA.” As indicated in Table 16,

Table 15

Question 6: Where is the Genetic Information of the Cell? Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (*n* = 10)		Group 1 (*n* = 109)		Group 2 (*n* = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	60	60	64	48	24	30
Discrimination index	0	0.5	0.55	1	0.33	0.33

fourth-grade students (n = 10) in Group 1 did have a decrease in mean score from pretest (M = 1.5) to posttest (M = 1.20); however, this was not a statistically significant difference. Fifth-grade Group 1 is the only group of students to have a statistically significant difference in mean responses for “the food we eat contains DNA” question. These fifth-grade students had a mean difference of 0.31 from pretest (M = 1.52, SD = 0.502) to posttest (M =1.21, SD = 0.411), $t(102) = 6.108$, $p < .05$ (two-tailed) and a 95% confidence interval ranging from 0.19 to 0.39. Cohen’s d (d = 0.83) indicates a large effect size for this group. Fifth-grade Group 2 saw no statistically significant difference in mean from pretest to posttest.

Table 16

Question 7: The Food We Eat Contains DNA

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen’s *d*
Fourth, group 1[a]	10	1.5	0.53	1.20	0.42	0.3	1.96	-
Fifth, group 1	108	1.52	0.50	1.21	0.41	0.31	6.11*	0.83
Fifth, group 2	46	1.22	0.66	1.30	0.466	-0.09	-0.94	-

Note. 1 = correct response.

[a] Only one group of students.

*p < .05.

Discerning responses to "The food we eat contains DNA" was an easy question for fourth-grade Group 1 students (Table 17). Ninety percent of fourth-grade students taking this assessment answered correctly on both the pretest and the posttest. The same is not true for the fifth-grade students. The item difficulty designation index indicates if 21-60% of students answer the question correctly, the question is considered difficult. Therefore, Question 7 was difficult for all fifth-grade students on the pretest. The same index indicates that 70% or 78% of students answering correctly would indicate this question is moderately difficult for students (Matlock-Hetzel, 1997). Based on the item difficulty designation index, "the food we eat contains DNA" true or false statement did become less difficult for students after participating in the FARM Science Lab "Extraction of Life" lesson (Table 17).

Table 17

Question 7: The Food We Eat Contains DNA. Difficulty and Item Discrimination

	Fourth grade		Fifth grade			
	Group 1 (*n* = 10)		Group 1 (*n* = 109)		Group 2 (*n* = 46)	
Question analysis	Pre	Post	Pre	Post	Pre	Post
Difficulty index	90	90	50	78	52	70
Discrimination index	-0.3	-0.25	0.55	0	0.26	0.52

The discrimination value indicates how effectively one question separates high performing students from low performing students (Matlock-Hetzel, 1997). Though this separation was not the goal of this research, evaluating the discrimination value provides additional confidence in the questions as a measure of student knowledge. Fourth-grade

Group 1 students had negative discrimination values on both the pretest (-0.3) and the posttest (-0.25). The high percentage of fourth-grade students correctly answering this question (90%), the discrimination and difficulty index would suggest all students performed well on this assessment question (Table 17). Fifth-grade students in Group 2 and Group 1 pretest have discrimination values above 0.2; therefore, Question 7, "The food we eat contains DNA," is effective at discerning higher preforming students from lower performing students on the "Extraction of Life" assessment (Matlock-Hetzel, 1997). Fifth-grade Group 1 posttest has a discrimination value of 0, indicating for this grade level group, Question 7 was not effective at separating the low and high performing students on the "Extraction of Life" assessment.

Field Plastic

From February through June 2018, 615 students in third through fifth grades participated in the "Field Plastic" lesson (Appendix B). The breakdown of each grade level was as follows: 61 third-grade students, 302 fourth-grade students, and 252 fifth-grade. Of those students, 24% completed both the pretest and posttest: 45 third-grade students (74%), 55 fourth-grade students (18%), and 45 fifth-grade students (18%). The pretest and posttest included the same five questions. After March 26, 2018, "I don't know" was added as an option to all pretest multiple choice answers. In addition, one question was added to each the pretest and the posttest asking students to rate their excitement about and experience in the FARM Science Lab. All responses after March 26 are named Group 2. Mean scores in Table 18 are out of five points as the excitement and experience rating questions were not included in the test score as no wrong or right

answer was appropriate.

Third-grade students participated in the “Field Plastic” lesson prior to March 26, 2018; therefore, there is only one group of this grade level. These third-grade students were at two different schools visited by the FARM Science Lab. The third-grade population (*n* = 45) saw a nearly 1-point increase in mean from pretest to posttest. To compare these means a paired-sample *t* test was conducted with alpha set at .05 (Table 18). There was a statistically significant difference in mean from pretest (*M* = 1.31, *SD* = 0.87) to posttest (*M* = 2.27, *SD* = 1.03), $t(45) = 5.59$, $p < .05$ (two-tailed). The mean increase was 0.96 with a 95% confidence interval ranging from -1.33 to -0.61. The Cohen’s *d* (*d* = 1.18) indicated a large effect size. Fourth-grade students (*n* = 53) who participated in this lesson and completed both the pretest and the posttest did so after March 26, 2018; therefore, only fourth-grade Group 2 is included. Table 18 shows the fourth-grade students also had a statistically significant difference in means from pretest (*M* = 1.83, *SD* = 1.189) to posttest (*M* = 4.00, *SD* = 1.07), $t(53) = 10.09$, $p < .05$ (two-tailed). The mean increased by 2.17 points with a 95% confidence interval ranging from -2.60 to -1.74 and the Cohen’s *d* (*d* = 1.96) indicated a large effect size. Fifth-grade students participated in the “Field Plastic” lesson at the beginning and end of the timeframe of this study; therefore, there are two groups. Fifth-grade Group 1 students saw a statistically significant increase in mean from pretest (*M* = 1.28, *SD* = 0.96) to posttest (*M* = 4.39, *SD* = 0.7), $t(18) = 14.66$, $p < .05$ (two-tailed). The mean increase was 3.11 with a 95% confidence interval ranging from -3.59 to -2.66. The Cohen’s *d* (*d* = 4.89) indicated a large effect size. Fifth-grade Group 2 also saw a statistically significant

different in mean from pretest (*M* = 1.59, *SD* = 1.05) to posttest (*M* = 3.52, *SD* = 1.12), $t(27) = -7.54$, $p < .05$ (two-tailed). The mean increase was 1.93 with a 95% confidence interval ranging from - 2.45 to 1.40 with the Cohen's *d* (*d* = 2.05) indicating a large effect size.

Table 18

"Field Plastic" Pretest and Posttest Differences

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	45	1.31	0.87	2.27	1.03	-0.96	-5.59*	1.18
Fourth, Group 2[a]	53	1.83	1.19	4.00	1.07	-2.17	-10.9*	1.96
Fifth, Group 1	18	1.28	0.96	4.39	0.7	-3.11	-14.66*	4.89
Fifth, Group 2	27	1.5	1.05	3.52	1.12	1.3	-7.54*	2.05

Note. 5 = perfect score.

[a] Only one group of students.

*$p < .05$.

"Field Plastic" assessment Question 1 asked students "Which resource is renewable?" This multiple-choice question offered "coal" (coded as 1), "Corn" (coded as 2), "natural gas" (coded as 3), and "groundwater" (coded as 4) as possible answers. After March 26, 2018, "I don't know" (coded as 0) was added as a fifth option to the pretest only. As shown in Table 19, third-grade Group 1, fourth-grade Group 2 and fifth-grade Group 2 did not have a statistically significant difference in means. Fifth-grade Group 1 had a statistically significant difference in means. Fifth-grade Group 1 saw a 1.06 change in mean from pretest (*M* = 3.00, *SD* = 1.14) to posttest (*M* = 1.94, *SD* = 0.24), $t(18) = 3.7$, $p < .05$ (two-tailed). The difference in means had a 95% confidence interval ranging from 0.45 to 1.66 and the Cohen's *d* (*d* = 1.23) indicated a large effect size.

Table 19

Descriptive Statistics for Question 1: Which Resource Is Renewable?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1**	45	2.71	1.16	2.38	0.83	0.33	1.98	-
Fourth, Group 2**	53	2.21	1.46	2.02	0.24	0.19	0.93	-
Fifth, Group 1	18	3.0	1.14	1.94	0.24	1.06	3.7*	1.232
Fifth, Group 2	27	2.33	1.21	2.19	0.74	0.15	0.63	-

Note. 2 = correct answer.

[a] Only one group of students.

*$p < .05$.

A difficulty index calculation measured the percent of students (n) who correctly answered Question 1 of the "Field Plastic" lesson. Item discrimination value was calculated to determine the degree to which students who scored highly on the "Field Plastic" assessment also correctly answered this question. Table 20 outlines the difficulty index and item discrimination for the question "Which resource is renewable?" on the pretest and posttest. A range of 21-60% of students within a sample, correctly answering a question, indicated the question is to be considered difficult. The difficulty index value for all four groups of students indicate "Field Plastic" Question 1, "Which resource is renewable?" was difficult or very difficult on the pretest. Third-grade Group 1 saw an increase in the percent of students correctly answering this Question 1 on the posttest. This increased percent (64%) of students answering correctly moved Question 1 into the moderately difficult range of the item difficulty index. Fourth-grade Group 2 also saw improvement in percent of students answering correctly (94%), therefore rating posttest Question 1 as easy for these students (Table 20). Fifth-grade Group 1 also moved into the

easy range with a posttest item difficulty value of 94%. However, fifth-grade Group 2 moved from the difficult range on the pretest to the moderately difficult range on the posttest. It is recommended that the item discrimination value be 0.2 or higher for a question to be considered effectively separating the top range and the bottom range of students. All groups of students' item discrimination values meet or exceed this minimum value with the exception of the fifth-grade group 1 pretest. For the purpose of this study, the item discrimination values were building confidence in the reliability of the questions. The fifth-grade Group 1 pretest had a discrimination value of 0.16 (Table 20). This low item discrimination value combined with the high difficulty value (6%) indicate most fifth-grade Group 1 students incorrectly answered, "Which resource is renewable?" on the pretest. However, posttest difficulty and item discrimination values for fifth-grade Group 1 indicate students improved their scores after participation in the FARM Science Lab "Field Plastic" lesson.

Table 20

Question 1: Which Resource is Renewable? Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 45)		Group 2 (*n* = 53)		Group 1 (*n* = 18)		Group 2 (*n* = 27)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	31	64	28	94	6	94	48	78
Discrimination index	0.4	0.2	0.33	0.28	0.16	0.33	0.33	0.44

Question 2 challenged students to identify a product that could be used to create biodegradable packing materials (Table 21). Multiple-choice options included: "corn" (coded as 1), "oil" (coded as 2), "wood" (coded as 3), or "water" (coded as 4). All student

groups saw mean scores move closer to one—the correct response—from pretest to posttest; however, this difference in means was not significant for all groups. Third-grade Group 1 did have a statistically significant difference in mean from pretest (M = 2.52, SD = 0.93) to posttest (M = 1.64, SD = 0.97), $t(45) = 3.93$, $p < .05$ (two-tailed). The difference in means was 0.89 with a 95% confidence interval ranging from 0.43 to 1.34 and the Cohen's d (d = 0.83) indicated a large effect size. Fourth-grade Group 2 did see a statistically significant change in mean from pretest (M = 1.53, SD = 1.27) to posttest (M = 1.15, SD = 0.60), $t(52) = 2.08$, $p < .05$ (two-tailed). This 0.38 difference in means had a 95% confidence interval of 0.01 to 0.74, and the Cohen's d (d = 0.41) indicated a small effect size. Table 21 shows fifth-grade Group 1 had a statistically significant difference in means whereas fifth-grade Group 2 did not. Fifth-grade Group 1 saw a decrease in mean from pretest (M = 2.67, SD = 0.84) to posttest (M = 1.0, SD = 0.00), $t(18) = 8.42$, $p < .05$ (two-tailed). This statistically significant mean difference of 1.67 had a 95% confidence interval ranging from 1.25 to 2.08, and the Cohen's d (d = 2.19) value indicated a large effect size.

Table 21

Descriptive Statistics for Question 2: Which Product Could be used to Create Biodegradable Packing Material?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	45	2.52	0.95	1.64	0.97	0.89	3.93*	0.83
Fourth, Group 2[a]	53	1.53	1.27	1.15	0.60	0.38	2.08*	0.41
Fifth, Group 1	18	2.67	0.84	1.00	0.00	1.67	8.42*	2.19
Fifth, Group 2	27	1.44	1.48	1.00	0.00	0.44	1.56	-

Note. 1 = correct answer.

[a] Only one group of students.

*$p < .05$.

Based on the item difficulty designation index, the “Field Plastic” pretest question—“Which product could be used to create biodegradable packing material?”—was very difficult for third-grade Group 1 students as only 18% of these students (*n* = 45) correctly answered this question (Table 22). However, improvement was made on the posttest with 60% of third-grade students correctly answering Question 2, therefore, on the posttest the question was ranked as difficult. For fourth and fifth-grade students “Which product could be used to create biodegradable packing material?” was very or moderately difficult on the pretest but considered easy on the posttest based on the item difficulty designation index (Matlock-Hetzel, 1997).

Question 2 effectively separated the top and bottom scoring students in third and fourth grades as each of the pretest and posttest item discrimination values were 0.2 or higher. Item discrimination values were not higher than the minimum on the fifth grade Group 1 pretest. However, Table 22 indicates fifth-grade Group 2 pretest did meet the minimum item discrimination value. Whereas, the posttest item discrimination values were lower than 0.2; therefore, both high- and low-achieving students had answered this question similarly. This low item discrimination combined with the high percent of correct answers (difficulty) indicates most students were correctly answering “What product could be used to create biodegradable packing material?” after participating in the FARM Science Lab “Field Plastic” lesson.

Question 3 of the FARM Science Lab “Field Plastic” assessment asked students “What would you use to determine the physical properties of an object?” The multiple-choice question offered five options including: “sight” (coded as 1), “touch” (coded as 2),

Table 22

Question 2: Which Product Could be Used to Create Biodegradable Packing Material? Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 45)		Group 2 (*n* = 53)		Group 1 (*n* = 18)		Group 2 (*n* = 27)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	18	60	28	94	0	100	26	100
Discrimination index	0.27	0.67	0.47	0.23	0	0.17	0.22	0

“scale” (coded as 3), “ruler” (coded as 4), and “all of the above” (coded as 5). No group of students saw a statistically significant difference in mean response from pretest to posttest (Table 23).

Table 23

Descriptive Statistics for Question 3: What Would You Use to Determine the Physical Properties of an Object?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen’s *d*
Third, Group 1[a]	45	2.89	1.2	2.96	1.73	-0.07	-0.29	-
Fourth, Group 2[a]	53	3.68	1.75	3.94	1.5	-0.26	-0.99	-
Fifth, Group 1	18	3.78	1.63	4.78	0.94	-1.00	-2.09	-
Fifth, Group 2	27	2.96	1.97	3.63	1.6	-0.67	-1.72	-

Note. 5 = correct answer.

[a] Only one group of students.

*p < .05.

Table 24 shows each group of students saw an increase in percent of students correctly answering Question 3 from pretest to posttest. This indicates students found

"What would you use to determine the physical properties of an object?" less difficult as a result of the FARM Science Lab "Field Plastic" lesson. Fourth-grade Group 1 saw the largest increase in percent of students correctly answering from pretest to posttest. The difficulty value for third-grade Group 1, fourth-grade Group 2 and fifth-grade Group 2 all fell within the difficult range for their pretests. However, third-grade Group 1 students did not see enough improvement in percent correct on the posttest to change this question's item difficulty designation for that group, whereas, fourth-grade Group 1 and fifth-grade Group 2 moved from difficult to moderately difficult on the posttest. Fifth-grade Group 1 moved from very difficult to easy on the posttest.

Item discrimination indicates the effectiveness of a question at delineating the high scoring students from the lower scoring students, overall. Thus, providing confidence in the reliability of the question as a measure of knowledge. Most groups item discrimination value indicates Question 3 is effective at separating the top and bottom scoring students, some groups have more discrimination than others. For fifth-grade Group 1, Question 3, "What would you use to determine the physical properties of an

Table 24

Question 3: What Would You Use to Determine the Physical Properties of an Object? Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 45)		Group 2 (*n* = 53)		Group 1 (*n* = 18)		Group 2 (*n* = 27)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	27	38	56	68	13	94	41	56
Discrimination index	0.4	0.53	0.47	0.74	0.16	0.33	0.67	0.67

object?" on the pretest is not effective at deciphering high and low scoring students. While the Question 3, fifth-grade Group 1 posttest discrimination value does fall into the acceptable range to delineate groups, it is on the very low end of acceptable values. The remaining groups have acceptable pretest and posttest discrimination values.

Table 25 illustrates the four groups' responses to Question 4—"A biodegradable product will breakdown quicker in a landfill." The correct answer was true (coded as 1) and the second option was false (coded as 2). All Group 2 students were presented with a third option on the pretest only—"I don't know" (coded as 0)—which was added after March 26, 2018. Fifth-grade Group 2 was the only group to have a statistically significant difference in mean response from pretest (M = 0.70, SD = 0.72) to posttest (M = 1.22, SD = 0.42), $t(27) = 3.17$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from -0.85 to -0.18 and a Cohen's d (d = 0.86) indicating a large effect size. The less than one pretest mean response (0.70) indicated students were selecting "I don't know" (coded as 0) as a pretest response. Similarly, fourth-grade Group 2 saw a pretest mean of 1.0 yet had a standard deviation of 0.71, indicating some students were selecting "I don't know" (coded as 0) causing variation in responses. Because of this pretest response coded as 0, fourth-grade Group 2 saw an increase in mean from pretest to posttest; however, this was not a statistically significant difference. Group 1 students saw decreases in mean response from pretest to posttest, although these differences were not statistically significant. This indicates more students were selecting "true" (coded as 1) on the posttest than on the pretest meaning students were correctly answering Question 4 as a result of participating in the FARM Science Lab "Field Plastic" lesson.

Table 25

Descriptive Statistics for Question 4: A Biodegradable Product Will Breakdown Quicker In a Landfill

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	45	1.43	0.50	1.36	0.49	-0.07	0.83	-
Fourth, Group 2[a]	53	1.00	0.71	1.11	0.32	-0.11	-1.0	-
Fifth, Group 1	18	1.44	0.51	1.22	0.43	-0.22	1.72	-
Fifth, Group 2	27	0.70	0.72	1.22	0.42	-0.52	-3.17*	0.86

Note. 1 = correct answer.

[a] Only one group of students.

*$p < .05$.

The item difficulty value indicates the percent of students who correctly answered the question. For the pretest of all groups, Table 26 indicates Question 4, “A biodegradable product will breakdown quicker in a landfill,” landed in the difficult range. Whereas, on the posttest, the same question fell in the moderately difficult range. It is anticipated a question become less difficult after participation in the intervention; the FARM Science Lab “Field Plastic” lesson. For Question 4, all pretest and posttest groups met or exceeded the minimum item discrimination value with the exception of fifth-grade Group 1 pretest (Table 26).

The final question (Question 5) of the “Field Plastic” lesson assessment asked students to fill in a blank: “An agricultural scientist might investigate corn as an ingredient for_____.” Four multiple-choice options were given: “pop” (coded as 1), “plastic bags” (coded as 2), “fuel” (coded as 3), and “all of the above” (coded as 4). Table 27 explains students in Group 1 did not have a statistically significant difference in mean response. Both fourth-grade Group 2 and fifth-grade Group 2 did have statistically

Table 26

Question 4: A Biodegradable Product Will Breakdown Quicker In a Landfill. Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (n = 45)		Group 2 (n = 53)		Group 1 (n = 18)		Group 2 (n = 27)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	56	64	45	88	50	78	41	78
Discrimination index	0.73	0.73	0.61	0.46	0.06	0.83	0.78	0.56

significant differences in mean responses from pretest to posttest. Fourth-grade Group 2 saw a 1.0 difference in mean from pretest (M = 2.47, SD = 1.64) to posttest (M = 3.74, SD = 1.55), $t(53) = 3.24$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from -1.62 to -0.38. The Cohen's d (d = 0.63) indicated a medium effect size. Fifth-grade Group 2 had a difference in mean response of 0.96 from pretest (M = 2.19, SD = 1.76) to posttest (M = 3.15, SD = 1.63), $t(27) = 2.54$, $p < .05$ (two-tailed) with a 95% confidence interval of -1.74 to -0.18. The Cohen's d (d = 0.69) also indicated a medium effect size.

Table 27

Descriptive Statistics for Question 5: An Agricultural Scientist Might Investigate Corn as an Ingredient for______

		Pretest		Posttest				
Grade level group	n	M	SD	M	SD	Mean differences	t	Cohen's d
Third, Group 1[a]	45	2.36	1.54	3.02	1.53	-0.33	-1.08	-
Fourth, Group 2[a]	53	2.47	1.64	3.74	1.55	-1.0	-3.24*	0.63
Fifth, Group 1	18	3.61	1.24	3.89	1.84	-0.28	-0.59	-
Fifth, Group 2	27	2.19	1.76	3.15	1.63	-0.96	-2.54*	0.69

Note. 4 = correct answer.

[a] Only one group of students.

*$p < .05$.

For the “Field Plastic” lesson, Table 28 illustrates the pretest Question 5 was considered very difficult or difficult for third-, fourth- and fifth-grade students. Third-grade students did not see much change in percentage of students who correctly answered Question 5 from pretest to posttest meaning this question remained difficult for this group. However, many more fourth-grade students correctly answered, “An agricultural scientist might investigate corn as an ingredient for ____” on the posttest meaning this question became slightly less difficult after participation in the “Field Plastic” lesson. Fifth-grade students also saw a similar decrease in difficulty range from pretest to posttest, with an increase in percent of students correctly answering Question 5 (Table 28).

“Field Plastic” Question 5 (“An agricultural scientist might investigate corn as an ingredient for ______”) was effective at discerning these high and low scoring students for both third- and fourth-grade groups on the pretest and the posttest. However, Question 5 was not effective for discerning these groups on the pretest for either fifth-grade group. The fifth-grade groups saw an increase in item discrimination values on the posttest.

Table 28

Question 5: An Agricultural Scientist Might Investigate Corn as an Ingredient for______. Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 45)		Group 2 (*n* = 53)		Group 1 (*n* = 18)		Group 2 (*n* = 27)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	24	33	18	54	38	72	19	41
Discrimination index	0.27	0.53	0.38	0.92	0.05	0.33	0	0.78

For the “Field Plastic” lesson, Table 28 illustrates the pretest Question 5 was considered very difficult or difficult for third, fourth and fifth-grade students. Third-grade students did not see much change in percentage of students who correctly answered Question 5 from pretest to posttest meaning this question remained difficult for this group. However, many more fourth-grade students correctly answered, “An agricultural scientist might investigate corn as an ingredient for ______” on the posttest, meaning this question became slightly less difficult after participation in the “Field Plastic” lesson. Fifth-grade students also saw a similar decrease in difficulty range from pretest to posttest, with an increase in percent of students correctly answering Question 5 (Table 28).

“Field Plastic” Question 5 (“An agricultural scientist might investigate corn as an ingredient for _________”) was effective at discerning these high and low scoring students for both third and fourth-grade groups on the pretest and the posttest. However, Question 5 was not effective for discerning these groups on the pretest for either fifth-grade group. The fifth-grade groups saw an increase in item discrimination values on the posttest.

Parts Per What

During the duration of this study, 1,116 students in third through fifth-grade participated in the FARM Science Lab “Parts Per What” lesson (Appendix C): 356 third-grade students, 530 fourth-grade, and 230 fifth-grade students. Of those students, 412 completed both the pretest and posttest; 149 (42%) third-grade students, 133 (25%) fourth-grade students, and 130 (57%) fifth-grade students. The “Parts Per What”

assessment included five questions and all grade levels received the same questions on both the pretest and the posttest. After March 26, 2018, “I don’t know” was added as a response option to all pretest questions. In addition, one question was added to each the pretest and the posttest asking students to rate their excitement about and experience in the FARM Science Lab. All responses after March 26 are named Group 2. Mean scores in the tables below are out of 5 points as the excitement and experience-based questions were not included in the test score as no wrong or right answer was appropriate.

Third- and fourth-grade students participated in the “Parts Per What” lesson after March 26, 2018; therefore, only Group 2 data is displayed in Table 29 for these grades. To evaluate the *t*-test values, a priori $\alpha = .05$ was used. Both groups saw statistically significant increases in mean score from pretest to posttest. The third-grade Group 2 students saw a 2.43 increase in mean score from pretest ($M = 1.61$, $SD = 1.34$) to posttest ($M = 4.05$, $SD = 1.05$), $t(150) = 20.18$, $p < .05$ (two-tailed) with a 95% confidence interval of -2.67 to -2.2 and the Cohen’s *d* value ($d = 2.33$) indicating a large effect size. Fourth-grade Group 2 students saw an increase in mean from pretest ($M = 2.73$, $SD = 1.29$) to posttest ($M = 4.26$, $SD = 0.95$), $t(129) = 11.67$. $p < .05$ (two-tailed) with a 95% confidence interval ranging from -1.79 to -2.71 and the Cohen’s *d* ($d = 1.45$) indicating a large effect size. Fifth-grade students participated in the “Parts Per What” lesson both before and after March 26, 2018 providing data for Group 1 and Group 2. The fifth-grade Group 1 population is made up of students from two schools. One school, accounting for 102 of the 130 responses, took the assessment in paper copy due to technical difficulties with Google Forms. These were printed copies of the Google Forms assessment

questions. The completed assessment responses were entered into Google Forms so that the data could be analyzed along with all other assessment data. Neither fifth-grade group saw statistically significant differences in mean responses between pretest and posttest.

Table 29

"Parts Per What" Pretest Posttest Differences

Grade level group	*n*	Pretest *M*	Pretest *SD*	Posttest *M*	Posttest *SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	150	1.61	1.13	4.05	1.05	-2.43	-20.18	2.33
Fourth, Group 2[a]	130	2.73	1.29	4.26	0.95	-1.53	-11.67*	1.45
Fifth, Group 1	120	3.31	1.08	3.48	1.08	-0.17	-1.51	-
Fifth, Group 2	13	3.46	1.56	3.54	1.61	-0.08	-0.13	-

Note. 5 = perfect score.

[a] Only one group of students.

*p < .05.

Question 1 of the "Parts Per What" assessment asked students to evaluate the statement "Precipitation can cause contaminants to enter the water supply." Multiple choice responses included "true" (coded as 1), "false" (coded as 2), and after March 26, 2018, "I don't know" (coded as 0). Table 30 illustrates third and fourth-grade Group 2 had statistically significant changes in mean response from pretest to posttest. Third-grade Group 2 had a 0.41 increase in mean from pretest (*M* = 0.65, *SD* = 0.74) to posttest (*M* = 1.07, *SD* = 0.25), *t*(150) = 6.57, *p* < .05 (two-tailed) with a 95% confidence interval of -0.54 to -0.29. Cohen's *d* (*d* = 0.76) indicated a large effect size. Fourth-grade Group 2 also saw an increase in mean but with only a small effect size based on Cohen's *d* (*d* = 0.12). There was a 0.38 increase in mean from pretest (*M* = 0.75, *SD* = 0.62) to posttest (*M* = 1.13, *SD* = 0.40), *t*(129) = 5.81, *p* < .05 (two-tailed) with a 95% confidence interval

of -0.51 to -0.25. Neither fifth-grade group saw a statistically significant different in mean response to Question 1.

Table 30

Descriptive Statistics for Question 1: Precipitation Can Cause Contaminants to Enter the Water Supply

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 2[a]	150	0.65	0.74	1.07	0.25	-0.41	-6.57*	0.76
Fourth, Group 2[a]	130	0.75	0.62	1.13	0.40	-0.38	-5.81*	0.12
Fifth, Group 1	120	1.37	0.49	1.28	0.45	0.09	1.83	-
Fifth, Group 2	13	0.85	0.38	1.00	0.00	-0.15	-1.48	-

Note. 1 = correct response.

[a] Only one group of students.

*$p < .05$

For third- and fourth-grade Group 2 pretest Question 1 all fell into the difficult range whereas, for fifth-grade students, Question 1 was considered moderately difficult on the pretest (Table 31). After participation in the "Parts Per What" lesson, third-grade Group 2 students found Question 1—"Precipitation can cause contaminants to enter the water supply"—easy and fourth-grade Group 2 and fifth-grade Group 1 found the question moderately difficult. Fifth-grade Group 2 unexpectedly found "Parts Per What" Question 1 to be more difficult on the posttest than on the pretest.

Question 2 ("Michigan's Great Lakes play an important role in agriculture") required a true/false response. "True" was coded as one, "False" as two, and after March 26, 2018, "I don't know" was added as 0. Third- and fourth-grade students saw statistically significant changes in mean response from pretest to posttest (Table 32).

Table 31

Question 1: Precipitation Can Cause Contaminants to Enter the Water Supply. Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 150)		Group 2 (*n* = 130)		Group 1 (*n* = 120)		Group 2 (*n* = 13)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	33	93	55	83	64	73	84	69
Discrimination index	0.52	0.16	0.59	0.43	0.68	0.43	0.23	0.46

Third-grade Group 2 had a 0.33 difference in mean from pretest (*M* = 0.81, *SD* = 0.6) to posttest (*M* = 1.15, *SD* = 0.36), *t*(149) = 6.57, $p < .05$ (two-tailed) with a 95% confidence interval of 0.45 to 0.22 and the Cohen's *d* (*d* = 0.76) indicating a large effect size. Fourth-grade Group 2 saw less variation in mean response but still statistically significant difference from pretest (*M* = 0.89, *SD* = 0.45) to posttest (*M* = 1.06, *SD* = 0.24), *t*(130) = 3.74, $p < .05$ (two-tailed) with a 95% confidence interval of 0.26 to 0.08 and Cohen's *d* (*d* = 0.46) indicating a medium effect size. Both third- and fourth-grade Group 2 students had the "I don't know" option available on the pretest. This response was coded as 0; therefore, these groups logically have means less than one on the pretest in Table 32. This less than one value indicates some students were selecting "I don't know" when provided the option. However, after participation in the FARM Science Lab's lesson, "I don't know" was removed from the posttest multiple-choice options, therefore requiring students to select only either "true" or "false." Fifth-grade Group 1 did not have a statistically significant difference in mean response from pretest. Fifth-grade Group 2 students (*n* = 13) all correctly answered Question 2 on the pretest and posttest, there for

there is no deviation in means to further calculate a *t* value. This population is made up of students in one class at one school thus limiting the diversity of the population.

Table 32

Descriptive Statistics for Question 2: Michigan's Great Lakes Play an Important Role in Agriculture

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	150	0.81	0.6	1.15	0.36	-0.33	-6.57*	0.76
Fourth, Group 2[a]	130	0.89	0.45	1.06	0.24	-0.17	-3.74*	0.46
Fifth, Group 1	120	1.08	0.26	1.11	0.31	-0.03	-1.0	-
Fifth, Group 2	13	1.00	0.00	1.00	0.00	-	-	-

Note. 1 = correct response.

[a] Only one group of students.

**p* < .05.

For third-grade, fourth-grade and fifth-grade Group 1 students, Question 2 ("Michigan's Great Lakes play an important role in agriculture") was moderately difficult on the pretest. It is anticipated the questions would become easier after participation in the FARM Science Lab's "Parts Per What" lesson. This was the case for each of these groups. Table 33 indicates third-grade Group 2 and fifth-grade Group 1 did have an increase in percent of students correctly answering on the posttest; however, these groups remained in the moderately difficult range. Whereas, fourth-grade Group 2 moved into the easy range on the posttest. As shown in Table 33, all fifth-grade Group 2 students correctly answered both the pretest and the posttest question; therefore, this question was considered easy for this group.

The minimum value for effective item discrimination is 0.2. Third-grade, fourth-grade and fifth-grade Group 1 meet or exceed this value on the pretest. Because all

students are learning the same content at the same time in the FARM Science Lab then tested on this material, it is anticipated the posttest would have a lower item discrimination than the pretest within the same group of students. This is true for the third- and fourth-grade posttests (Table 33). This is not true for the two fifth-grade groups. Fifth-grade Group 1 has very similar difficulty and item discrimination values; therefore, there is almost no change between the group's responses on the pretest and posttest to Question 2 ("Michigan's Great Lakes play an important role in agriculture"). Fifth-grade Group 2 students all correctly answered this question on the pretest and posttest; therefore, the item discrimination value is negative and the same for the pretest and the posttest.

Table 33

Question 2: Michigan's Great Lakes Play an Important Role in Agriculture. Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 150)		Group 2 (*n* = 130)		Group 1 (*n* = 120)		Group 2 (*n* = 13)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	61	85	79	94	90	89	100	100
Discrimination index	0.58	0.28	0.36	0.16	0.2	0.23	-0.23	-0.23

Question 3 presented a multiple-choice question to all students asking, "A hydrologist would need to measure which fraction to measure a part per million of contamination" and provided the following multiple-choice responses: "1/1,000" (coded as 1), "1/10,000" (coded as 2), "1/1,000,000" (coded as 3), "1/10,000,000" (coded as 4) and after March 26, 2018, "I don't know"(coded as 0) was added to the pretest. Three of

the four student groups saw statistically significant differences in mean response from pretest to posttest on Question 3. Table 34 illustrates the largest population, third- grade Group 2 (*n* = 150), had a 1.79 difference in mean from pretest (*M* = 0.91, *SD* = 1.37) to posttest (*M* = 2.71, *SD* = 0.77), *t*(149) = 14.08, *p* < .05 (two-tailed) with a 95% confidence interval of -2.05 to -1.54 and the Cohen's *d* (*d* = 1.63) value indicating a large effect size. Fourth-grade Group 2 had a 1.23 difference in mean from pretest (*M* = 1.72, *SD* = 1.52) to posttest (*M* = 2.95, *SD* = 0.52), *t*(129) = 9.1, *p* < .05 (two-tailed) with a 95% confidence interval ranging from -1.5 to -0.1 and the Cohen's *d* (*d* = 1.13) indicating a large effect size (Table 34). Fifth-grade Group 2 also saw a statistically significant difference in mean (1.36) from pretest (*M* = 1.38, *SD* = 1.56) to posttest (*M* = 2.77, *SD* = .93), *t*(13) = 3.96, *p* < .05 (two-tailed) with a 95% confidence interval from -2.15 to -0.62 with the Cohen's *d* (*d* = 1.55) value indicating a large effect size. Fifth-grade Group 1 was the only group to not have a statistically significant difference in mean responses on Question 3.

Table 34

Descriptive Statistics for Question 3: A Hydrologist Would Need to Measure Which Fraction to Measure a Part Per Million of Contamination?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	150	0.91	1.37	2.71	0.77	-1.79	-14.08*	1.63
Fourth, Group 2[a]	130	1.72	1.52	2.95	0.52	-1.23	-9.1*	1.13
Fifth, Group 1	120	2.68	0.83	2.81	0.94	-0.13	-1.24	-
Fifth, Group 2	13	1.38	1.56	2.77	0.93	-1.36	-3.96*	1.55

Note. 3 = correct response.

[a] Only one group of students.

**p* < .05.

The item difficulty designation considers a question very difficult if 0-20% of students in a given population answer the question correctly. It is expected a pretest question would be categorized as more difficult for a group of students than a posttest question following participation in the FARM Science Lab's lesson. As indicated in Table 35, "A hydrologist would need to measure which fraction to measure a part per million of contamination," would be considered very difficult for third-grade Group 2 (17%). The categorization of this question only improves to "moderately difficult" on the posttest for these third-grade students (72%). Question 3 was considered difficult for fourth-grade Group 2 (43%) and fifth-grade Group 2 (46%) on the pretest then improved to moderately difficult on the posttest. The difficulty of Question 3 moved in the opposite of anticipated direction for fifth-grade Group 1 (Table 35). Sixty-two percent of fifth-grade Group 1 students correctly answered the pretest Question 3 whereas only 58% of these students correctly answered the posttest Question 3.

Item discrimination should decrease after participation in an intervention such as the FARM Science Lab lessons because all students are receiving the same information then being given the same posttest assessment. All pretest groups in Table 35 meet the minimum item discrimination value of 0.2 for Question 3 and are, therefore, effective at delineating between the top and bottom scoring students indicating this. All groups except third-grade Group 2 show a decrease in discrimination from pretest to posttest, as expected. Third-grade Group 2 shows more delineation between the overall high and low scoring students on the posttest than on the pretest for the question "a hydrologist would need to measure which fraction to measure a part per million of contamination."

Table 35

Question 3: A Hydrologist Would Need to Measure Which Fraction to Measure a Part per Million of Contamination? Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 150)		Group 2 (*n* = 130)		Group 1 (*n* = 120)		Group 2 (*n* = 13)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	17	72	43	86	62	58	46	62
Discrimination index	0.34	0.62	0.48	0.32	0.63	0.58	0.92	0.69

This multiple-choice question asked students “Farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms?” Five response options included: “Drip Irrigation” (coded as 1), “Plant filter strips” (coded as 2), “Use a computer to measure soil moisture levels” (coded as 3), “Apply fertilizer in specific measured amounts, at specific times during the growing season” (coded as 4), “All of the above” (coded as 5), and after March 26, 2018, a sixth option was added, “I don’t know” (coded as 0). As with Question 3, Group 2 of each grade level had a statistically significant difference in mean response from pretest to posttest (Table 36). Third-grade Group 2 had a 2.39 difference in mean response from pretest (M = 1.93, SD = 2.07) to posttest (M = 4.32, SD = 1.29), $t(149) = 12.61$, $p < .05$ (two-tailed) with a 95% confidence interval of -2.77 to 2.02 with a Cohen’s d (d = 1.46) indicating a large effect size. Table 36 illustrates fourth-grade Group 2 saw a slightly less difference in mean response for the question “farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms,” yet still statistically significant from pretest (M = 3.21, SD = 3.16) to posttest (M = 4.59, SD = 1.03), $t(129) = 6.94$, $p < .05$

(two-tailed) with a 95% confidence interval ranging from -1.78 to -0.99 with a Cohen's *d* (*d* = 0.86) indicating a large effect size. The smallest population, fifth-grade Group 2 (*n* = 13), saw a 1.54 difference in mean response from pretest (*M* = 3.15, *SD* = 2.44) to posttest (*M* = 4.69, *SD* = 0.48), $t(13) = 2.31$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from -2.99 to -0.87 and a Cohen's *d* (*d* = 0.91) indicating a large effect size. The only group without a statistically significant difference in mean response was fifth-grade Group 1.

Table 36

Descriptive Statistics for Question 4: Farmers Could Use Which of the Following Tool(s) to Conserve and Prevent Water Contamination on Their Farms?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	150	1.93	2.09	4.32	1.29	-2.39	-12.61*	1.46
Fourth, Group 2[a]	130	3.21	3.16	4.59	1.03	-1.39	-6.94*	0.86
Fifth, Group 1	120	3.33	1.72	3.64	1.67	-0.31	-1.80	-
Fifth, Group 2	13	3.15	2.44	4.69	0.48	-1.54	-2.31*	0.91

Note. 5 = correct response.

[a] Only one group of students.

*$p < .05$.

For third, fourth, and fifth-grade Group 1 students, the difficulty value for pretest Question 4 fell into the difficult category on the item difficulty designation scale (Table 37). Third- and fourth-grade Group 2 saw increase in the percent of students who correctly answered "farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms" on the posttest; therefore, this question became easier for these students following participation in the "Parts Per What" lesson.

While fifth-grade Group 1 also saw an increase in percent of students correctly answering Question 4 on the posttest, it was not a large enough increase to move the difficulty value out of the difficult range. Fifth-grade Group 1 did see an increase in percent of students correctly answering Question 4; however, both pretest and posttest difficulty values fall into the moderately difficult range on the item difficulty designation. All grade level groups met or exceeded the minimum item discrimination value of 0.2 for Question 4 (Table 37).

Table 37

Question 4: Farmers Could Use Which of the Following Tool(s) to Conserve and Prevent Water Contamination on Their Farms? Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (*n* = 150)		Group 2 (*n* = 130)		Group 1 (*n* = 120)		Group 2 (*n* = 13)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	21	76	51	83	45	56	62	69
Discrimination index	0.4	0.54	0.68	0.45	0.35	0.68	0.92	0.69

The final question (Question 5) on the “Parts Per What” assessment provided students with two options to fill in the blank: “When a hydrologist dilutes contaminated water, there is _______ of the contaminant in the water.” The multiple-choice options were “more” (coded as 1) or “less” (coded as 2). After March 26, 2018, a third option, “I don’t know” (coded as 0) was added. Only two of the four student groups saw a statistically significant difference in mean response from pretest to posttest (Table 38). Third-grade Group 2 had a mean difference of 0.87 between pretest (*M* = 0.91, *SD* = 0.82) and posttest (*M* = 1.78, *SD* = 0.42), $t(149) = 11.99$, $p < .05$ (two-tailed) with a 95%

confidence interval ranging from -1.02 to -0.73 and the Cohen's *d* (*d* = 1.38) indicating a large effect size. Fourth-grade Group 2 had a mean difference of 0.68 between pretest (*M* = 1.15, *SD* = 0.85) and posttest (*M* = 1.83, *SD* = 0.38), $t(129) = 8.58$, $p < .05$ (two-tailed) with a 95% confidence interval of -0.83 to -0.52 and the Cohen's *d* (*d* = 1.06) value indicating a large effect size. As indicated in Table 38, neither fifth-grade group had a statistically significant difference in mean response from pretest to posttest.

Table 38

Descriptive Statistics for Question 5: When a Hydrologist Dilutes Contaminated Water, There is __________ of the Contaminant in the Water

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, Group 1[a]	150	0.91	0.82	1.78	0.42	-0.87	-11.99*	1.38
Fourth, Group 2[a]	130	1.15	0.85	1.83	0.38	-0.68	-8.58*	1.06
Fifth, Group 1	120	1.67	0.47	1.72	0.45	-0.05	-0.97	-
Fifth, Group 2	13	1.23	0.93	1.54	0.52	-0.31	-1.00	-

Note. 2 = correct response.

[a] Only one group of students.

**p* < .05.

Based on the difficulty designation index, Question 5 was difficult for third-, fourth- and fifth-grade Group 2 students, with the percent of students correctly answering the question falling between 21-60% (Table 39). These students saw improvement after participation in the FARM Science Lab "Parts Per What" lesson, posttest Question 5 to the moderately difficult category. Fifth-grade Group 2 students saw no change in percent of students correctly answering, "When a hydrologist dilutes contaminated water, there is __________ of the contaminant in the water," from pretest to posttest; therefore, this

question was considered difficult for students in both instances.

Item discrimination indicates a question's effectiveness at separating the overall top preforming students from the lower performing students. All Question 5 grade level groups exceed the minimum item discrimination value of 0.2. Fourth-grade Group 2 pretest and fifth-grade Group 2 pretest and posttests have very high item discrimination values (Table 39). This indicates students who performed well on this question also have a relatively high score on the overall "Parts Per What" assessment.

Table 39

Question 5: When a Hydrologist Dilutes Contaminated Water, There is _________ of the Contaminant in the Water. Difficulty and Item Discrimination

	Third grade		Fourth grade		Fifth grade			
	Group 1 (n = 150)		Group 2 (n = 130)		Group 1 (n = 120)		Group 2 (n = 13)	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	29	78	44	83	65	70	54	54
Discrimination index	0.5	0.52	0.73	0.4	0.35	0.35	0.69	0.92

Resourceful Bean

The final lesson in this study saw the largest sample size in this study as 1,809 students in third through fifth grades participated in the FARM Science Lab's "Resourceful Bean" lesson: 654 third-grade students, 879 fourth-grade students, and 276 fifth-grade students. Of those, 541 (30%) students completed both the pretest and posttest for the "Resourceful Bean" lesson; 214 (33%) third-grade students, 222 (25%) fourth-grade students, and 105 (38%) fifth-grade students. The "Resourceful Bean" pretest and posttest consisted of the same five multiple-choice questions. After March 26, 2018, the

option “I don’t know” was added as a response option on the pretest only in order to help decrease error by limiting guessing. Also, at that time, two opinion-based questions were added, asking students’ opinions of the FARM Science Lab experience. However, the test scores are calculated out of five points as the excitement and experience rating questions are not included in the score.

The “Resourceful Bean” lesson is the only lesson in this study to have populations in all three grades in both Group 1 and Group 2 (Table 40). It is also the only lesson with statistically significant differences in mean score from pretest to posttest for all groups. A priori $\alpha = .05$ was used to interpret the *t*-test values. Third-grade Group 1 ($n = 133$) had a statistically significant mean difference of 0.81 points between pretest ($M = 3.26$, $SD = 1.21$) and posttest ($M = 4.06$, $SD = 1.01$), $t(133) = 6.84$, $p < .05$ (two-tailed) with a 95% confidence interval of 1.04 to 0.57 and a Cohen’s *d* value ($d = 0.84$) indicating a large effect size. Third-grade Group 2 had a statistically significant mean difference of 0.78 from pretest ($M = 2.56$, $SD = 1.33$) to posttest ($M = 3.34$, $SD = 1.36$), $t(82) = 4.45$, $p < .05$ (two-tailed) with a 95% confidence interval of -1.13 to -0.43 and a Cohen’s *d* value ($d = 0.7$) indicating a medium effect size. Table 40 indicates fourth-grade Group 1 had a statistically significant difference in mean score of 0.64 from pretest ($M = 3.55$, $SD = 1.21$) to posttest ($M = 4.20$, $SD = 0.95$), $t(148) = 5.89$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from -0.86 to -0.43 and a Cohen’s *d* value ($d = 0.69$) indicating a medium effect size. Fourth-grade Group 2 had a statistically significant difference in mean of 0.6 from pretest ($M = 2.97$, $SD = 1.22$) to posttest ($M = 2.90$, $SD = 0.42$), $t(71) = 3.84$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from

-1.01 to -0.32 and the Cohen's *d* value (*d* = 0.64) indicating a medium effect size. Fifth-grade Group 1 had a statistically significant difference in mean score (1.324) from pretest (*M* = 3.32, *SD* = 1.067) to posttest (*M* = 4.65, *SD* = 1.32), $t(34) = 6.73$, $p < .05$, (two-tailed) with a 95% confidence interval ranging from -1.72 to 0.92 and the Cohen's *d* (*d* = 1.63) value indicating a large effect size. Fifth-grade Group 2 did have a statistically significant difference in mean from pretest (*M* = 2.15, *SD* = 1.49) to posttest (*M* = 4.51, *SD* = 0.68), $t(67) = 12.75$, $p < .05$ (two-tailed). The Cohen's *d* (*d* = 2.20) value indicated a large effect size.

Table 40

"Resourceful Bean" Pretest and Posttest Differences

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, group 1	133	3.26	1.22	4.06	1.01	-0.81	-6.84*	0.84
Third, group 2	82	2.56	1.33	3.34	1.36	-0.78	-4.45*	0.70
Fourth, group 1	148	3.55	1.21	4.20	0.95	-0.64	-5.89*	0.69
Fourth, group 2	71	2.97	1.22	2.90	0.42	-0.66	-3.84*	0.64
Fifth, group 1	34	3.32	1.07	4.65	0.54	-1.32	-6.73*	1.63
Fifth, group 2	67	2.15	1.49	4.51	0.68	-2.36	-12.75*	2.20

Note. 5 = perfect score.

*$p < .05$.

"Resourceful Bean" Question 1 asked students "Which item cannot be made of soybeans?" Four multiple choice response were provided: "Tofu" (coded as 1), "Animal feed" (coded as 2), "Notebook paper" (coded as 3), and "Cooking oil" (coded as 4). After March 26, 20018, a fifth option, "I don't know" (coded as 0) was added to all pretest questions to reduce error in student guessing. The correct response was "Notebook

paper." Table 41 indicates Group 1 of each grade level did not see a statistically significant difference in mean response. All grades' Group 2 saw a statistically significant difference in mean from pretest to posttest. Third-grade Group 2 had a 0.57 statistically significant difference in mean response from pretest (*M* = 1.99, *SD* = 1.37) to posttest (*M* = 2.56, *SD* = 0.86), *t*(82) = 3.50, $p < .05$ (two-tailed) with a 95% confidence interval of -0.9 to -0.25 and Cohen's *d* (*d* = 0.55) value indicating a medium effect size. Fourth-grade Group 2 saw a 0.69 difference in mean from pretest (*M* = 2.21, *SD* = 1.21) to posttest (*M* = 2.9, *SD* = 0.42), *t*(71) = 4.53, $p < .05$ (two-tailed) with a 95% confidence interval ranging from -0.99 to -0.39 and a Cohen's *d* value (d = 0.76) indicated a large effect size (Table 41). Fifth-grade Group 2 saw the largest difference in mean for these grade groups with a 1.12 increase in mean from pretest (*M* = 1.85, *SD* = 1.5) to posttest (*M* = 2.97, *SD* = 0.24), *t*(67) = 6.02, $p < .05$ (two-tailed) with a 95% confidence interval from -1.49 to -0.75 and a Cohen's *d* value (*d* = 1.04) indicated a large effect size.

Table 41

Descriptive Statistics for Question 1: Which Item Cannot be Made of Soybeans?

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, group 1	133	2.76	0.74	2.85	0.62	-0.09	-1.16	-
Third, group 2	82	1.99	1.37	2.56	0.86	-0.57	-3.50*	0.55
Fourth, group 1	148	2.8	0.68	2.78	0.65	0.06	0.71	-
Fourth, group 2	71	2.21	1.22	2.90	0.42	-0.69	-4.53*	0.76
Fifth, group 1	34	2.91	0.51	3.00	0.17	0.12	-1.07	-
Fifth, group 2	67	1.85	1.50	2.97	0.24	-1.12	-6.02*	1.04

Note. 3 = correct answer.

*$p < .05$.

Table 42 indicates pretest Question 1 was considered difficult for third-grade Group 2 (51%) and fifth-grade Group 2 (44%) students. Whereas, Question 1 was considered moderately difficult (21-60%) for all other pretest groups. Third-grade Group 2 still found Question 1 (“Which item cannot be made from soybeans”) difficult on the posttest. For third-grade Group 1 and fourth-grade Group 1, Question 1 remained moderately difficult on the posttest. Fourth-grade Group 2 and fifth-grade Group 2 saw an increase in percent of students correctly answering Question 1 moving the posttest question into the easy category (Table 42).

Item discrimination value is being used to provide confidence in reliability of each question as a measure of student knowledge. All groups expect fourth-grade Group 2 posttest, fifth-grade Group 1 posttest, and fifth-grade Group 2 posttest met or exceeded the minimum value (Table 42).

Table 42

Question 1: Which Item Cannot be Made of Soybeans? Difficulty and Item Discrimination

	Third grade				Fourth grade				Fifth grade			
	Group 1 *n* = 133		Group 2 *n* = 82		Group 1 *n* = 148		Group 2 *n* = 71		Group 1 *n* = 34		Group 2 *n* = 67	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	72	81	51	51	80	80	65	94	83	97	44	97
Discrimination index	0.49	0.49	0.22	0.76	0.39	0.47	0.63	0.13	0.34	0.08	0.63	0.09

The second question of the “Resourceful Bean” assessment provided students with a true or false statement; “Soy crayons are made from a renewable resource.” “True”

was coded as 1, "false" was coded as 2, and after March 26, 2018, "I don't know" was coded as 0. Three of the six student groups saw statistically significant differences in mean from pretest to posttest, as shown in Table 43. Third-grade Group 1 had a statistically significant 0.15 decrease in mean from pretest (*M* = 1.31, *SD* = 0.46) to posttest (*M* = 1.16, *SD* = 0.37), $t(133) = 3.19$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from 0.06 to 0.24 and the Cohen's *d* value ($d = 0.39$) indicated a small effect size. Third-grade Group 2 also saw a statistically significant change in mean response from pretest (*M* = 0.93, *SD* = 0.69) to posttest (*M* = 1.16, *SD* = 0.37), $t(82) = 2.81$, $p < .05$ (two-tailed) with a 95% confidence interval of -0.40 to -0.07 and the Cohen's *d* value ($d = 0.44$) indicated a small effect size. Table 43 indicates fourth-grade Group 1 was the final group with a statistically significant difference in mean response for Question 2. This group saw a 0.18 decrease in mean from pretest (*M* = 1.28, *SD* = 0.45) to posttest (*M* = 1.10, *SD* = 0.3), $t(148) = 4.61$, $p < .05$ (two-tailed) with a 95% confidence interval of 0.11 to 0.26 with the Cohen's *d* value ($d = 0.54$) indicating a

Table 43

Descriptive Statistics for Question 2: Soy Crayons are made from a Renewable Resource

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, group 1	133	1.31	0.46	1.16	0.36	0.15	3.19*	0.391
Third, group 2	82	0.93	0.69	1.16	0.37	-0.24	-2.83*	0.442
Fourth, group 1	148	1.28	0.45	1.10	0.3	0.19	4.61*	0.536
Fourth, group 2	71	1.03	0.48	1.05	0.22	-0.02	-0.26	-
Fifth, group 1	34	1.18	0.39	1.03	0.17	0.15	1.97	-
Fifth, group 2	67	0.97	0.71	1.05	0.22	-0.08	-0.87	-

Note. 1 = correct answer.

*$p < .05$.

medium effect size. The remaining three groups did not see statistically significant changes in mean response.

Using the item difficulty designation, questions can be categorized based upon the percent of students who correctly answered the question. For third-grade Group 2 and fifth-grade Group 2, pretest Question 2 could be categorized as difficult (21-60%). Third-grade Group 1 (69%), fourth-grade Group 1 (72%), and 2 (68%) and fifth-grade group 1 (80%) fall into the moderately difficult range (61-90% correct) for the pretest (Table 44). Third-grade Group 2 students improved their responses to Question 2 on the posttest, moving from difficult to moderately difficult. Third-grade Group 1 students also saw an increase in percent of students correctly answering—"Soy crayons are made from a renewable resource"— however this increase was not enough to reclassify the question; it remained as moderately difficult. All fourth and fifth-grade groups transitioned Question 2 from moderately difficult to easy after participation in the "Resourceful Bean" lesson.

All pretest questions exceed 0.2, meaning students who correctly answered Question 2 also likely performed well on the "Resourceful Bean" assessment overall (Table 44). Fourth-grade Group 2 and both fifth-grade groups do not meet this minimum value for posttest Question 2. Because all students participated in the same intervention, the FARM Science Lab "Resourceful Bean" lesson, and were asked the same question afterward, it was expected there would be a decrease in discrimination following the intervention. While the other student groups' posttest item discrimination values do exceed the minimum of 0.2, each group's value for "soy crayons are made from a renewable resource," decreased after participation in the "Resourceful Bean" lesson.

Table 44

Question 2: Soy Crayons are Made from a Renewable Resource. Difficulty and Item Discrimination

	Third grade				Fourth grade				Fifth grade			
	Group 1 *n* = 133		Group 2 *n* = 82		Group 1 *n* = 148		Group 2 *n* = 71		Group 1 *n* = 34		Group 2 *n* = 67	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	69	84	51	75	72	91	68	93	80	95	46	94
Discrimination index	0.67	0.39	0.59	0.43	0.57	0.26	0.72	0.17	0.51	0.16	0.85	0.18

Question 3 asked students to fill in the blank—“A product engineer would need to ________ soybeans to make a soy-based foam.” Multiple-choice options included “crush” (coded as 1), “freeze” (coded as 2), “float” (coded as 3), or “dye” (coded as 4). After March 26, 2018, the option “I don’t know” (coded as 0) was added to the pretest only. The correct answer was crush. All grade levels’ Group 1 saw a statistically significant difference in mean response for Question 3 (Table 45). Third-grade Group 1 saw a 0.21 decrease in mean response from pretest (M = 1.62, SD = 0.91) to posttest (M = 1.41, SD = 0.85), $t(133) = 2.07$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from 0.01 to 0.41 and the Cohen’s d value (d = 0.25) indicated a small effect size. Fourth-grade Group 1 saw a 0.19 statistically significant decrease in mean response from pretest (M = 1.62, SD = 1.01) to posttest (M = 1.43, SD = 0.9), $t(148) = 2.29$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from 0.03 to 0.35 and the Cohen’s d (d = 0.27) indicated a small effect size. The final statistically significant difference in mean response indicated in Table 45 was fifth-grade Group 1 with a 0.77 decrease in mean from pretest (M = 1.79, SD = 1.01) to posttest (M = 103, SD = 0.17),

$t(34) = 4.26$, $p < .05$ (two-tailed) with a 95% confidence interval ranging from 0.40 to 1.13 and the Cohen's *d* ($d = 1.03$) indicating a large effect size. All grades' Group 2 did not have a statistically significant difference in mean response from pretest to posttest.

Table 45

Descriptive Statistics for Question 3: A product Engineer Would Need to ______ Soybeans to Make a Soy-Based Foam

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, group 1	133	1.62	0.91	1.41	0.85	0.21	2.07*	0.253
Third, group 2	82	1.32	1.05	1.48	1.0	-0.6	-1.0	-
Fourth, group 1	148	1.62	1.01	1.43	0.9	0.19	2.29*	0.266
Fourth, group 2	71	1.35	1.04	1.10	0.38	0.25	1.96	-
Fifth, group 1	34	1.79	1.01	1.03	0.17	0.77	4.26*	1.034
Fifth, group 2	67	0.88	1.02	1.15	0.56	-0.27	-1.83	-

Note. 1 = correct answer.

*$p < .05$.

As indicated in Table 46, third-grade Group 1 pretest, fourth-grade Group 1 and 2 pretest, and fifth-grade Group 1 and 2 pretest all fall into the difficult range by using Matlock-Hetzel's (1997) calculation. Fourth-grade Group 1 pretest was classified as moderately difficult with 66% of students correctly answering. All groups of third- and fourth-grade students improved from pretest to posttest moving posttest Question 3 into the moderately difficult range for these students. For both groups of fifth-grade students, the posttest Question 3 ("a product engineer would need to _____ soybeans to make a soy-based foam") fell into the easy range.

All groups of students met or exceed the 0.2 discrimination value on the pretest (Table 46). The closer the value is to 1.0, the more this question differentiates the top and

bottom scoring students. These higher discrimination values indicate there is quite a bit of difference from the top third and bottom third of each group. While the goal of this study is not to discriminate between the groups, these values provide confidence in the reliability of the assessment questions. Most groups also met or exceed this value on the posttest as well, however many posttest item discrimination values in Table 46 are lower than the same group's pretest value for the question "a product engineer would need to _______ soybeans to make a soy-based foam." This is expected after participation in an intervention such as the FARM Science Lab lessons.

Table 46

Question 3: A Product Engineer Would Need to ______ Soybeans to Make a Soy-Based Foam. Difficulty and Item Discrimination

	Third grade				Fourth grade				Fifth grade			
	Group 1 *n* = 133		Group 2 *n* = 82		Group 1 *n* = 148		Group 2 *n* = 71		Group 1 *n* = 34		Group 2 *n* = 67	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	60	77	45	76	66	77	51	68	54	97	37	93
Discrimination index	0.58	0.45	0.66	0.40	0.61	0.49	0.68	0.93	0.51	0.08	0.68	0.18

Question 4, illustrated in Table 47, presented students with a sentence to finish by multiple-choice response. The sentence asked students to consider the following, "To make lip balm from beeswax and soybeans, first heat causes the beeswax to change state from a _______." The multiple-choice options included: "gas to a liquid" (coded as 1), "solid to a liquid" (coded as 2), "liquid to a solid" (coded as 3), "gas to a solid" (coded as 4), and, after March 26, 2018, "I don't know (coded as 0) was added as an option the

pretest only. The correct response was “solid to a liquid” (coded as 2). Two grade level groups showed a statistically significant difference in mean response from pretest to posttest. Fourth-grade Group 1 saw a statistically significant 0.236 difference in mean response from pretest (M = 2.45, SD = 0.72) to posttest (M = 2.22, SD = 0.49), t(148) = 2.74, p < .05 (two-tailed), with a 95% confidence interval ranging from 0.10 to 0.37 and the Cohen’s d value (d = 0.32) indicating a small effect size (Table 47). Fifth-grade Group 2 also saw a statistically significant difference in mean (0.58) from pretest (M = 1.81, SD = 1.2) to posttest (M = 2.39, SD = 0.60), t(67) = 3.56, p < .05 (two-tailed) with a 95% confidence interval of -0.91 to 0.1 with a Cohen’s d value (d = 0.62) indicating a medium effect size. All remaining groups did not have statistically significant differences in mean from pretest to posttest.

Table 47

Descriptive Statistics for Question 4: To Make Lip Balm from Beeswax and Soybeans, First Heat Causes the Beeswax to Change State from a _______

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen’s *d*
Third, group 1	133	2.30	0.8	2.18	0.64	0.12	1.52	-
Third, group 2	82	1.96	1.15	2.18	0.67	-0.22	-1.50	-
Fourth, group 1	148	2.45	0.72	2.22	0.49	0.24	2.74*	0.319
Fourth, group 2	71	2.10	1.06	2.31	0.52	-0.21	-1.53	-
Fifth, group 1	34	2.18	0.8	2.29	0.52	-0.11	-0.75	-
Fifth, group 2	67	1.81	1.2	2.39	0.60	-0.58	-3.56*	0.615

Note. 2 = correct answer.

*p < .05.

The percent of students correctly answering the question, “To make lip balm from beeswax and soybeans, first heat causes the beeswax to change state from a _______,” on

each group's pretest indicates students found this question difficult, based on the difficulty index (Table 48). Third-grade Group 2 students found question four difficult on the posttest as well. Whereas third-grade Group 1, fourth-grade Group 1 and both fifth-grade groups saw enough improvement in student responses to move to the question rating into the moderately difficult category. Fourth-grade Group 2 posttest Question 4 moved from being categorized as difficult on the pretest to easy on the posttest.

Item discrimination compared high and low scorning students on that particular question to determine if an assessment question effectively discerns students who know the content from those who do not. All Question 4 pretest groups met or exceeded the minimum discrimination value of 0.2 (Table 48). All posttest Question 4 groups, except fourth-grade Group 2, also meet or exceed this minimum value. Fourth-grade Group 2 only has a 0.08 item discrimination value which paired with the group's difficulty designation indicate almost all students (99%) correctly answered this question.

Table 48

Question 4: To Make Lip Balm from Beeswax and Soybeans, First Heat Causes the Beeswax to Change State from a ______________. Difficulty and Item Discrimination

	Third grade				Fourth grade				Fifth grade			
	Group 1 *n* = 133		Group 2 *n* = 82		Group 1 *n* = 148		Group 2 *n* = 71		Group 1 *n* = 34		Group 2 *n* = 67	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	41	66	28	59	50	76	39	99	43	73	35	66
Discrimination index	0.38	0.71	0.66	0.83	0.69	0.51	0.34	0.08	0.43	0.81	0.55	0.84

The final question of the "Resourceful Bean" assessment was a true/false statement. Students were asked to evaluate the sentence, "Michigan farmers grow soybeans." Multiple-choice options included "true" (coded as 1), "false" (coded as 2), and after March 26, 2018, "I don't know" (coded as 0) was added. The correct answer was true (coded as 1). All grades' Group 1 saw a statistically significant difference in response from pretest to posttest. Table 49 indicates third-grade Group 1 saw a 0.13 difference in response from pretest (M = 1.17, SD = 0.3) to posttest (M = 1.04, SD = 0.19), t(133) = 3.72, p < .05 (two-tailed) with a 95% confidence interval of 0.06 to 0.2 with a Cohen's d (d = 0.46) indicating a medium effect size. Fourth-grade Group 1 saw a 0.08 difference in mean response from pretest (M = 1.12, SD = 0.33) to posttest (M = 1.04, SD = 0.2), t(148) = 2.74, p < .05 (two-tailed) with a 95% confidence interval of 0.11 to 0.08 with a Cohen's d (d = 0.32) indicating a small effect size. Fifth-grade Group 1 saw the largest difference in mean (0.27) response from pretest (M = 1.26, SD = 0.45) to posttest (M = 1.0, SD = 0.0), t(34) = 3.45, p < .05 (two-tailed) with a 95% confidence

Table 49

Descriptive Statistics for Question 5: Michigan Farmers Grow Soybeans

		Pretest		Posttest				
Grade level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Third, group 1	133	1.17	0.38	1.04	0.19	0.13	3.72*	0.46
Third, group 2	82	1.02	0.44	1.12	0.33	-0.1	-1.73	-
Fourth, group 1	148	1.12	0.33	1.04	0.2	0.08	2.74*	0.32
Fourth, group 2	71	1.08	0.50	1.01	0.12	0.07	1.50	-
Fifth, group 1	34	1.26	0.45	1.0	0.00	0.27	3.45*	0.84
Fifth, group 2	67	0.96	0.71	1.03	0.17	-0.08	-0.87	-

Note. 1 = correct answer.

*p < .05.

interval of 0.11 to 0.42 with a Cohen's *d* (*d* = 0.84) value indicating a large effect size (Table 49). All grades' Group 2 did not have a statistically significant difference in mean response from pretest to posttest.

For pretest Question 5, all but one group of students found "Michigan farmers grow soybeans" to be moderately difficult. Fifth-grade Group 2 only had 49% of students (*n* = 67) correctly answer Question 5, putting this question in the difficult category for that group (Table 50). All groups saw improvement on the posttest, with third-grade Group 1, fourth-grade Group 1 and 2, and fifth-grade group 1 and 2 all falling into the easy category with the percent of students correctly answering the question equating to 91% or higher. Third-grade Group 2 students saw a decrease in percent of students correctly answering Question 5 from pretest to posttest, therefore for this group, the question remained categorized as moderately difficult.

All groups' pretest item discrimination value was above the minimum value of 0.2 (Table 50). This indicates there are differences in how the top third and bottom third of students are answering Question 5 on the pretest. However, on the posttest, most

Table 50

Question 5: Michigan Farmers Grow Soybeans. Difficulty and Item Discrimination

	Third grade				Fourth grade				Fifth grade			
	Group 1 *n* = 133		Group 2 *n* = 82		Group 1 *n* = 148		Group 2 *n* = 71		Group 1 *n* = 34		Group 2 *n* = 67	
Question analysis	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Difficulty index	82	95	80	75	87	96	75	99	74	100	49	97
Discrimination index	0.47	0.12	0.37	0.58	0.22	0.08	0.59	0.08	0.26	0.00	0.63	0.04

groups did not meet the minimum item discrimination value. After participating in the FARM Science Lab "Resourceful Bean" lesson, these students focused their answers so much so nearly all students were correctly answering, "Michigan farmers grow soybeans."

Student Excitement

After March 26, 2018, one question was added to the pretest and one question to the posttest to gather students' opinions of the FARM Science Lab experience. The new first question on all pretests was "I am excited to learn about the science of farming." "Yes" (coded as 1) and "No" (coded as 2) were the multiple-choice options provided.

To analyze data from this first pretest question, students were combined into grade level groups. These students participated in any of the FARM Science Lab's four lessons. Due to the overall high percent of "yes" responses, data from individual lessons were combined for publication. Nearly all students were excited to learn about the science of farming (Table 51).

Table 51

Student Excitement to Learn about Farming and Science

Excitement response	Third grade (%) (n = 232)	Fourth grade (%) (n = 255)	Fifth grade (%) (n = 146)
Yes	92	93	83
No	8	7	17

As with the "student excitement" pretest question, Table 52 combines responses from each of the four lessons into grade level groups. Most students across all three grade levels found the FARM Science Lab to be "awesome" or "good" (Table 52).

Table 52

Student Rating of FARM Science Lab Experience

Experience Rating	Third grade (%) (*n* = 216)	Fourth grade (%) (*n* = 235)	Fifth grade (%) (*n* = 148)
Was awesome	65	64	52
was good	16	19	24
Was just okay	11	12	16
could have been better	7	4	7
was bad	1	1	1

Research Question 2

What are teacher perceptions of the FARM Science Lab mobile classroom model regarding increased academic and agricultural literacy understandings?

Classroom teachers were required to participate the FARM Science Lab experience along with their students. An electronic teacher survey (Appendix F) was sent by email to the one contact at each school who coordinated the FARM Science Lab's visit by Michigan Agriculture in the Classroom staff. This school coordinator was asked to send the survey link to all teachers who took their classes to the FARM Science Lab. From February through June 2018, 150 third through fifth-grade teachers participated in the FARM Science Lab. Of those teachers, 72 completed the teacher survey; 28% (*n* = 20) taught third-grade, 34% (*n* = 25) taught fourth-grade, 25% (*n* = 18) taught fifth-grade and 12% (*n* = 9) selected "I don't see my grade here." In some instances, teachers team taught across more than one grade or school staff other than the daily classroom teacher, such as a physical education teacher, paraprofessional or substitute teacher, brought students to the FARM Science Lab which could make up the "I don't see my grade here"

responses.

The teacher survey contained 11 questions. Five of the questions focused on the engagement of the students while in the FARM Science Lab and the grade-appropriateness of the material. For each of these questions (Table 53), the following Likert scale responses were provided: "Strongly disagree" (coded as 1), "Disagree" (coded as 2), "Neutral" (coded as 3), "Agree" (coded as 4), and "Strongly Agree" (coded as 5). Based on mean response, responding teachers agreed the FARM Science Lab addressed appropriate educational outcomes for their grade level (*M* = 4.08) and agreed that their students' understanding of agriculture increased as a result of the experience (*M* = 4.13). While teachers' felt their students had an increase understanding of agriculture as a result of the FARM Science Lab, these teachers had a neutral response (*M* = 3.39) about their own increase in understanding about Michigan agriculture.

Table 53

Student Engagement and Grade Level Content (*n* = 72)

Teacher statements	Mean	*SD*
The FARM Science Lab Experience addressed appropriate educational outcomes for my grade level	4.08	1.10
My students were actively engaged in the lesson taught	4.38	0.91
I have an increased understanding of Michigan agriculture after my FARM Science Lab experience.	3.39	0.99
My students have an increased understanding of Michigan agriculture after our FARM Science Lab experience.	4.13	0.93
The FARM Science Lab educator used effective teaching strategies to engage students.	4.26	0.95

Note. 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

Four of the FARM Science Lab teacher survey questions provided "yes" or "no" as response options (Table 54). The first question asked specifically about the teacher's

own expectations of the program. Teachers who selected “no” for this question were offered a field to type an explanation as to why expectations were not met. Only two teachers provided comments. One teacher’s comments indicated her students participated in the “Field Plastic” lesson and due to a problem with ingredients her students’ corn plastic experiment did not turn out. The second teacher indicated he or she did not know what to expect; therefore, they answered no to the question. The remaining three questions asked about the use of resources connected to the FARM Science Lab such as the pre-visit assessment and Michigan Agriculture in the Classroom’s teacher materials. The responding teachers (*n* = 72) indicated their expectations were met (96%). Also, many teachers did participate in the pre-visit student assessment (88%). Less teachers were interested in using Michigan Agriculture in the Classroom resources or reserving the FARM Science Lab again.

Table 54

Teacher Expectations and Future Use (*n* = 72)

Teacher questions	Yes (%)	No (%)	Maybe (%)
Were your expectations for the FARM Science Lab program met?	96	4	—
My students participated in the pre-visit assessment.	88	13	—
I plan to explore the Michigan Agriculture in the Classroom food and agricultural educational materials at www.miagclassroom.org	75	25	—
Would you consider reserving the FARM Science lab in the future?	82	4	14

To further understand teachers’ perceptions of using agriculture as a means by which to exemplify science concepts, this question, “Based on your experience in the FARM Science Lab, how effectively do you think agriculture topics/examples can be

used to contextualize science and convey important principles or concepts"? Likert-scale options included "Highly Effective" (coded as 1), "Very Effective" (coded as 2), "Moderately Effective" (coded as 3), "Slightly Effective" (coded as 4) and "Not at All Effective" (coded as 5). Table 55 illustrates the teachers' mean response, indicating this group of teachers believe agricultural examples could be very effective to teach science concepts and principles. The small standard deviation (*SD* = 0.85) indicates teachers' perceptions did not vary much regarding the effectiveness of using agriculture to contextualize science.

Table 55

Agriculture as a Way to Contextualize Science

Teacher question	*M*	*SD*
Based on your experience in the FARM Science Lab, how effectively do you think agriculture topics/examples can be used to contextualize science and convey important principles or concepts?	1.99	0.85

Note. 1 = Highly Effective, 2 = Very Effective, 3 = Moderately Effective, 4 = Slightly Effective, 5 = Not at All Effective.

Research Question 3

What are the differences between urban, suburban, and rural student gains from pretest to posttest?

The National Center for Education Statistics (NCES) maintains a database of all public schools in the U.S. including demographic and geographic information. This database segments school locales into 12 categories from large cities to remote rural locations. While this database offers 12 very specific categories, for the purpose of this

study, the categories of "rural remote," "fringe," "town distant," and "rural distant" were combined to be considered rural. Also, "suburban large," "suburban midsize," "suburban small," and "city small" were combined to be considered suburban. In February through June 2018, the FARM Science Lab visited 22 schools: 0 urban, 4 suburban and 18 rural schools. One school visited was a private school and, therefore, not cataloged in the NCES database. For the purpose of this study, the one private school visited was given the category of the public elementary school in the same town.

Based on NCES classifications, the majority of the schools visited during the data collection period of this study were in rural locations. Only three groups of FARM Science Lab lesson/grade pairs were part of a geographic segmentation. Within fourth-grade (Table 56) Group 2 completing the "Field Plastic" lesson, the rural and suburban groups had approximately the same numbers of students. This rural subset (n = 29) represents students at one school, and the suburban subset (n = 24) also is made up of students from only one school. This is a small population in these categories, and may not provide enough data to make generalizations. The rural students did have a slightly higher mean score (M = 1.86) on the pretest than the suburban students (M = 1.79); whereas, the suburban students scored higher on the posttest (M = 4.58) than the rural students (M = 3.52). The suburban students saw a greater gain in scores from pretest to posttest with a mean difference of 2.79 over the mean score of rural students (1.66). The differences in the mean score were statistically significant with a Cohen's d (d = 3.07) indicating a large effect size for each group.

The "Resourceful Bean" lesson's fourth and fifth-grade Group 2 students could be

Table 56

Suburban and Rural Mean Pretest and Posttest Score Segmentation, "Field Plastic" Lesson

Geographic location	Grade-level group	*n*	Pretest *M*	Pretest *SD*	Posttest *M*	Posttest *SD*	Mean differences	*t*	Cohen's *d*
Rural	Fourth, group 2	29	1.86	1.16	3.52	1.15	-1.66	-5.54*	1.46
Suburban	Fourth, group 2	24	1.79	1.25	4.58	0.58	-2.79	-10.65*	3.07

Note. Score out of 5.

* $p < .05$

separated into rural and suburban categories (Table 57). Again, the rural and suburban groups of students are nearly the same size. In this lesson, rural fourth-grade students had a lower mean score on the pretest (M = 2.85) than the suburban fourth-grade students (M = 3.17). However, both geographic groups had nearly the same posttest score mean. The rural and suburban fourth-grade students both had a statistically significant difference in mean score from pretest to posttest. The population of fifth-grade students has a large discrepancy between rural and suburban. The total number of fifth-grade Group 2 students was not large (n = 67) however, only 18 students were from a rural location and all were at the same school. The suburban population was made up of 49 students from one school as well. Table 57 indicates the rural fifth-grade students saw a slightly larger increase in mean score from pretest to posttest and performed better than the suburban students on the posttest. This fifth-grade Group 2 rural population had a statistically significant difference in mean score from pretest (M = 2.06, SD = 1.47) to posttest (M = 4.78, SD = 0.55). The larger suburban fifth-grade Group 2 population did not have a statistically significant difference in scores from pretest to posttest.

Table 57

Suburban and Rural Mean Pretest and Posttest Score Segmentation, "Resourceful Bean" Lesson

			Pretest		Posttest				
Geographic location	Grade-level group	*n*	*M*	*SD*	*M*	*SD*	Mean differences	*t*	Cohen's *d*
Rural	Fourth, group 2	29	1.86	1.16	3.52	1.15	-1.66	-5.54*	1.46
Suburban	Fourth, group 2	24	1.79	1.25	4.58	0.58	-2.79	-10.65*	3.07
Rural	Fifth, Group 2	18	2.06	1.47	4.78	0.55	-2.77	-8.21*	2.74
Suburban	Fifth, Group 2	49	2.184	1.51	4.41	0.71	-2.22	-10.08	-

Note. Score out of 5.
* $p < .05$.

Summary of Results

The purpose of this study was to evaluate the effectiveness of Michigan's FARM Science Lab mobile classroom as a modality for teaching agriculture-themed, standards-based lessons to third through fifth-grade students to increase their understanding of agriculture. Chapter IV outlined the statistical analysis of data collected from this program to answer the three research questions presented. Research Question 1 found 15 of 17 groups of third through fifth-grade students to have significant differences in mean score from pretest to posttest after participating in the FARM Science Lab intervention. These 15 groups had either a medium or large effect sized based on the Cohen's d value. These findings indicate nearly all students had a change in knowledge after participation in the FARM Science Lab. After March 26, 2018, students were asked about their excitement to learn about farming and science as well as to rate the FARM Science Lab experience. Most students across all three grade levels were excited to learn about the

science of farming. Students also highly rated the FARM Science Lab experience.

To understand teacher feedback about the FARM Science Lab, Research Question 2 analyzed surveys collected from third through fifth-grade teachers who participated in the mobile classroom program. These teachers indicated the FARM Science Lab program addressed appropriate educational standards for their respective grade levels. The teachers believed their students were engaged in the programing and that the FARM Science Lab Regional Educator used effective teaching techniques throughout the lesson. These teachers indicated interest in additional Michigan Agriculture in the Classroom resources available online. On average, these teachers believed agriculture could be very effectively used to contextualize science concepts.

Research Question 3 segmented the results from Research Question 1 into rural, suburban and urban groups for further analysis. The FARM Science Lab did not visit any schools in urban areas during the time of this study. The "Field Plastic" and "Resourceful Bean" lessons had larger groups of rural and suburban visits so as to more clearly compare change within the geographic groups. Each lesson showed significant change from pretest to posttest with in either rural or suburban students.

CHAPTER V

DISCUSSION

The purpose of this study was to evaluate the effectiveness of Michigan's FARM Science Lab mobile classroom as a modality for teaching agriculture-themed, standards-based lessons to third through fifth-grade students to increase their understanding of agriculture. The data from pretests, posttests and teacher surveys given by Michigan Agriculture in the Classroom staff has been analyzed to answer three research questions related to this purpose. Chapter V will discuss the research questions, findings related to hypotheses, and recommendations.

Research Questions

Research Question 1

Research Question 1 compared pretests and posttest across third, fourth, and fifth-grade student participants of the FARM Science Lab to analyze knowledge gain as a result of the intervention. The pre-post assessments contained the same questions for all grade levels within each lesson. After March 26, 2018, one additional question was added to the pretest and one to the posttest to gather students' opinions of the experience. Also, "I don't know" was added as a multiple-choice option to the pretest only at that time. Any responses after these additions made up Group 2 responses. Each grade/lesson combination was compared in its own pre-post pairing within its respective group.

The additions made on March 26, 2018, thus splitting the data in to Group 1 (prior to March 26) and Group 2 (after March 26), created resulted in the doubling of data.

While these groupings allowed for a more effective comparison of data, the data set would have been more straightforward if “I don’t know” had been a pretest option from the beginning. Due to the high probability of students guessing, Group 1 pretest responses could have a high amount of error in measurement of knowledge change. Overall, 15 of 17 groups showed a statistically significant increase in total test score from pretest to posttest after participation in the FARM Science Lab lessons. Therefore, the null hypothesis was partially rejected; there was a statistically significant difference from pretest to posttest for most students. No third-grade students participated in the “Extraction of Life” lesson. This was not surprising as this lesson’s content is more appropriate for older students. Upon further investigation of the fourth-grade students who participated in the “Extraction of Life” lesson (n = 10), this population represented one class at a private school. On four of the five “Parts Per What” lesson questions, third-graders had a less than one mean response on the pretest. This indicates more third-graders were selecting “I don’t know” (coded as 0) than other grades on the pretest. Lessons “Extraction of Life” and “Parts Per What” also do not meet many third-grade educational standards and are better suited for older grades.

When segmenting the data further to analyze each question of each lesson, some groups did not see statistically significant differences in mean response from pretest to posttest on every question. However, in most cases improvement could be seen from pretest to posttest response, even if this difference was not statistically significant. For both significant changes and nonsignificant changes, often, the standard deviation decreased from pretest to posttest suggesting students were narrowing their answers with

more selecting the correct option on the posttest. One question on the "Extraction of Life," "Parts Per What," and "Field Plastic" lessons offered "all of the above" as a multiple-choice option. Though this is an accepted testing practice, these three questions saw high standard deviation values suggesting students were not comprehending all other options were correct.

Similarly, the difficulty values decreased from pretest to posttest showing students found questions easier on the posttest than on the pretest. However, in almost all cases, questions were never ranked easier than "moderately difficult" for third-grade students. In most cases, item discrimination decreased as well, indicating less polarization in response between the overall high and low scoring students on each question. This would suggest more students were correctly answering the questions following participation in the intervention. Though the goal of this study was not to discriminate between high and low achieving students, the use of the item discrimination value as a measure gives more confidence in the reliability of the questions.

Group 2 students were asked on the pretest if they were "excited to learn about the science of farming." Overwhelmingly, students across all three grades answered yes to this question. Following participation in the FARM Science Lab, students were asked to rate their experience. "It was awesome" and "was good" received nearly 80% or more of each grade level's responses. Students' excitement and enjoyment of the FARM Science Lab may be attributed to the novelty of learning in a colorful trailer contributing to a motivation for learning (Willis, 2007). Mobile classrooms have the unique ability to provide an exciting, new environment for learning that could stimulate further motivation

for students to continue learning about the topic.

Several part-time regional educators deliver the content in the FARM Science Lab. These educators could have influence over student responses. While each educator is teaching from the same lesson plan, each could vary in delivery.

Research Question 2

Michigan Agriculture in the Classroom provided teachers a survey following participation in the FARM Science Lab programming. This data analysis focused on the teachers of the third through fifth-grade students discussed in Research Question 1. These teachers (n = 72) generally liked the FARM Science Lab experience. Teachers found the lesson content appropriate for their grade level and thought the FARM Science Lab educator was using engaging teaching methods. Teachers who responded to this survey stated their students had also taken the pretest and posttest. While this is a good check-point, understanding why some teachers did not have their students complete one or both assessments would have been beneficial information. Based on this data, the null hypothesis was rejected; the teachers had a positive perception of the contextualization of science in agriculture, food, and natural resources.

Teachers indicated interest in looking up additional agricultural educational materials online. While teachers believed their students’ understanding of agriculture increased as a result of the FARM Science Lab experience, teachers did not necessarily believe their own understanding of agriculture increased. The FARM Science Lab lessons align with the National Agricultural Literacy Outcomes for grade 3-5; therefore, it is possible teachers found the agricultural content to be too low level to increase their adult

understanding of the subject. In addition, Research Question 3 indicated more than 80% of schools visited were located in rural areas. The teachers may live in these rural areas, having more exposure to agricultural practices, and therefore may be more agriculturally literate. Teachers indicated agriculture could be a very effective way to contextualize science and convey important principles or concepts. This response supports the work of the National Agriculture in the Classroom Organization and the National Center for Agricultural Literacy to further promote ways to implement agriculture-based lessons into classroom teaching.

Research Question 3

During the time of this study, the FARM Science Lab visited 22 schools in suburban and rural locations. The mobile lab did not travel to any urban locations. Many lesson/grade groups were all located in rural areas with no urban or suburban students of the same grade participating to provide an effective comparison in the effect of geographic location on knowledge gain. Of the three groups that did have a rural and suburban population to compare, there were some differences in scores between students' responses in each geographic location. These populations were small; therefore, these differences may not be generalized to the larger population. In addition, in some instances, all the students compared were from the same school further limiting this finding. Rural students did not always score higher overall, or higher on the pretests. Suburban students did not always see the largest gain from pretest to posttest.

Limitations Revisited

As with all research, this study has limitations. These limitations were outlined in Chapter I and are worth reviewing to connect recommendations with the findings. This study did include students in one state and should not be generalized beyond populations similar to those who participated in the FARM Science Lab. Only 31% of students participating in the FARM Science Lab from February through June 2018 completed both the pretest and the posttest provided by Michigan Agriculture in the Classroom staff. One school printed paper copies of the pretest and posttest to overcome a technical challenge; however, the other 70% of schools did not provide feedback as to why the assessments were not completed. Assessments were taken at various intervals after each FARM Science Lab lesson, varying from one hour to one month after participation. Maturation, prior knowledge, and apprehension about taking a test over material not yet taught were limitations to this study. Adding "I don't know" to the pretest questions was one way to overcome some of these limitations. This allowed students a lower pressure option on the pretest to make up for possible lack of prior knowledge or apprehension. Increased standard deviation values on pretests indicated students were using this option, which suggests some error from guessing was reduced.

Final Conclusions and Recommendations

Based on the findings of this study, the FARM Science Lab is making a difference in students' agricultural understanding, at a basic knowledge level, after a short intervention. Based on Bloom's Taxonomy or Webb's Depth of Knowledge

Taxonomy, the assessment questions are only reaching a basic level of knowledge, recall and remembering (Perkins, 2008). The assessment questions are testing the recall of facts rather than an understanding of a whole concept about science or agriculture. The 2014 definition of an agriculturally literate person suggests changes are not only needed in knowledge but also in attitudes, skills, behaviors and practices in order to apply this agricultural knowledge to daily life (Spielmaker et al., 2014). The focus of lessons and assessment questions could be narrowed and aligned more closely with National Agricultural Literacy Outcomes (NALO), to further measure this higher-order comprehension of the agricultural concepts (Spielmaker & Leising, 2013). Focusing each lesson could also allow for more higher-order observations thus resulting in understanding of higher-order science concepts based on Kolb's Experiential Learning Theory (Baker, Robinson, & Kolb, 2012). This depth could push students beyond simple knowledge-based recall toward further application of a concept. Based on student performance, the FARM Science Lab lessons should focus on fewer grades per lesson to better align with grade level educational standards. If one grade level group of students wanted to return multiple days in a row, lesson content could dive deeper into one NALO, providing the students with more depth on the same topic rather than many different topics to build a progression of learning. Although the difference in mean response is not significant for each question for each grade level and lesson group, there is an increase in correct response for most groups. More methods of conducting pre-post testing need to be investigated to obtain higher response rates for a more diverse and potentially more statistically significant population of respondents. Formative responses

could be collected on the iPads throughout the lesson as a way to measure student learning in place of a posttest. Other forms of assessment, beyond multiple choice questions, such as building concept maps could also be considered. Several regional educators teach the FARM Science Lab's lessons as it moves around the state. It was out of the scope of this study to correlate student response to regional educators; however, Michigan Agriculture in the Classroom staff should consider this correlation as a means for evaluation of regional educators and to determine the need for training provided to these part-time staff. Dewey's *Experience and Education* indicates not all forms of experiential learning may be educational. Some could be wrong or misinformed (Dewey, 1938). While the FARM Science Lab controls many possible factual errors by providing staff to teach the agricultural lessons, further correlating this data to each regional educator could point out any weaknesses in instruction.

Teachers who responded to the survey had positive feedback about their experiences. Further follow up should be conducted with teachers who did not respond to investigate their views of the program. Teachers who responded to the teacher survey indicated their students also took the pretest and posttest evaluations. This suggests this group of teachers' dedication to fulfilling the assessment request of the FARM Science Lab; however, it does not tell researchers much about why other teachers did not hold high value for these assessments and survey. Teachers indicated interest in using resources from the Michigan Agriculture in the Classroom website. Further investigation is needed to determine if this is actually happening. Analytics from the website could refute or support this interest. Continued follow-up with these teachers through

newsletters, mail, professional development, or social media could promote use of agriculture examples within their own lessons, extending the reach of the FARM Science Lab. Some teachers indicated they had little information about the FARM Science Lab prior to its arrival because another teacher or administrator had coordinated the visit. While FARM Science Lab staff can only have so much influence over the actions of school staff, further evaluation of the reservation process could determine ways to help all teachers feel comfortable with the requirements of the mobile classroom's visit.

The FARM Science Lab did not visit any urban locations from February through June 2018. Only two suburban schools were visited. Therefore, the null hypothesis was accepted as there was not enough data to determine much difference in knowledge gain between geographic segments. Data from the small suburban population suggests student's agricultural knowledge is similar to that of rural students, to reach students with the least geographic connection to agriculture, mobile classrooms need to visit urban and suburban areas. The Michigan Agriculture in the Classroom program is operated by Michigan Farm Bureau. Major funders of this project are county Farm Bureaus and other agricultural businesses (Michigan Agriculture in the Classroom, n.d.). It is important to build relationships with funders by providing visibility of the FARM Science Lab at schools in their communities; however, to move the agricultural literacy needle, mobile classrooms must move more broadly to urban and suburban students.

Future Research

The assessments evaluated in this study made observations about change at a basic knowledge level. Future research could investigate how mobile agricultural

classrooms help students form deeper opinions about agriculture or make different decisions in their daily lives. Future research could also build upon Willis' work equating novelty of experience to motivation to learn. Would students be motivated to learn more about an agricultural or science concept after participation in the FARM Science Lab? A study with a control group or quasi-experimental research design could be conducted to compare the students' learning of similar content from in-classroom instruction with the same instruction inside the mobile classroom. This research could also consider the merit and worth of mobile agricultural classrooms and classroom-based interventions about agriculture. Evaluating the merit of mobile classrooms and in-classroom agricultural programming would measure the intrinsic value of each program type (Lincoln & Guba, 1980). Evaluating the worth of mobile classroom and in-classroom agricultural programming would outline the input costs such as time, money, human or program resources of each type of program. Assessing merit and worth of different modalities of increasing agricultural literacy could provide state Agriculture in the Classroom staff a foundation for program development decision making.

With some adjustments, the methodology of this study could be continued to build a larger data set for the FARM Science Lab, including evaluation of any repeating students from one year to the next. A longitudinal study should be conducted to evaluate what content students have retained or were motivated to further investigate a year, two years, or more after participation in the FARM Science Lab. Finally, replication of this study's methodology across other mobile classroom programs could deepen the understanding of best practices for these short, novel, experiential learning interventions.

REFERENCES

American Farm Bureau Federation. (n.d.). *Our food link*. Retrieved from http://www.fb.org/programs/womens-leadership-program/our-food-link/

Baker, M., Robinson, J. S., & Kolb, D. A. (2012). Experiential learning theory with a comprehensive agricultural education model. *Journal of Agricultural Education, 53*(4), 1-16. doi: 10.5032/jae.2012.04001

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1992). Theory into practice: How do we link? In T. M Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction: A conversation* (pp. 17-34). Hillsdale, NJ: Erlbaum.

Bonate, P. L. (2000). *Analysis of pretest-posttest designs*. Boca Raton, Florida: CRC Press.

Brandt, M. R. (2016). *Exploring elementary students' agricultural and scientific knowledge using evidence centered design* (Master's thesis). Retrieved from http://digitalcommons.unl.edu/natresdiss/131/

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42. Retrieved from http://journals.sagepub.com.dist.lib.usu.edu/doi/abs/10.3102/0013189X018001032

Bunzeck, N., & Düzel, E. (2006). Absolute coding of stimulus novelty in the human substantia Nigra/VTA. *Neuron, 51*(3), 369-379. Retrieved from https://doi.org/10.1016/j.neuron.2006.06.021

Center for Food Integrity. (2015). *A clear view of transparency and how it builds consumer trust.* Retrieved from http://www.foodintegrity.org/clear-view-transparency-builds-consumer-trust/

Choi, J. I., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational Technology Research and Development*, *43*(2), 53-69. Retrieved from http://www.jstor.org/stable/30220993

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Routledge.

Dewey, J. (1938). *Experience & education*. New York, NY: Simon & Schuster.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). *Taking science to school: learning and teaching science in grades K-8*. Washington, DC: The National Academies Press.

Frick, M. J. (1990). *A definition and the concepts of agricultural literacy: A national study* (unpublished doctoral dissertation). Iowa State University, Ames, IA.

Hornby, A. S. (2015). *Oxford advanced learner's dictionary of current English*. Retrieved from http://www.oxfordlearnersdictionaries.com/us/definition/english/novelty_1

Johnson, R. B., & Christensen, L. (2014). *Educational research: Quantitative, qualitative and mixed approaches*. Los Angeles, CA: Sage.

Jones, A. L., & Stapleton, M. K. (2017). Correction: 1.2 million kids and counting—Mobile science laboratories drive student interest in STEM. *PLOS Biology 15*(7), 1-8. Retrieved from https://journals.plos.org/plosbiology/article/file?id=10.1371/journal.pbio.2001692&type=printable

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Retrieved from http://academic.regis.edu/ed205/kolb.pdf

Kolb, D. A. (2014). *Experiential learning experience as the source of learning and development*. Upper Saddle River, NJ: Pearson Education.

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

Laurent, C. (2011). Change things up with novelty learning. *Education Week: Teacher* [online version]. Retrieved from http://www.edweek.org/tm/articles/2011/12/19/fp_laurent2.html

Leising, J. G. (Ed). (1994). *The food and fiber systems literacy framework with learner outcomes for grades k-12 literacy*. Stillwater, OK: Department of Agricultural Education, Communications and 4-H Youth Development, Oklahoma State University.

Leising, J. G., Pense, S. L., & Igo, C. (2000). An assessment of student agricultural literacy knowledge based on the food and fiber systems literacy framework. *Journal Southern Agricultural Education Research, 50*(1) 146-151.

Lincoln, Y., & Guba, E. (1980). The distinction between merit and worth in evaluation. *Educational Evaluation and Policy Analysis*, 2(4), 61-71. doi: 10.2307/1163674

Maltese, A., & Tai, R. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685. doi: 10.1080/09500690902792385

Matlock-Hetzel, S. (1997, January). *Basic concepts in item and test analysis*. Paper presented at the Annual Meeting of the Southwest Educational Research Association, Austin, TX. Retrieved from https://files.eric.ed.gov/fulltext/ED406441.pdf

McLaughlin, J. A., & Jordan, G. B. (2004). Using logic models. In K. Newcomer, H. Hatry, & J. Wholey (Eds.), *Handbook of practical program evaluation* (pp. 7-32). San Francisco, CA: Jossey-Bass. doi: 10.1002/9781119171386

Miller, A., & Spielmaker, D. M. (2018, July). *Investigating Mobile Agricultural Classrooms for Agricultural Literacy Programming*. Poster session presented at the Mobile Lab Coalition Annual Conference, Detroit, MI.

Michigan Agriculture in the Classroom. (n.d.). *About us*. Retrieved from https://miagclassroom.org/about/index.cfm

Mobile Laboratory Coalition. (2016). *Vision of the mobile laboratory coalition*. Retrieved from http://www.mobilelabcoalition.com/wp/

National Agriculture in the Classroom. (n.d.). *About agriculture in the classroom*. Retrieved from http://agclassroom.org/get/about.htm

National Center for Education Statistics. (n.d.a). *About us*. Retrieved from https://nces.ed.gov/about/

National Center for Education Statistics. (n.d.b). *Common core of data glossary*. Retrieved from https://nces.ed.gov/ccd/commonfiles/glossary.asp

National Research Council. (1988). *Understanding agriculture: New directions for education*. Retrieved from http://www.nap.edu/catalog/766/understanding-agriculture-new-directions-for-education

National Research Council. (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press. Retrieved from https://www.nap.edu/read/13165/chapter/1

Pense, S., Leising, J., Portillo, M., & Igo, C. (2005). Comparative assessment of student agricultural literacy in selected agriculture in the classroom programs. *Journal of Agricultural Education, 46*(3) 107-118. doi: 10.5032/jae2005.03107

Perkins, D. (2008). *Levels of thinking in Bloom's taxonomy and Webb's depth of knowledge*. Retrieved from https://education.ohio.gov/getattachment/Topics/Teaching/Educator-Evaluation-System/How-to-Design-and-Select-Quality-Assessments/DOK-Compared-to-Blooms-Taxonomy.pdf.aspx

Quay, J. (2003) Experience and participation: Relating theories of learning. *The Journal of Experiential Education, 26*(2) 105-116.

Roberts, T. G., Harder, A., & Brashears, M. T. (2016). *American Association for Agricultural Education national research agenda: 2016-2020*. Gainesville, FL: Department of Agricultural Education and Communication. Retrieved from http://aaaeonline.org/resources/Documents/AAAE_National_Research_Agenda_2016-2020.pdf

Spielmaker, D. M., & Leising, J. G. (2013). *National agricultural literacy outcomes*. Logan, UT: Utah State University, School of Applied Sciences & Technology. Retrieved from http://agclassroom.org/teacher/matrix

Spielmaker, D. M., Pastor, M., & Stewardson, D. M. (2014, May). *A logic model for agricultural literacy programming*. Poster presented at *the* 41st annual meeting of the American Association for Agricultural Education, Snowbird, UT.

Taylor, E., & Wozniak, R. (1996). *Pure experience, the response to William James: An introduction*. Retrieved from http://psychclassics.yorku.ca/James/TaylorWoz.htm

Willis, J. (2007). The neuroscience of joyful education. *Educational Leadership, 64* [online version]. Retrieved from http://www.ascd.org/publications/educational-leadership/summer07/vol64/num09/The-Neuroscience-of-Joyful-Education.aspx

Young, M. F. (1993). Instructional design for situated learning. *Educational Technology Research and Development, 41*(1) 43-58. Retrieved from http://www.jstor.org/stable/30218369

Zabawa, R. (2012). *Tuskegee Institute movable school*. Retrieved from http://www.encyclopediaofalabama.org/article/h-1870

APPENDICES

Appendix A

Logic Model for Agricultural Literacy

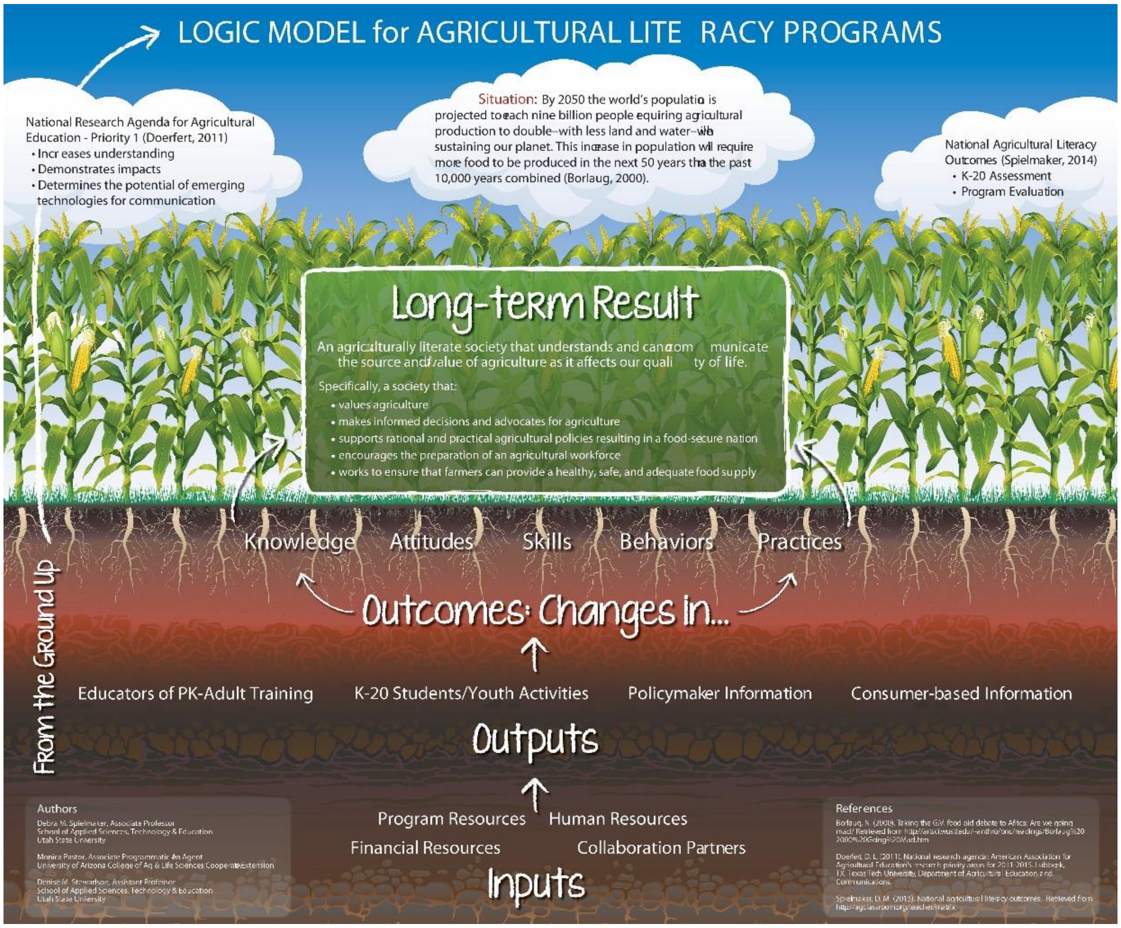


Figure A1. Logic model for agricultural literacy.

Appendix B

Extraction of Life Lesson Plan and Assessment

Extraction of Life

Grade Level: 3rd-5th grade	Topic: Wheat and Genetics	Estimated Time: 50 minutes

Brief Lesson Description: Students will unravel plant genetics by identifying structures within a plant cell, discovering the location of DNA inside each cell. Using wheat as an example, students will follow a procedure to extract plant DNA. Throughout the guided discussion and experiment, students will explore careers related to plant science and facts about Michigan agriculture.

Next Generation Science Standards:

Performance Expectation(s):

3-LS3-1: Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.

LS3.B: Variation of Traits: Different organisms vary in how they look and function because they have different inherited information.

3-LS3-2: Use evidence to support the explanation that traits can be influenced by the environment.

4-LS1-1: Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

5-PS1-1: Develop a model to describe that matter is made of particles too small to be seen.

National Agricultural Literacy Outcomes:

T3.3-5 f: Identify careers in food, nutrition and health.

T4.3-5 c: Identify examples of how the knowledge of inherited traits is applied to farmed plants and animals in order to meet specific objectives (i.e., increased yields, better nutrition, etc.).

T4.3-5 d: Provide examples of science being applied in farming for food, clothing, and shelter products.

T5.3-5 b: Discover that there are many jobs in agriculture.

T5.3-5 d: Explain the value of agriculture and how it is important in daily life.

Specific Learning Outcomes

Students will:

1. Identify components of DNA including phosphates, sugars, nitrogen bases (adenine, thymine, cytosine, and guanine), and double-helix twisting structure.
2. Explain the function of the cell wall, cytoplasm, nucleus and chromosomes of a plant cell, recognizing cells are too small to be seen with the naked eye.
3. Name one career related to the study of genetics.

Narrative / Background Information

Prior Student Knowledge:

1. **Students should be familiar with:**
    a. Basic role of a farmer
    b. Plants are living organisms
    c. Basic role of a scientist
    d. Humans and plants inherit traits/genetic material from their parents

Materials

Student Station Set-up

Each station should have the following:

- One per student pencil
- One per student lab sheet
- Measuring spoons
- Hand lens
- Test tub rack
- One test tube
- One plastic cup
- One popsicle stick
- One bottle of hand soap
- One container of wheat germ
- One container baking soda
- One container meat tenderizer

Teacher Station Set-up

Positioned under document camera:

- Laminated DNA Lab Sheets (cell diagram side first)

Additional Items:

- Plant Cell Model
- DNA Structure Model

For DNA extraction:

- 1 quart measuring bowl filled half full with warm water
- Cold denatured alcohol

TEACHER NOTE:
Heat water for approximately 3 minutes prior to start of lesson, it will cool to appropriate temperature by the time it's needed.

Use small graduated cylinder in the refrigerator to prep denatured alcohol. 2/3 full will be enough for each station to receive one pipette. Leave in refrigerator until needed.

Engage-15 minutes

PURPOSE:
Activities capture the students' attention, connect their thinking to the situation, and help them access current knowledge. This sequence of lessons initiates the learning tasks. The activities should (1) activate prior knowledge and make connections between past and present learning experiences, and (2) anticipate activities and focus students' thinking on the learning outcomes of current activities. The learner should become mentally engaged in the concepts, practices, abilities, and skills of the curriculum unit.

1. **Ask:** How do you think farms or farming and science are connected?
   a. Allow students to lead discussion, but drive toward appropriate scientific components in plant, animal and food science. Understanding how plants grow, animal nutrition, making food and keeping it safe are all parts of science.
   b. Use Michigan commodity posters on the lab walls to guide discussion using locally grown examples.
2. **Explain:** Today we are going to be plant scientists. The first step in an experiment is to think about what we already know about what we are studying. So as plant scientists, we

have to think about what we already know about plants.

a. **Ask:** What do we know about plants? Drive students to discuss plants needs such as water, sunlight, processes like photosynthesis, etc. Also, discuss plant looks, uses, products, etc. Each plant is different because of its genetics, just like you and I are different because of our genetics. Like humans, plants inherit traits from their parents. Plant scientists study plant genetics to understand how plants pass on traits to their offspring. This helps a farmer predict which plants will produce the highest yield, a certain color flower, grow taller or shorter, or have larger fruit. To learn more about this genetic make-up, first we have to think about what we already know about plants and how they function.
b. Use plant cell model to explain all living things are made of cells. Plant and animal cells are slightly different, today we are focusing on a plant cell.

3. **Label:** Guide students to label parts of the plant cell diagram. Today, we are only labeling a few parts that are important to identify and find the parts important to the genetic make-up of a plant cell. (see attached answer key)

> TEACHER NOTE:
> *Label the laminated copy under the document camera and project it onto the TV so students can follow along.*
>
> *Guide students to use learning practices, such as crossing off words out of the word bank as the words are used.*

   a. Cell Wall—a ridged membrane which provides structure to the cell.
      Unique to plants, as plants don't have bones or muscles to help them stand up. Plants rely on this wall to give them structure.
   b. Cytoplasm—fills the inside of the cell to house the organelles (other parts of a cell).
   c. Chloroplast—unique to plant cells, important for photosynthesis, the process by which plants make their own food.
   d. Nucleus—command center of the cell, regulates all the processes of the cell and houses the cell's genetic information.
   e. Chromosomes—house genetic information of a cell, called DNA.
4. **Transition:** Plant scientists have to be able to isolate or separate that DNA from the rest of the cell in order to study it. Today, we are going to take that first step, to isolate the DNA.
   a. Today the plant cells we will be using come from this plant (show dish of wheat seeds).
   b. Discuss uses of wheat.
   c. Much of the wheat grown in Michigan is milled into flour then sold to Kellogg's to make cereal!

Explore and Explain—30 minutes

PURPOSE:
Students investigate initial ideas and solutions in meaningful contexts. This phase provides students with a common base of experiences within which they identify and begin developing concepts, practices, abilities, and skills. Students actively explore the contextual situation through investigations, reading, web searches, and discourse with peers.
PURPOSE:
Based on an analysis of the exploration, students develop an explanation for the concept and practices. Their understanding is clarified and modified through the teacher's descriptions and definitions. This phase focuses on developing an explanation for the activities and situations students have been exploring. They verbalize their understanding of the concepts and practices. The teacher introduces formal labels, definitions, and explanations for concepts, practices, skills, and abilities.

1. **Students: Add 1 teaspoon of wheat germ into the plastic cup and stir with a popsicle stick a few** times. The water should start to change color, a light yellow.
2. **Teacher:** Pour warm water into each groups' cups, **about 1/3 full.**
3. **Students: Add two full pumps of hand soap into** the cup/beaker, stir a few more times, but not so hard that you generate many/large bubbles.
4. **Students: Add 1/2 tsp baking soda and 1/4 tsp meat tenderizer** into the cup; **stir slowly for 5-10 minutes.**
5. **Teacher:** While we are stirring, let's talk about the structure of what we're looking for, DNA, Deoxyribonucleic Acid. Continue to stir your mixture and take turns so that everyone can complete their lab sheet and have a chance to stir the mixture. Use DNA model to assist in completing DNA diagram.
    a. Does anyone know what the structure/shape of DNA is called? (Double Helix)
        i. Outside structure of the helix is made of sugars and phosphates. (purple and red on model)
        ii. Inside "rungs" are made up of bases, which have specific pairings. These pairs always match in the same way.
        iii. In science, sometimes we use complicated words, so we can use the first letters as abbreviations. Adenine and Thymine pair together, so A and T. Guanine and Cytosine pair together, so G and C.
        iv. Walk students through guessing all the pairs down the rest of the diagram on their lab sheet. "If this one is an A, then its partner must be a ....." and so on.
        v. Explain this diagram is extremely enlarged and the colors are for labeling purposes and do not reflect actual color of DNA.
6. After 5-10 minutes has passed, instruct students to stop stirring and let the contents of the cup settle.
7. **Teacher:** Demonstrate how to use the pipette.
8. **Students:** Use the pipette to move **only the liquid** portion of the mixture to the test tube. Fill the test tube to where the rack hits the tube, approximately 2/3 full. We do not want the solids from the bottom of the cup in the test tube!
9. **Teacher:** Add 1 pipette of cold denatured alcohol to the test tube liquid. Instruct students to leave the test tube sit for a minute, without touching or shaking the tube.
10. **Teacher:** While we are waiting for a minute, let's talk about what we have done.
    a. First we added water to the wheat germ. Water expands the cells.
    b. The soap breaks down the bonds that hold the cells together. Remember, we only want to look at one tiny part of the cell.

TEACHER NOTES
Water needs to be warm, not hot. Err on the side of a little too warm.

When pouring water into cups with wheat germ, 1/3 to ½ full is fine. Less is more as this will make the concentration of other ingredients higher.

TEACHER NOTE
Emphasize the gentle transfer of liquids using pipettes.

Students should leave test tubes in the racks while transferring the liquids so as not to spill or shake up the mixture.

Points that maybe helpful to understand but may not be appropriate to explain to the students:
The enzyme in the meat tenderizer which assists in the breakdown of the nucleus membrane is called papain.
The baking soda helping keep a near-neutral pH of the solution, which might be too complex to explain at this level.

c. The meat tenderizer contains an enzyme which completes the breakdown of the membrane around the nucleus.
d. The baking soda helps to increase the effectiveness of this enzyme.
e. Last we added cold denatured alcohol. This helps the DNA to precipitate (separate) from the rest of the solution. We should be able to see this now at the top of the liquid in our test tube.

11. Students: Watch the DNA strands appear at the interface (where the two layers meet) between the wheat germ solution and the denatured alcohol. We are looking for those twisty, double-helix strands coming from a white cloud of DNA.

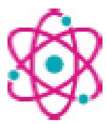
Evaluate-5 minutes

PURPOSE:
Students assess their understanding of the concepts, and teachers have the opportunity to assess student learning. This phase emphasizes students assessing their understanding and abilities and provides opportunities for teachers to evaluate students' understanding of concepts and practices identified in performance expectations.

Teachers have been provided pre and posttest links for their selected lesson. The same questions are asked on both assessments. Use these questions to review and wrap up the day's learning.

_______ contain DNA. Living Things or Non-Living Things

Which photo shows the structure of DNA?

A plant scientist would need to know DNA's base pairs always have the same partners, A-T and C-G. True or False

A person who studies wheat genetics is a
Plant scientist
Account manager
Veterinarian
Water conservationist

Farmers and plant scientists need to know about inherited traits to
Increase yield, select for flower color, predict fruit size, determine plant height, all of the above

Where is the genetic information of the cell? Cell wall, cytoplasm, nucleus, chloroplast

The food we eat contains DNA. True or false

Sources:

1. Adapted from Agricultural Biotechnology, From DNA to GMOs, Michigan Agriculture in the Classroom.
2. Wheat Germ DNA Extraction, Flinn Scientific.
3. Diagram labels and definitions adapted from Florida State University Molecular Expressions.

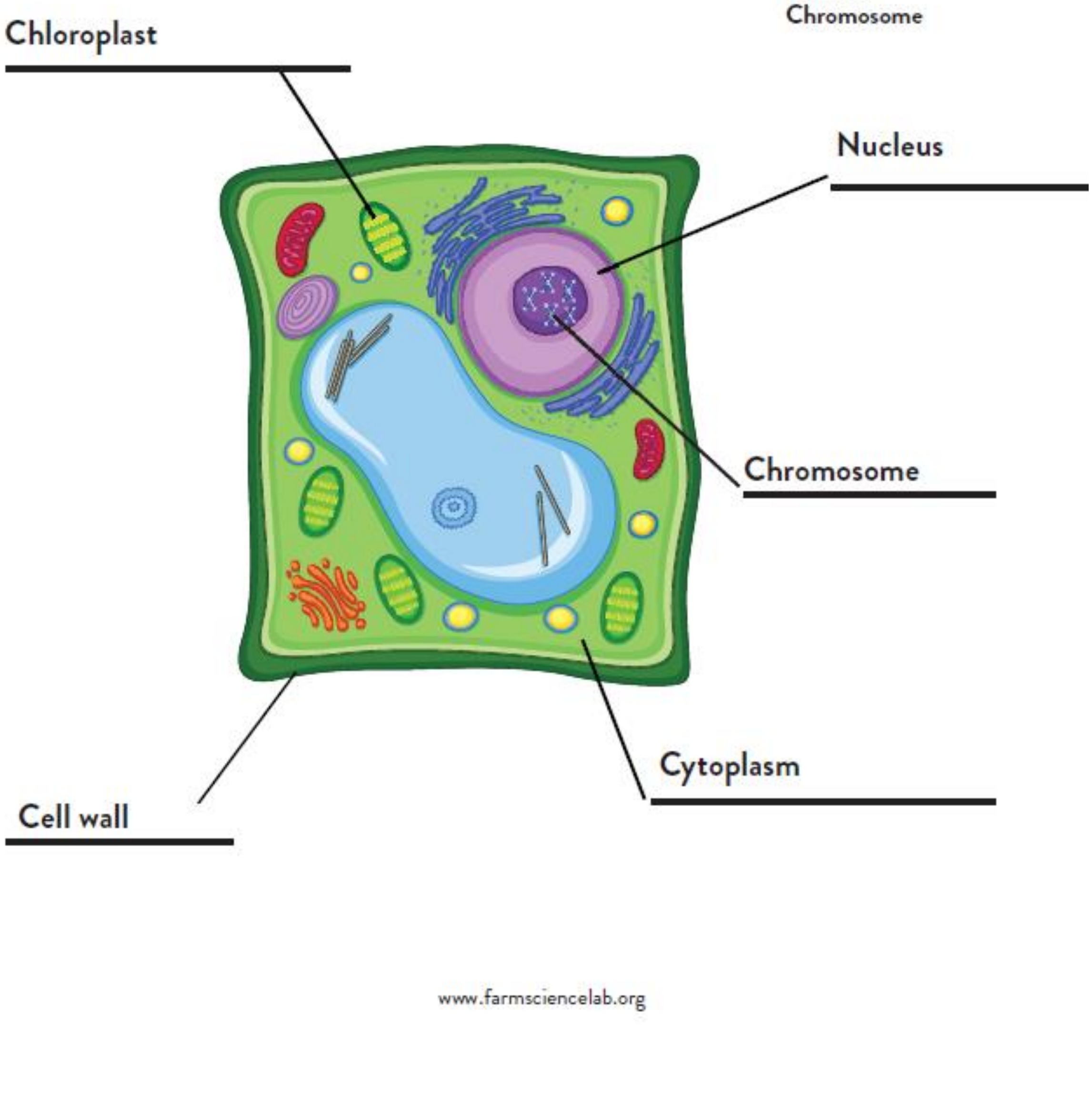
FARM
Food, Agriculture & Resources in Motion
Science Lab

Name ______________________

Extraction of Life Lab Sheet

Label the plant cell diagram.

Word Bank
Chloroplast
Cell Wall
Cytoplasm
Nucleus
Chromosome

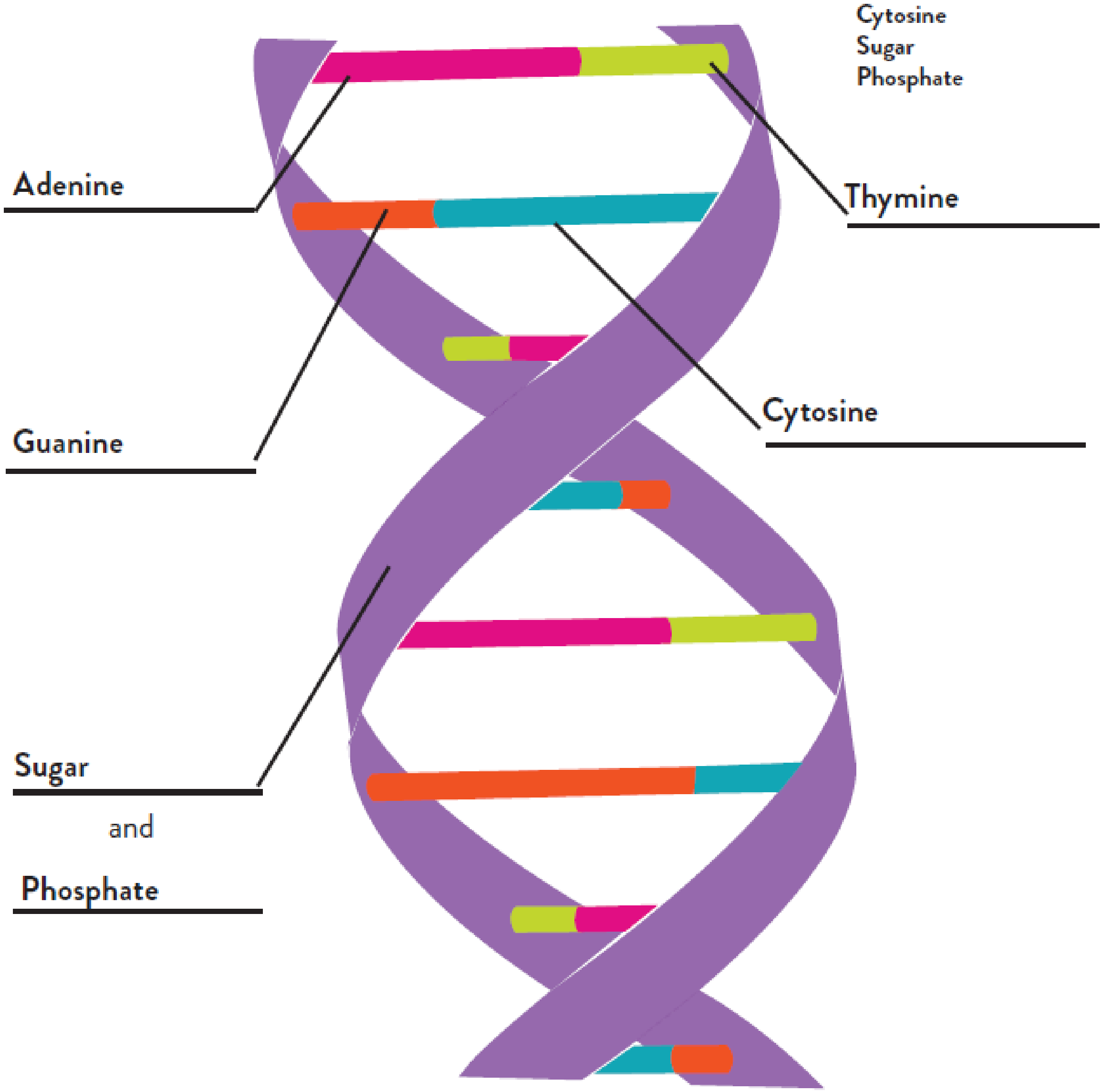


FARM
Food, Agriculture & Resources in Motion
Science Lab

Name ______________________________

Word Bank
Adenine
Guanine
Thymine
Cytosine
Sugar
Phosphate

Deoxyribonucleic Acid (DNA)



FARM
Food, Agriculture & Resources in Motion

Extraction of Life

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

What is your student number? *

Your answer

What grade are you in? *

Choose

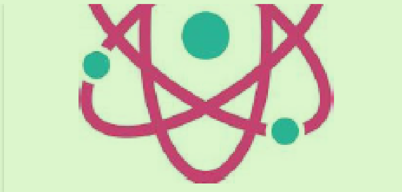
Who is your teacher? *

Choose

_______________ contain DNA.

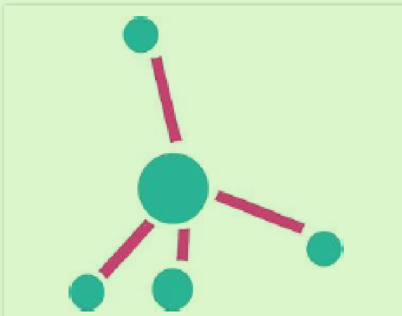
- Living things
- Non-living things

Which photo shows the structure of DNA?



A

B



C

A plant scientist would need to know DNA's base pairs always have the same partners, A-T and C-G.

- True
- False

A person who studies wheat genetics is a

- Plant scientist
- Account manager
- Veterinarian

- Water conservationist

Farmers and plant scientists need to know about inherited traits to

- increase yield
- select for flower color
- predict fruit size
- determine plant height
- All of the above

Where is the genetic information of the cell?

- Cell Wall
- Cytoplasm
- Nucleus
- Chloroplast

The food we eat contains DNA

- True
- False

Page 1 of 1

SUBMIT

Group 2 Pretest

Extraction of Life

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number? ***

____

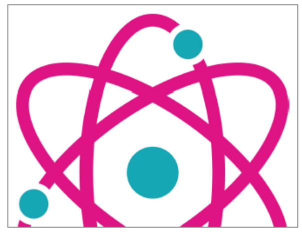
2. **What grade are you in? ***
Mark only one oval.
- 3rd Grade
- 4th Grade
- 5th Grade
- I don't see my grade here.

3. **Who is your teacher? ***
Mark only one oval.
- Bacha
- Kozlo
- Theobald
- Mayes

4. **I am excited to learn more about science on the farm. ***
Mark only one oval.
- yes
- no

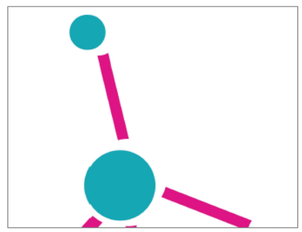
5. **_______________ contain DNA. ***
Mark only one oval.
- Living things
- Non-living things
- I don't know

6. **Which photo shows the structure of DNA? ***
Mark only one oval.



A

B



C

I don't know

7. **A plant scientist would need to know DNA's base pairs always have the same partners, A-T and C-G. ***
Mark only one oval.
- True
- False
- I don't know

t genetics is a *

9. **Farmers and plant scientists need to know about inherited traits to ***
Mark only one oval.
- increase yield
- select for flower color
- predict fruit size
- determine plant height
- All of the above
- I don't know

10. **Where is the genetic information of the cell? ***
Mark only one oval.
- Cell Wall
- Cytoplasm
- Nucleus
- Chloroplast
- I don't know

11. **The food we eat contains DNA ***
Mark only one oval.
- True
- False
- I don't know

Group 2 Posttest

Extraction of Life

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number?** *

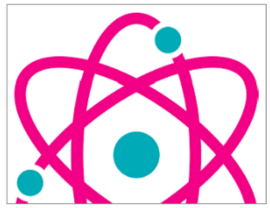
____

2. **What grade are you in?** *
Mark only one oval.
- ◯ 3rd Grade
- ◯ 4th Grade
- ◯ 5th Grade
- ◯ I don't see my grade here.

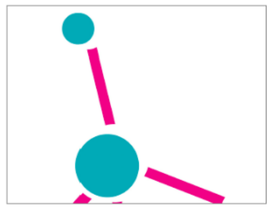
3. **Who is your teacher?** *
Mark only one oval.
- ◯ Bacha
- ◯ Kozlo
- ◯ Theobald
- ◯ Mayes

4. **______________ contain DNA.** *
Mark only one oval.
- ◯ Living things
- ◯ Non-living things

5. **Which photo shows the structure of DNA?** *
Mark only one oval.


- ◯ A


- ◯ B


- ◯ C

6. **A plant scientist would need to know DNA's base pairs always have the same partners, A-T and C-G.** *
Mark only one oval.
- ◯ True
- ◯ False

person who studies wheat genetics is a *
ark only one oval.
- ◯ Plant scientist
- ◯ Account manager
- ◯ Veterinarian
- ◯ Water conservationist

8. **Farmers and plant scientists need to know about inherited traits to** *
Mark only one oval.
- ◯ increase yield
- ◯ select for flower color
- ◯ predict fruit size
- ◯ determine plant height
- ◯ All of the above

9. **Where is the genetic information of the cell?** *
Mark only one oval.
- ◯ Cell Wall
- ◯ Cytoplasm
- ◯ Nucleus
- ◯ Chloroplast

10. **The food we eat contains DNA** *
Mark only one oval.
- ◯ True
- ◯ False

11. **I thought the FARM Science Lab ____________.** *
Mark only one oval.
- ◯ was awesome.
- ◯ was good.
- ◯ was just okay.
- ◯ could have been better.
- ◯ was bad.

Appendix C

Field Plastic Lesson Plan and Assessment

Field Plastic

Grade Level: 3rd-5th	Topic: Corn	Estimated Time: 50 minutes

Brief Lesson Description: Students will describe how plant-based products are used in daily life. Then, students will make observations, predictions and write a hypothesis while investigating the differences between a biodegradable packing peanut and a petroleum-based packing peanut. In groups, students will make a corn-based plastic to take home.

Next Generation Science Standards:

Performance Expectation(s):

3-5ETS1-1: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

5-PS1-2: Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

5-PS1-3: Make observations and measurements to identify materials based on their properties.

5-PS1-4: Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

National Agricultural Literacy Outcomes:

T1.3-5 e: Recognize the natural resources used in agricultural practices to produce food, feed, clothing, landscaping plants, and fuel (e.g., soil, water, air, plants, animals, and minerals).

T2.3-5 b: Distinguish between renewable and non-renewable resources used in the production of food, feed, fuel, fiber (fabric or clothing) and shelter.

T4.3-5 d: Provide examples of science being applied in farming for food, clothing, and shelter products.

T5.3-5 b: Discover that there are many jobs in agriculture.

T5.3-5 d: Explain the value of agriculture and how it is important in daily life.

Specific Learning Outcomes:

Students will be able to:

1. Identify renewable and nonrenewable resources and define biodegradable.
2. Compare petroleum and plant based-Styrofoam by running a series of tests and comparing the results.
3. Identify types of physical properties.
4. Describe how plants can be used in everyday products such as food, fuel and fiber.

Narrative / Background Information

Prior Student Knowledge:

Students should be familiar with:

a. Basic role of a farmer
b. Plants are living organisms
c. Basic role of a scientist
d. How to use measuring spoons
e. Basic understanding of physical and chemical properties, or observing characteristics of objects

Materials

Student Station Set-up:

Each student station should have the following:

- One corn-based grocery item
- 1 Styrofoam packing peanut in a small container with a lid
- 1 corn foam packing peanut in a small container with a lid
- 1 water bottle (2 tablespoons will be needed, plus some for packing peanut investigation)
- 2 tablespoons of corn starch, pre-measured in a container
- 1 dropper bottle of corn oil
- 1 sandwich size Ziploc bag, labeled with station number
- 1 set of measuring spoons
- 1 pencil per student
- 1 Field Plastic Lab Sheet per student

TEACHER'S NOTE

Pre-measure corn starch one to two classes in advance for quick transitions.

2 drops of food coloring is needed per bag of corn plastic mixture. Students do not use the food coloring. Teacher should walk around placing two drops in each bag when ready.

Typically stations are set for 3 students each. Use class counts provided to determine set up.

Teacher Station Set-up

- 2 additional sandwich size Ziploc bags labeled with station numbers (for dividing plastic for students to take home)
- Container/ear of field corn
- Microwave
- Hot pad
- Laminated lab sheet with document camera

Engage-10 minutes

PURPOSE:

Activities capture the students' attention, connect their thinking to the situation, and help them access current knowledge. This sequence of lessons initiates the learning tasks. The activities should (1) activate prior knowledge and make connections between past and present learning experiences, and (2) anticipate activities and focus students' thinking on the learning outcomes of current activities. The learner should become mentally engaged in the concepts, practices, abilities, and skills of the curriculum unit.

1. **Ask:** How do you think farms or farming and science are connected?
    a. Allow students to lead the discussion, but drive toward appropriate scientific components in plant, animal and food science. Such as understanding how plants grow, animal nutrition, making food, keeping it safe, and what products we can make from agricultural products are all parts of science.
    b. Use Michigan commodity posters on the lab walls to guide discussion using locally grown examples.
2. **Instruction:**
    a. Provide each station with one corn-based product sample.
    b. Ask students to examine the products at their station, figure out what it is, if they've used the product before, etc.
    c. Ask each group to report to the class what item they have, identifying any similarities as the groups report, leading students to conclude all products have corn as a main ingredient.
    d. Ask students why we might want products made from plants. Answers could include: corn is a vegetable, taste-based, etc. Drive toward the idea that plants are a renewable resource, we can plant more each year, harvest each year, and easily make more products from them.
    e. Highlight one group that had the cup and the plastic bag. These are examples of items that could be made from petroleum, a **non-renewable resource. Product Engineers** help us to look for new ways to make/manufacture common items from different ingredients, like using a renewable resource such as corn to preplace a non-renewable resource like petroleum in plastics. Today we are going to think like product engineers to investigate items made of corn.

Explore-15 minutes

PURPOSE:
Students investigate initial ideas and solutions in meaningful contexts. This phase provides students with a common base of experiences within which they identify and begin developing concepts, practices, abilities, and skills. Students actively explore the contextual situation through investigations, reading, web searches, and discourse with peers.

1. **Explain:** As part of the process of an experiment, scientists have to make observations. One set of characteristics that can be observed are an object's physical proprieties.
2. **Ask:** Can anyone name a physical property?
    a. Guide students through making observations of the physical properties of an ear of field corn (or field corn in a container if ear isn't available) as a demonstration of how to observe physical properties.
    b. Students should fill in types of physical properties on the Field Plastic Lab Sheet. Responses could include color, weight, texture, size, floating or sinking, etc.
3. Now that we understand more about physical properties, we are going to make observations about these packing peanuts. One packing peanut is made from corn and one is not.

TEACHER'S NOTE
Be clear these are NOT real peanuts nor do they contain any peanut material. Students and teachers may be concerned with the use of the word peanut due to allergies.

4. Discuss observations of physical properties, asking groups to share observations.
5. Tell students another way to observe objects is to see what happens when they are put in water. Have students predict (a scientific guess) what will happen to the two different packing peanuts in water. Students will share a variety of responses. *Students should turn their predictions into a hypothesis statement (a complete sentence) and write it at the bottom of their lab sheet.*
6. Instruct students to fill each packing peanut's container half full with water.
    a. Students should continue recording observations as they watch the packing peanuts for a few minutes.
7. As a class, discuss the student's observations. (Students should explain that the corn peanut broke apart, while the Styrofoam peanut remained unchanged and intact.)
8. Ask Did your results prove or disprove your hypothesis? What did we learn?

Explain—2-3 minutes

PURPOSE:
Based on an analysis of the exploration, students develop an explanation for the concept and practices. Their understanding is clarified and modified through the teacher's descriptions and definitions. This phase focuses on developing an explanation for the activities and situations students have been exploring. They verbalize their understanding of the concepts and practices. The teacher introduces formal labels, definitions, and explanations for concepts, practices, skills, and abilities.

TEACHER NOTE
Lower grade levels will need stronger guidance in this portion of the lesson. Be aware of grade appropriate terms for these definitions.

1. Explain to the students that peanuts reacted differently to water because the corn-based packing peanut is biodegradable.
    a. Ask: What does biodegradable mean? Why would we want a packing peanut to be biodegradable? What do we usually do with packing peanuts when we are done with them? Drive students to realize the importance of biodegradable products, including need to reduce waste, use renewable resources as ingredients, recycle, danger to wildlife or farm animals if littered in the environment, etc.

Vocabulary for the lab:
Biodegradable: capable of being decomposed by bacteria or other living organisms.
Non-renewable resource: cannot be reproduced or regenerated within one generation.
Renewable resource: can be replaced by nature or humans at a sustainable rate.
Petroleum: a liquid mixture derived from crude oil, considered a fossil fuel, taking thousands of years to make deep underneath the earth's surface.
Physical property: can be observed or measured without changing the composition of matter. *Physical properties* are used to observe and describe matter.
Recyclable: capable of being reused.

Elaborate—10 minutes

PURPOSE:
Students have opportunities to expand and apply their understanding of the concepts within new contexts and situations. These lessons extend students' conceptual understanding through opportunities

for students to apply knowledge, skills and abilities. Through new experiences, the learners transfer what they have learned and develop broader and deeper understanding of concepts about the contextual situation and refine their skills and abilities.

1. Ask students, “Can we make something from corn here today?” Have students raise hands to vote yes or no.
2. As packaging engineers we are going to make plastic from corn.
3. Walk the students through the following lab procedures. Stress the importance of following directions and working as a team:
   a. Place 2 tablespoons cornstarch (already measured out in plastic cups) into your labeled Ziploc bag.
   b. Add 4 drops of corn oil to the cornstarch.
   c. Add 2 tablespoons water to the corn oil and cornstarch mixture.
   d. Place 2 drops of food coloring to the mixture. **Teacher completes this step.**
   e. Carefully close the Ziploc bag and explain how to knead (mix) the contents.
   f. Explain that all the lumps need to be out of the mixture, make sure there is no corn starch on the corners of the bag. The mixture should be liquid in nature.
   g. Once well mixed collect each group’s bag.
   h. Heat one bag at a time. Make sure the bag is placed flat in microwave. Heat the mixture in a microwave for 30 seconds at a high setting. ***Careful the contents are extremely hot, use pot holder if needed.***
   i. Once cooled, tear plastic into equal pieces for each lab partner and place in separate bags for students to take home.
   j. While plastic is heating, show students a quick video of a Michigan corn farmer.
      1. Highlight sections of video such as green corn plants, dried corn, harvest, combine, feeding to cattle, etc. and connect to previous discussions in lesson.

TEACHER’S NOTE

Instruct students to write their station number on their lab sheet so they remember which plastic bag belongs to them later.

If time is running short, the volunteer could microwave plastic after students have left and take cooled, completed product to the classroom before the end of the day.

Evaluate

PURPOSE:
Students assess their understanding of the concepts, and teachers have the opportunity to assess student learning. This phase emphasizes students assessing their understanding and abilities and provides opportunities for teachers to evaluate students’ understanding of concepts and practices identified in performance expectations.

EVALUATE:

Summative Assessment (Quiz / Project / Report):

To wrap up lesson, review key terms used throughout lesson and in assessment questions including:

1. Which resource is renewable? Coal, corn, natural gas, ground water
2. Which product could be used to create biodegradable packing material? corn
3. What would you use to determine the physical properties of an object? Sight, touch, scale, ruler, all of the above

4. A biodegradable product will breakdown quicker in a landfill.– **true** or false

5. An agricultural scientist might investigate corn as an ingredient for: pop, plastic bags, fuel, **all of the above**

Sources/Credits:

1. Adapted from Corn an A-maizing Plant, Oregon, Utah and Illinois Agriculture in the Classroom
2. Adapted from Pennsylvania Mobile Ag Ed Science Lab Lesson, *Corn to Plastic*.
3. Information adapted and used from, https://www.agexplorer.com/

FARM
Food, Agriculture & Resources in Motion
Science Lab

Name ____________________

Field Plastic Lab Sheet

List examples of physical properties:

Weight	Texture/feel	
Size	Float/Sink	
Color		

Record your observations.

Styrofoam Packing Peanut	Corn-Based Packing Peanut
Smooth	Squishy
S-Shaped	Less white
Hard	looks like a noodle
Bright white	Smells funny
Bigger	Smaller
Floats	Floats at first
Justs gets wet	Slimey
	Dissolves/breaks down

Hypothesis

If I add water to the corn peanut then it will dissolve.

If I add water to the styrofoam peanut then it will float.

FARM
Food, Agriculture & Resources in Motion
Science Lab

Field Plastic

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

What is your student number? *

Your answer

What grade are you in? *

- 3rd Grade
- 4th Grade
- 5th Grade
- I don't see my grade here.

Who is your teacher? *

Choose

Which resource is renewable?

- Coal
- Corn
- Natural Gas

Groundwater

Which product could be used to create biodegradable packing material?

- Corn
- Oil
- Wood
- Water

What would you use to determine the physical properties of an object?

- Sight
- Touch
- Scale
- Ruler
- All of the above

A biodegradable product will breakdown quicker in a landfill.

- True
- False

An agricultural scientist might investigate corn as an ingredient for

- pop
- plastic bags
- fuel

◯ All of the above

Page 1 of 1

SUBMIT

Never submit passwords through Google Forms.

Group 2 Pretest

Field Plastic

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number?** *

2. **What grade are you in?** *
   Mark only one oval.
   - 3rd Grade
   - 4th Grade
   - 5th Grade
   - I don't see my grade here.

3. **Who is your teacher?** *
   Mark only one oval.
   - Porzondek
   - Held
   - Gajda

4. **I am excited to learn more about science on the farm.** *
   Mark only one oval.
   - Yes
   - No

5. **Which resource is renewable?** *
   Mark only one oval.
   - Coal
   - Corn

6. **Which farm product could be used to create biodegradable packing material?** *
   Mark only one oval.
   - Corn
   - Oil
   - Wood
   - Water
   - I don't know.

7. **What would you use to determine the physical properties of an object?** *
   Mark only one oval.
   - Sight
   - Touch
   - Scale
   - Ruler
   - All of the above
   - I don't know

8. **A biodegradable product will breakdown quicker in a landfill.** *
   Mark only one oval.
   - True
   - False
   - I don't know.

9. **An agricultural scientist might investigate corn as an ingredient for** *
   Mark only one oval.
   - pop
   - plastic bags
   - fuel
   - All of the above
   - I don't know.

Group 2 Posttest

Field Plastic

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number?** *

2. **What grade are you in?** *
Mark only one oval.
- 3rd Grade
- 4th Grade
- 5th Grade
- I don't see my grade here.

3. **Who is your teacher?** *
Mark only one oval.
- Porzondek
- Held
- Gajda

4. **Which resource is renewable?** *
Mark only one oval.
- Coal
- Corn
- Natural Gas
- Groundwater

5. **Which farm product could be used to create biodegradable packing material?** *
Mark only one oval.
- Corn
- Oil
- Wood

6. **What would you use to determine the physical properties of an object?** *
Mark only one oval.
- Sight
- Touch
- Scale
- Ruler
- All of the above

7. **A biodegradable product will breakdown quicker in a landfill.** *
Mark only one oval.
- True
- False

8. **An agricultural scientist might investigate corn as an ingredient for** *
Mark only one oval.
- pop
- plastic bags
- fuel
- All of the above

9. **I thought the FARM Science Lab ____________.** *
Mark only one oval.
- was awesome.
- was good.
- was just okay.
- could have been better.
- was bad.

Appendix D

Parts Per What Lesson Plan and Assessment

FARM Science Lab

Parts Per What

Grade Level: 4th-5th grade	Topic: Water Conservation/ Protection	Estimated Time: 50 minutes

Brief Lesson Description:
Students will demonstrate water flow through a watershed, identifying landforms and possible sources of water contamination. Then, students will explore ways farmers work to protect the environment, including watersheds, by planting buffers trips, using precision technologies to apply fertilizers or manage water use on their farms. Finally, students will dilute a "contaminant" in a water sample to demonstrate water clarifying practices. Lesson includes division of fractions and decimals starting with 1/10 and progressing to 1/1,000,000.

Next Generation Science Standards

Performance Expectation(s):

4-ESS2-1: Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.

5-ESS2-1: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

5-PS1-1: Develop a model to describe that matter is made of particles too small to be seen.

National Agricultural Literacy Outcomes:

T1.3-5 c: Identify land and water conservation methods used in farming systems (wind barriers, conservation tillage, laser leveling, GPS planting, etc.)

T1.3-5 e: Recognize the natural resources used in agricultural practices to produce food, feed, clothing, landscaping plants, and fuel (e.g., soil, water, air, plants, animals, and minerals).

T2.3-5 e: Understand the concept of stewardship and identify ways farmers/ranchers care for soil, water, plants, and animals.

T4.3-5 d: Provide examples of science being applied in farming for food, clothing, and shelter products.

T5.3-5 b: Discover that there are many jobs in agriculture.

Specific Learning Outcomes:
Students will be able to:

1. Identify possible sources of surface and ground water contamination.
2. Recognize how water is used in agricultural production and the conservation practices employed by farmers to maintain or improve the quality of our water.
3. Measure the dilution of a contaminant in water by dividing fractions of the contaminant in a water sample.
4. Name two careers related to water quality.

Narrative / Background Information

Prior Student Knowledge:
Students should be familiar with:

1. Understand fractions
2. Know the difference between a numerator and denominator
3. Understand the basic steps of the water cycle
4. Understand what makes something a pollutant

Materials

Student Lab Group Set-up
1 package of food coloring in plastic container
1 plastic sample cup half full of clean water
1 well plate (label wells 1-7)
1 pipette
1 per student Parts Per What Lab Sheet
1 per student pencil
1 plain 8.5x11" paper
4 colored washable markers
1 small water spray bottle (to be shared between stations)

Teacher Workstation Set-up
1 5 gallon pail
1 pipette
1 plastic sample cup of water

Engage-10 minutes

PURPOSE:
Activities capture the students' attention, connect their thinking to the situation, and help them access current knowledge. This sequence of lessons initiates the learning tasks. The activities should (1) activate prior knowledge and make connections between past and present learning experiences, and (2) anticipate activities and focus students' thinking on the learning outcomes of current activities. The learner should become mentally engaged in the concepts, practices, abilities, and skills of the curriculum unit.

1. **Ask:** How do you think farms or farming and science are connected?
    a. Allow students to lead discussion, but drive toward appropriate scientific components in plant, animal and food science. Understanding how plants grow, animal nutrition, making food and keeping it safe are all parts of science.
    b. Use Michigan commodity posters on the lab walls to guide discussion using locally grown examples.
    c. Ask students to identify what things farmers need to grow the items discussed above. Use guided questions until students identify water as a need. Continue class discussion to help students recognize the importance of water in our lives, including the importance of our Great Lakes in precipitation and as a water source. Today we are going to be hydrologists, a water scientist who studies the movement, quality and distribution of water on Earth.
2. **Instruction:** Let's investigate more about how water moves on Earth. Each lab group should have an 8 ½ x 11 sheet of paper. Instruct them to crumple the paper into a tight ball. Gently open the paper, but don't flatten completely. Tell students that this piece of crumpled paper represents a watershed. On their paper watershed, the highest points represent hills and the lowest wrinkles represent valleys.
3. Choose one color of water-soluble marker and have the groups mark the highest points (hilltops) on their watershed (crinkled paper). Discuss with students the "high points" in your community and also areas of high elevation that students may have visited.
4. Discuss with students that most bodies of water are in lower elevations. Choose a second color (preferably a shade of blue) and mark the places where different bodies of water might be: creeks, rivers, lakes, etc.
5. Have students think of creeks, rivers, and lakes that they have visited and describe the land around these water features.

6. With a third color, mark two to three spaces to represent human settlements: housing, factories, shopping centers, office buildings, schools, etc. These spaces will likely be between the highpoints and water. Discuss with students what impact these areas might have on the bodies of water (Use the water for drinking, sanitation, etc. actions such as lawn irrigation, pollution, etc. can impact the water sources).
7. With a fourth color, mark two to three agricultural areas where plants and/or animals could be raised; again between the highpoints and water. Discuss with students the needs of these plants and animals (water, food, shelter) and also how the actions of the animals might impact the water.
8. Use the spray bottles to lightly spray the finished maps. The spray represents rain (precipitation) falling into the watershed.

TEACHER NOTES:
Instruct students to spray away from iPads and also remove the blue mats.

Explain-5 minutes

PURPOSE:
Based on an analysis of the exploration, students develop an explanation for the concept and practices. Their understanding is clarified and modified through the teacher's descriptions and definitions. This phase focuses on developing an explanation for the activities and situations students have been exploring. They verbalize their understanding of the concepts and practices. The teacher introduces formal labels, definitions, and explanations for concepts, practices, skills, and abilities.

1. Discuss students' observations about how water travels through the system. Some questions to ask:
   a. What changes did you observe in the maps?
   b. Where does most of the rain fall?
   c. What path does the water follow?
   d. What happens to the human settlement areas – are they in the way of a raging river or crumbling hillside?
   e. Where are possible sources of water pollution? What would happen if a contaminant entered the water supply?
   f. What happens to the agricultural areas – would the water flowing from these areas impact any other areas?
   g. What actions do you think farmers take in real life to protect the water quality?

As students wrap up, explain our farmers have an important role to plan in the quality of our water and our water resources. Water is needed for livestock and for plants to grow. One dairy cow can drink on average 30 gallons of water in a day (source: MSUE). Plants also need clean, healthy water to drink. Farmers use different tools to be sure they're using water responsibly.

i. Drip Irrigation: Farmers use this type of irrigation piping that brings the water directly to the roots of the plants so less is lost to evaporation.
ii. Filter strips: Farmers plant strips of wild flowers or grasses between their crops and flowing water sources, such as a stream or river. The grasses filter the water as it moves from the crop field toward the water source to remove any impurities before it reaches the stream or ditch.

iii. Technology to measure soil moisture: Farmers use devices to measure the amount of moisture in the soil, then they evaluate weather predictions to only irrigate (water) plants when additional water is needed.
iv. Application rates: Farmers use technology in tractors and in spraying equipment to apply precise amounts of fertilizer or pesticides on their crops, if needed. These tools measure out the small amounts of the product as a farmer drives across the field, applying it only where it's needed.
v. While using any of these methods, a farmer could rely on a hydrologist to assist them in testing the water quality in water for plants, livestock or in water sources near their farmland. The hydrologist would measure for contaminants using this parts per million measure and help the farmer adjust any necessary practices to keep the water clean and healthy.

Elaborate-25 minutes

PURPOSE:
Students have opportunities to expand and apply their understanding of the concepts within new contexts and situations. These lessons extend students' conceptual understanding through opportunities for students to apply knowledge, skills, and abilities. Through new experiences, the learners transfer what they have learned and develop broader and deeper understanding of concepts about the contextual situation and refine their skills and abilities.

TEACHER NOTES:
PPM, in an aqueous solution, we assume that the density of water is 1.00 g/mL (how much space water takes up). Therefore, it is common to associate 1 gram of water with 1 mL of water. PPM corresponds to 1 mg/L).

Be sure to have a cup of clean water, pipette, and the empty five gallon pail near the teacher's station prior to starting this lesson.

1. **Instruction:** While we all do everything we can to not cause water contamination, sometimes it happens. Hydrologists test water quality to ensure it is clean and safe for us to drink and use. A hydrologist uses a very small unit of measure to identify contaminants in water. This unit is called a part per million.
2. **Demonstrate:** If this five gallon bucket were full of water, this little drop (*drip one drop of water from a pipette into the bucket*) would be one part per million. Through the use of scientific lab equipment, a hydrologist can detect this small amount of contamination in water.
3. We are going to simulate contaminated water to see what a part per million of contamination would look like.
4. One scientific tool used today is a pipette to gently transfer liquids from one place to another. Demonstrate how to use a pipette.
5. **Instruction:** Start by putting nine drops of water into wells numbered 1-7 in your well plate.
6. Add one drop of food coloring to well number one.
7. **Ask:** Now, with the water and the one drop of food coloring, how many total drops of liquid are in well number one? (10) And, how many drops of food coloring is in well number one? (1) So, if we were going to make the amount of food coloring in well number one into a fraction, how would that fraction look? (1/10). Guide students to fill this in on their lab sheet, then help students translate the fraction into a decimal. Also, have students begin to fill in the color observed in well #1 on their lab sheet.

8. **Ask:** What do we predict will happen to the color (concentration) of if we continue this pattern (dilution)?
9. **Instruction:** Use the pipette to transfer one drop of water from well #1 to well #2. Guide students to fill in this fraction on their lab sheet. We have divided that 1/10 by 10 to make it 1/100 concentration. Translate this new fraction into a decimal and fill in the color observed.

TEACHER NOTES:
If further demonstration of moving the liquid from well 1 to 2 and 2 to 3 is needed, consider placing a well plate under the document camera and doing the dilution along with the students.

10. **Continue:** Instruct students to continue to move one drop from well #2 to #3 and so on. If students are confident in dividing fractions, instruct them to continue filling in the lab sheet columns as they go. If students need more coaching, guide them to fill in color observations for each cell on their own. Then, work though the continued division of fractions together after all water drops have been transferred.
11. **Instruction:** Based on their observations, ask students to answer the remaining questions on their lab sheet.

Evaluate

PURPOSE:
Students assess their understanding of the concepts, and teachers have the opportunity to assess student learning. This phase emphasizes students assessing their understanding and abilities and provides opportunities for teachers to evaluate students' understanding of concepts and practices identified in performance expectations.

Teachers have been provided pre and post-test links for their selected lesson. The same questions are asked on both assessments. Use these questions to review and wrap up the day's learning.

Michigan's Great Lakes play an important role in agriculture. **True** or false

Precipitation can cause contaminants to enter the water supply. **True** or false

A hydrologist would need to measure which fraction to measure a part per million of contamination.
1/1,000
1/10,000
1/1,000,000
1/10,000,000

Farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms
Drip irrigation
Plant filter strips
Use a computer to measure soil moisture levels
Apply fertilizer in specific measured amounts, at specific times during the growing season
All of the above

When a hydrologist dilutes contaminated water, there is ________ of the contaminant in the water.
More
Less

Sources/Credits: 1. Explore activity adapted from Wad-a-Watershed, Illinois and Minnesota Agriculture in the Classroom 2. Dilution and water cycle activities adapted from Michigan Ag in the Classroom Lesson, *Water.* 3. Parts per Million calculations adapted from National Environmental Services Center, On Tap Magazine.

FARM
Food, Agriculture & Resources in Motion
Science Lab

Name ______________________

Parts Per What? Lab Sheet

What does PPM stand for?

Parts per Million

After completing well numbers one and two, what do you predict will happen as we continue the experiment?

Answers will vary. Should indicate the color will continue to get lighter

Well Number	Color of Liquid	Concentration-Fraction	Concentration-Decimal
1	Dark Purple	1/10	0.1
2	Purple	1/100	0.01
3	Red	1/1,000	0.001
4	pink	1/10,000	0.0001
5	light pink	1/100,000	0.00001
6	no color	1/1,000,000	0.000001
7	no color	1/10,000,000	0.0000001

Describe two ways farmers protect and conserve water.

FARM

Food, Agriculture & Resources in Motion

Parts Per What

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

What is your student number? *

Your answer

What grade are you in? *

Choose

Who is your teacher? *

Choose

Precipitation can cause contaminants to enter the water supply.

- True
- False

Michigan's Great Lakes play an important role in agriculture.

- True
- False

A hydrologist would need to measure which fraction to measure a part per million of contamination.

- ◯ 1/1,000
- ◯ 1/10,000
- ◯ 1/1,000,000
- ◯ 1/10,000,000

Farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms?

- ◯ Drip Irrigation
- ◯ Plant filter strips
- ◯ Use a computer to measure soil moisture levels
- ◯ Apply fertilizer in specific measured amounts, at specific times during the growing season
- ◯ All of the above

When a hydrologist dilutes contaminated water, there is _______ of the contaminant in the water.

- ◯ more
- ◯ less

Page 1 of 1

SUBMIT

Never submit passwords through Google Forms.

Group 2 Pretest

Parts Per What

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number? ***

2. **What grade are you in? ***
   Mark only one oval.
   - 3rd Grade
   - 4th Grade
   - 5th Grade
   - I don't see my grade here.

3. **Who is your teacher? ***
   Mark only one oval.
   - Bacha
   - Kozlo
   - Theobald
   - Mayes

4. **I am excited to learn more about science on the farm. ***
   Mark only one oval.
   - Yes
   - No

5. **Precipitation can cause contaminants to enter the water supply. ***
   Mark only one oval.
   - True
   - False
   - I don't know

6. **Michigan's Great Lakes play an important role in agriculture. ***
   Mark only one oval.

7. **A hydrologist would need to measure which fraction to measure a part per million of contamination. ***
   Mark only one oval.
   - 1/1,000
   - 1/10,000
   - 1/1,000,000
   - 1/10,000,000
   - I don't know

8. **Farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms? ***
   Mark only one oval.
   - Drip Irrigation
   - Plant filter strips
   - Use a computer to measure soil moisture levels
   - Apply fertilizer in specific measured amounts, at specific times during the growing season
   - All of the above
   - I don't know.

9. **When a hydrologist dilutes contaminated water, there is _______ of the contaminant in the water. ***
   Mark only one oval.
   - more
   - less
   - I don't know

Group 2 Posttest

Parts Per What

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number?** *

2. **What grade are you in?** *
   Mark only one oval.
   - 3rd Grade
   - 4th Grade
   - 5th Grade
   - I don't see my grade here.

3. **Who is your teacher?** *
   Mark only one oval.
   - Bacha
   - Kozlo
   - Theobald
   - Mayes

4. **Precipitation can cause contaminants to enter the water supply.** *
   Mark only one oval.
   - True
   - False

5. **Michigan's Great Lakes play an important role in agriculture.** *
   Mark only one oval.
   - True
   - False

6. **A hydrologist would need to measure which fraction to measure a part per million of contamination.** *
   Mark only one oval.
   - 1/1,000

7. **Farmers could use which of the following tool(s) to conserve and prevent water contamination on their farms?** *
   Mark only one oval.
   - Drip Irrigation
   - Plant filter strips
   - Use a computer to measure soil moisture levels
   - Apply fertilizer in specific measured amounts, at specific times during the growing season
   - All of the above

8. **When a hydrologist dilutes contaminated water, there is _______ of the contaminant in the water.** *
   Mark only one oval.
   - more
   - less

9. **I thought the FARM Science Lab _____________.** *
   Mark only one oval.
   - was awesome.
   - was good.
   - was just okay.
   - could have been better.
   - was bad.

Appendix E

Resourceful Bean Lesson Plan and Assessment

FARM Science Lab

Resourceful Bean

Grade Level: 3rd-5th	Topic: Soybeans	Estimated Time: 50 minutes

Brief Lesson Description: Explore renewable and non-renewable resources through an investigation of soy-based materials. First, students will learn the steps a soybean takes from farm to final product. Then, students will carry out a test to observe differences between a soy crayon and a petroleum-based crayon. Finally, students will assist in making their own soy-based lip balm. Throughout the lesson, agricultural career connections are made and Michigan agriculture facts are shared.

Next Generation Science Standards:

Performance Expectation(s):

3-5ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

5-ESS3-1: Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

5-PS1-4: Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

5-PS1-2: Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

National Agricultural Literacy Outcomes:

T2.3-5 b: Distinguish between renewable and non-renewable resources used in the production of food, feed, fuel, fiber (fabric or clothing) and shelter.

T4.3-5 d: Provide examples of science being applied in farming for food, clothing, and shelter products.

T5.3-5 b: Discover that there are many jobs in agriculture.

T5.3-5 d: Explain the value of agriculture and how it is important in daily life.

Specific Learning Outcomes

Students will:

1. Arrange the processing steps of a soybean from farm to final product.
2. Compare petroleum and plant-based crayons by running a series of tests and comparing the results.
3. Identify renewable and nonrenewable resources.
4. Name two careers involved in the making of soy-based materials.
5. Predict changes in states of matter when a solid is heated or cooled.

Narrative / Background Information

Prior Student Knowledge

1. **Students should be familiar with:**
    a. Basic role of a farmer
    b. Plants are living organisms
    c. Basic role of a scientist

Materials
<u>**Student Lab Group Set-up**</u> *Each station should have the following:* • One plastic container of crayons labeled A • One plastic container of crayons labeled B • One per student Resourceful Bean Lab Sheet • One per student pencil • One set of soybean product process cards <u>**Teacher Workstation Set-up**</u> *Soy oil demonstration:* • Small, electric chopper • Sample of soybeans • Cup of water *Positioned under document camera:* • Hotplate • 1-quart sauce pan *Items prepared for making lip balm:* • Hot Pad/Trivet • Rubber Spatula • Digital Scale • 100 mL Plastic Beaker • 200 mL Plastic Beaker • 30-1 oz. Sauce Cups lined up on a paper towel, lids removed and set aside • Container of beeswax for students to measure (1.7 oz. will be needed) • Soybean oil prepared for students to measure (150 mL will be needed) • 1 gallon Ziploc bag for storage of cooled lip balm, labeled as such with a marker
Engage—15 minutes PURPOSE Activities capture the students' attention, connect their thinking to the situation, and help them access current knowledge. This sequence of lessons initiates the learning tasks. The activities should (1) activate prior knowledge and make connections between past and present learning experiences, and (2) anticipate activities and focus students' thinking on the learning outcomes of current activities. The learner should become mentally engaged in the concepts, practices, abilities, and skills of the curriculum unit.
1. **Ask:** How do you think farms or farming and science are connected? a. Allow students to lead discussion, but drive toward appropriate scientific components in plant, animal and food science. Understanding how plants grow, animal nutrition, making food and keeping it safe are all parts of science. b. Use Michigan commodity posters on the lab walls to guide discussion using locally grown examples. Specifically point out the soybean poster, showing the beans that are grown in Michigan. 2. **Instruction:**

a. Today's focus will be on plant science and the products of plants, specifically soybean plants.
b. We are going to be product engineers today! We are going to investigate how everyday products are made from plants.
c. Let's figure out how products we use are made from these little beans (*show sample container of soybeans*).
d. At each station is a set of cards. On each card is a picture of one step in the process from farm to store/finished product. Right now, the cards are out of order, in your lab groups, work together to put the steps in order, from final product to farm. Identify which picture is the final product, the thing you could use as it is. Then work backward, to figure out how the item is made.

TEACHER NOTES:
There are two sets of five different soy-based products: tofu (human food), cattle eating (animal feed), soyfoam car seats (Ford uses soyfoam in all cars), cooking oil and crayons. If all stations are in use, the five products will be represented twice in the work groups/stations; allow students from each group help to name the steps. See attachments for correct order of items.

As groups are working, move around to the stations providing help as needed.

3. **Report out:**
   a. Once each group is complete, ask groups to report for each product, to the whole class what product was made from soybeans and what steps were necessary to get it from farm to product.
   b. Help students see similarities and differences in the steps for the products.
4. **Transition:** Let's test out some of these soy-based products.

Explore-10 minutes

PURPOSE
Students investigate initial ideas and solutions in meaningful contexts. This phase provides students with a common base of experiences within which they identify and begin developing concepts, practices, abilities, and skills. Students actively explore the contextual situation through investigations, reading, web searches, and discourse with peers.

1. Instruct students to color side A of the Resourceful Bean Lab Sheet with the crayons in box A.
2. Ask students to close box A and transition to side B of the lab sheet using crayons from box B.
3. As students are finishing, point out the T-chart at the bottom of the page. Ask students to write observations about each crayon in the respective boxes at the bottom of the page. *Some hints could include: Which crayon is brighter?, which colored more smoothly?, which is more bumpy on the paper?, do they have a smell? etc.*

TEACHER NOTES:
Only one box of crayons should be open at a time to avoid confusion!

Allow approximately 10 minutes to color and use 5 minutes to summarize comparisons and transition.

Encourage students to test all colors and to utilize the same colors of both box A and B for a fair comparison.

Some students will want to finish coloring the full drawing in the lab. Assure students they can take the lab sheets with them to finish later.

If you are behind on time, you can shorten the coloring timeframe to get back on track.

4. As a class, review observations. Ask for volunteers to share observations.
5. By now most students have guessed one crayon is made from soybeans. Ask students to predict which crayon they believe is the soybean crayon.
6. Reveal crayon B is the Prang Brand (soybean) crayon. Show students packaging for both A and B crayons.
7. **Summarize:**
    a. Both crayons colored our lab sheets. In some cases, we couldn't decide which one was made from soybeans.
    b. Product engineers help us make new products or make the same products from new ingredients.
    c. Plants, like soybeans, are a renewable product. What does that mean? (Answer: We can easily grow more each year.) The Crayola crayons are made with a petroleum-based wax. Petroleum is non-renewable meaning it takes hundreds of years for the earth to make more petroleum.
8. **Transition:** How can we make our own soy-based product?

Explain-10 minutes

Based on an analysis of the exploration, students develop an explanation for the concept and practices. Their understanding is clarified and modified through the teacher's descriptions and definitions. This phase focuses on developing an explanation for the activities and situations students have been exploring. They verbalize their understanding of the concepts and practices. The teacher introduces formal labels, definitions, and explanations for concepts, practices, skills, and abilities.

1. **Explain:** Oil can be extracted from soybeans. This is something produced naturally by the plant in its beans. This oil can then be used as an ingredient in many of the products we have discussed today.
2. **Demonstrate:** Anytime oil and water is combined, like some salad dressings (show example) we can see the soybean oil in water, if we crush up the beans. Quickly blend a few soybeans in the chopper, and add water to show the soybean mash and the oil separating in the water.
3. **Explain:** What we just demonstrated is a smaller scale example of how the processors make soybean oil

Elaborate-10 minutes

PURPOSE

Students have opportunities to expand and apply their understanding of the concepts within new contexts and situations. These lessons extend students' conceptual understanding through opportunities for students to apply knowledge, skills, and abilities. Through new experiences, the learners transfer what they have learned and develop broader and deeper understanding of concepts about the contextual situation and refine *their* skills and abilities.

Prior to making the soybean lip balm, explain to students that lotions or make-up are another category of product that could be made from soybeans.

Ask students to all take a seat on the floor. Call up individual volunteers to help with the weights/measures of ingredients. All students should watch the pan on the TV via the document camera.

Lip Balm Recipe
1.7 oz. beeswax
150 mL soybean oil

Pour both ingredients into pan, one at a time. Turn heat on high, stirring occasionally. While it's melting, discuss the reaction taking place. Drive students to the understanding that the solid (beeswax) is melting when heated, turning it into a liquid – changing the state of matter.

Once fully melted, pour a small amount into the 1 ounce sauce cup, hold up for students to see. Ask students to predict what will happen to this liquid as it cools (it will solidify).

TEACHER'S NOTES:
While waiting for the ingredients to melt, use evaluation questions to review the day's learning.

This recipe is fairly forgiving. Exact quantities are not necessary. It takes approximately 8-10 minutes to fully melt, if the pan is completely cool from the start.

Check the refrigerator for pre-made lip-balm, bagged in quantities of 30. If none are present, pre-make a batch before the first class arrives, so the cooled lip balm can be given to the teacher for distribution to the class. Each class will receive a batch from the class prior, or one that is stored in the refrigerator.

Evaluate – 5 minutes

PURPOSE
Students assess their understanding of the concepts, and teachers have the opportunity to assess student learning. This phase emphasizes students assessing their understanding and abilities and provides opportunities for teachers to evaluate students' understanding of concepts and practices identified in performance expectations.

Teachers have been provided pre and post-test links for their selected lesson. The same questions are asked on both assessments. Use these questions to review and wrap up the day's learning.

Which item cannot be made of soybeans? Tofu, Animal feed, **Notebook paper**, Cooking oil

Soy crayons are made from a renewable resource.
True or False

A product engineer would need to ________ soybeans to make a soy-based foam. **Crush**, freeze, float, dye

To make lip balm from beeswax and soybeans, first heat causes the beeswax to change state from a: Gas to a liquid, **Solid to a liquid**, liquid to a solid, gas to a solid

Michigan farmers grow soybeans. **True** or false

Vocabulary for the lab:
Biodegradable: capable of being decomposed by bacteria or other living organisms.
Nonrenewable energy: not able to be restored, replaced, recommenced, etc: *nonrenewable resources*

Renewable energy: a source of energy that is not depleted by use, such as water, wind or solar power.
Petroleum: a liquid mixture of hydrocarbons that is present in certain rock strata and can be extracted and refined to produce fuels including gasoline, kerosene and diesel oil; oil.

Sources/Credits:

1. Adapted from Pennsylvania Mobile Ag Ed Science Lab Lesson, *Colorful Bean*
2. Soy lip balm recipe modified from Ohio Soybean Council www.soyohio.com

FARM
Food, Agriculture & Resources in Motion
Science Lab

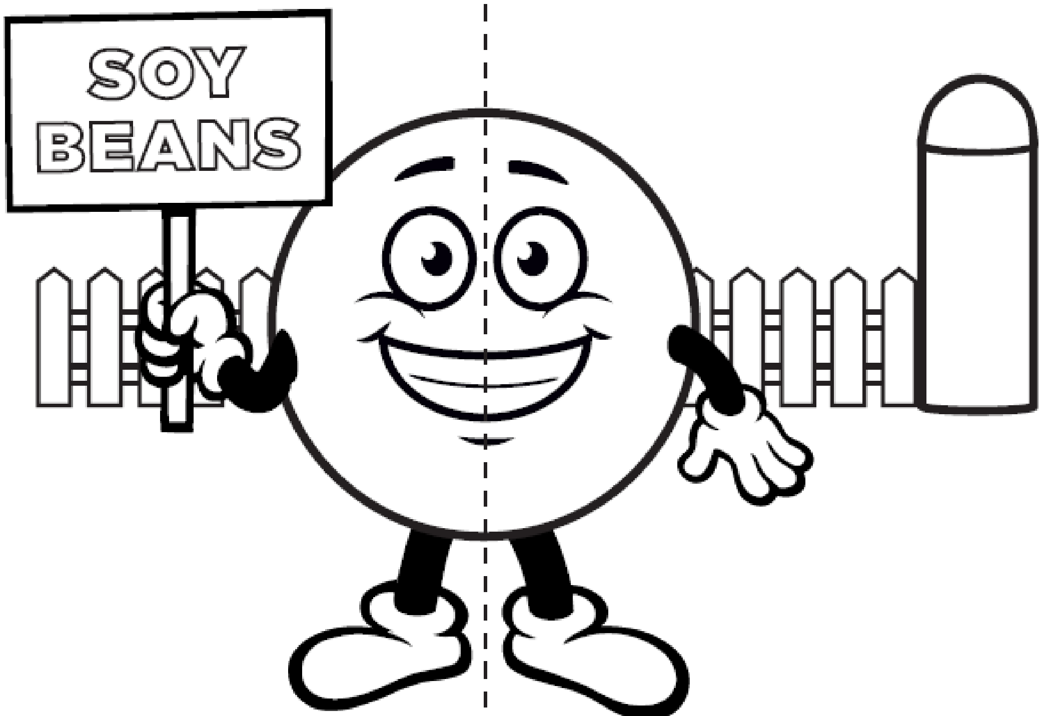
Name ____________________

A crayons

Made from ____________________

B crayons

Made from ____________________



Record your observations.

Crayon A	Crayon B

FARM
Food, Agriculture & Resources in Motion
Science Lab

Resourceful Bean

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

What is your student number? *

Your answer

What grade are you in? *

- 3rd Grade
- 4th Grade
- 5th Grade
- I don't see my grade here.

Who is your teacher? *

Choose

Which item cannot be made of soybeans?

- Tofu
- Animal feed
- Notebook paper

◯ Cooking oil

Soy crayons are made from a renewable resource.

◯ True

◯ False

A product engineer would need to ______ soybeans to make a soy-based foam.

◯ crush

◯ freeze

◯ float

◯ dye

To make lip balm from beeswax and soybeans, first heat causes the beeswax to change state from a

◯ gas to a liquid

◯ solid to a liquid

◯ liquid to a solid

◯ gas to a solid

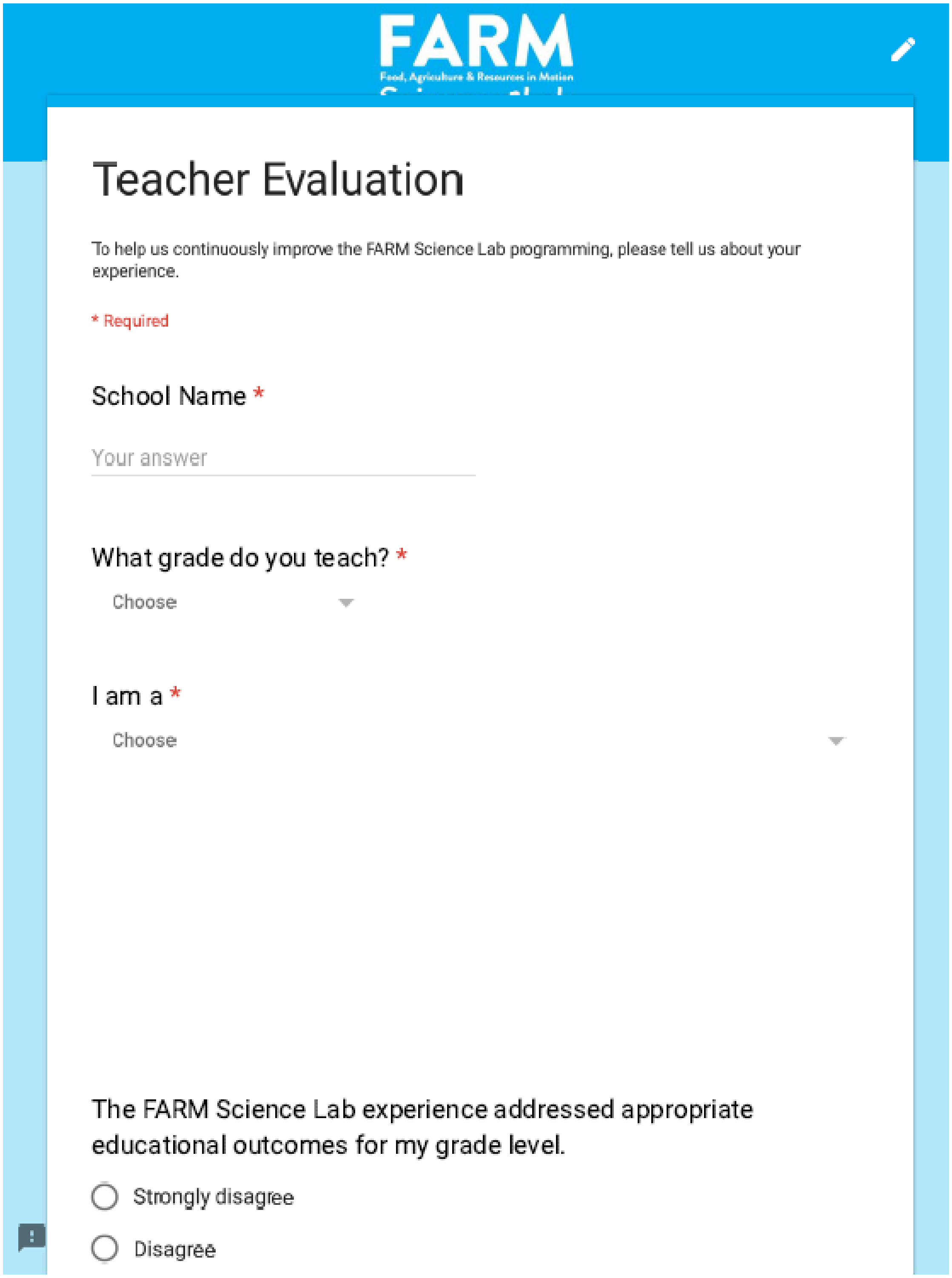
Michigan farmers grow soybeans.

◯ True

◯ False

Appendix F

Teacher Evaluation



FARM
Food, Agriculture & Resources in Motion

Teacher Evaluation

To help us continuously improve the FARM Science Lab programming, please tell us about your experience.

* Required

School Name *

Your answer

What grade do you teach? *

Choose

I am a *

Choose

The FARM Science Lab experience addressed appropriate educational outcomes for my grade level.

- Strongly disagree
- Disagree

○ Neutral

○ Agree

○ Strongly agree

Were your expectations for the FARM Science Lab program met?

○ Yes

○ No

If no, please explain.

Your answer

My students were actively engaged in the lesson taught.

○ Strongly disagree

○ Disagree

○ Neutral

○ Agree

○ Strongly agree

I have an increased understanding of Michigan agriculture after my FARM Science Lab experience.

○ Strongly disagree

○ Disagree

- Neutral
- Agree
- Strongly agree

My students have an increased understanding of Michigan agriculture after our FARM Science Lab experience.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

Based on your experience in the FARM Science Lab, does agriculture adequately contextualize science to convey important principles or concepts?

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

The FARM Science Lab educator used effective teaching strategies to engage students.

- Strongly disagree
- Disagree

- ◯ Neutral
- ◯ Agree
- ◯ Strongly agree

My students participated in the pre-visit assessment.

- ◯ Yes
- ◯ No

I plan to explore the Michigan Agriculture in the Classroom food and agricultural educational materials at www.miagclassroom.org

- ◯ Yes
- ◯ No

Would you consider reserving the FARM Science Lab in the future?

- ◯ Yes
- ◯ No
- ◯ Maybe

Please provide any additional comments or feedback about the FARM Science Lab program.

Your answer

Page 1 of 1

SUBMIT

Never submit passwords through Google Forms.

Group 2 Pretest

Resourceful Bean

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number?** *

2. **What grade are you in?** *
   Mark only one oval.
   - 3rd Grade
   - 4th Grade
   - 5th Grade
   - I don't see my grade here.

3. **Who is your teacher?** *
   Mark only one oval.
   - Option 1
   - Option 2
   - Option 3

4. **I am excited to learn more about science on the farm.**
   Mark only one oval.
   - Yes
   - No

5. **Which item cannot be made of soybeans?** *
   Mark only one oval.
   - Tofu
   - Animal feed
   - Notebook paper
   - Cooking oil
   - I don't know

6. **Soy crayons are made from a renewable resource.** *
   Mark only one oval.
   - True
   - False
   - I don't know.

7. **A product engineer would need to _______ soybeans to make a soy-based foam.** *
   Mark only one oval.
   - crush
   - freeze
   - float
   - dye
   - I don't know

8. **To make lip balm from beeswax and soybeans, first heat causes the beeswax to change state from a** *
   Mark only one oval.
   - gas to a liquid
   - solid to a liquid
   - liquid to a solid
   - gas to a solid
   - I don't know

9. **Michigan farmers grow soybeans.** *
   Mark only one oval.
   - True
   - False
   - I don't know

Group 2 Posttest

Resourceful Bean

Please answer these questions to the best of your ability. If you don't understand a question, ask your teacher.

* Required

1. **What is your student number?** *

2. **What grade are you in?** *
   Mark only one oval.
   - 3rd Grade
   - 4th Grade
   - 5th Grade
   - I don't see my grade here.

3. **Who is your teacher?** *
   Mark only one oval.
   - Option 1
   - Option 2
   - Option 3

4. **Which item cannot be made of soybeans?** *
   Mark only one oval.
   - Tofu
   - Animal feed
   - Notebook paper
   - Cooking oil

5. **Soy crayons are made from a renewable resource.** *
   Mark only one oval.
   - True
   - False

6. **A product engineer would need to _______ soybeans to make a soy-based foam.** *
   Mark only one oval.
   - crush
   - freeze
   - float
   - dye

7. **To make lip balm from beeswax and soybeans, first heat causes the beeswax to change state from a** *
   Mark only one oval.
   - gas to a liquid
   - solid to a liquid
   - liquid to a solid
   - gas to a solid

8. **Michigan farmers grow soybeans.** *
   Mark only one oval.
   - True
   - False

9. **I thought the FARM Science Lab ____________.** *
   Mark only one oval.
   - was awesome.
   - was good.
   - was just okay.
   - could have been better.
   - was bad.

Appendix G

Pre-Existing Data Release

7373 W. Saginaw Hwy. • P.O. Box 30960
Lansing, MI 48909-8460

Amelia Miller
School of Applied Sciences, Technology & Education
Utah State University
2300 Old Main Hill
Logan, Utah 84322

Dear Amelia,

As a part of Michigan Agriculture in the Classroom's Food, Agriculture and Resources in Motion (FARM) Science Lab program, we are administering pretests and posttests to all students who participate in our programing. In addition, we are asking all participating teachers to complete a post-evaluation of our program. It is our intent to use this data to better our programing and continue to build positive relationships with educators.

I am writing to indicate my permission to use this preexisting data from the 2017-18 school year for the purposes of your thesis research as a part of your Master of Science in Agriculture Extension and Education program. All raw data will be provided to you for use in this project.

Sincerely,

Tonia Ritter
Manager, Promotion and Education
Michigan Farm Bureau